Outer Dowsing Offshore Wind

Preliminary Environmental Information Report

Volume 1, Chapter 11: Marine Mammals

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Abbreviations

Acronym	Expanded name
ADD	Acoustic Deterrent Device
AIS	Automatic Identification System
AoS	Area of Search
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
BEIS	Department for Business, Energy & Industrial Strategy (now the Department for Energy Security and Net Zero (DESNZ))
BND	Bottlenose dolphin
CEA	Cumulative Effect Assessment
CI	Confidence Interval
CIEEM	Chartered Institute of Ecology and Environmental Management
CITES	Convention of International Trade in Endangered Species
CoCP	Code of Construction Practice
COWRIE	Collaborative Offshore Wind Energy Research into the Environment
CSIP	Cetacean Stranding Investigation Programme
CV	Coefficient of Variation
DAERA	Department of Agriculture, Environment and Rural Affairs
DCO	Development Consent Order
DEB	Dynamic Energy Budget
DEPONS	Disturbance Effect on Harbour Porpoise in the North Sea
DECC	Department of Energy & Climate Change, now the Department for Energy Security and Net Zero (DESNZ)
Defra	Department for Environment, Food and Rural Affairs (Defra, not DEFRA)
DESNZ	Department for Energy Security and Net Zero, formerly Department of Business, Energy and Industrial Strategy (BEIS), which was previously Department of Energy & Climate Change (DECC).
DPH	Detection Positive Hours
ECC	Export Cable Corridor
EDR	Effective Deterrence Range
EEA	European Economic Area
EIA	Environment Impact Assessment
EMF	Electromagnetic Frequency
EPP	Evidence Plan Process
EPS	European Protected Species
EQT	Effective Quiet Threshold
ES	Environmental Statement
ETG	Expert Topic Group
EU	European Union
GS	Grey Seal
GT R4 Ltd	The Applicant. The special project vehicle created in partnership between Corio Generation (a wholly owned Green Investment Group portfolio company), Gulf Energy Development and TotalEnergies

Acronym	Expanded name
HF	High Frequency
HP	Harbour Porpoise
HRA	Habitat Regulations Assessment
HS	Harbour Seal
IAMMWG	Inter-Agency Marine Mammal Working Group
ICES	International Council Exploration of the Sea
IPC	Infrastructure Planning Commission
IROPI	Imperative Reasons of Over-riding Public Interest
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
kJ	Kilojoule
LF	Low Frequency
LSE	Likely Significant Effect
LWT	Lincolnshire Wildlife Trust
MDS	Maximum Design Scenario
MHWS	Mean High Water Springs
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MPA	Marine Protected Area
MPCP	Marine Pollution Contingency Plan
MU	Management Unit
MW	Mega Watt
MWH	Minke whale
NMFS	National Marine Fisheries Centre
NOAA	National Oceanographic Atmospheric Administration
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
NW	Northwest
OP	Offshore Platform
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
ORCP	Offshore Reactive Compensation Platform
ORJIP	Offshore Renewables Joint Industry Programme
OSPAR	Oslo / Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
OWF	Offshore Windfarm
PAM	Passive Acoustic Monitoring
PCW	Phocid Carnivore in Water
PEIR	Preliminary Environmental Information Report
PEMP	Project Environment Management Plan
PTEC	Perpetuus Tidal Energy Centre
PTS	Permanent Threshold Shift
RIAA	Report to Inform Appropriate Assessment
RMS	Root Mean Squared
SAC	Special Area of Conservation

Acronym	Expanded name
SAFESIMM	Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
SCOS	Special Committee on Seals
SEL	Sound Exposure Level
SIP	Site Integrity Plan
SMRU	Sea Mammal Research Unit
SNCB	Statutory Nature Conservation Bodies
SNS	Southern North Sea
SPA	Special Protected Area
SPL	Sound Pressure Level
SSC	Suspended Sediment Concentration
SSSI	Sites of Special Scientific Interest
SW	Southwest
TTS	Temporary Threshold Shift
TWT	The Wildlife Trust
UXO	Unexploded Ordnance
VHF	Very High Frequency
VMP	Vessel Management Plan
WTG	Wind Turbine Generator
ZoI	Zone of Influence

Terminology

Term	Definition
AfL	Agreement for Lease. This was the original extent of the array area presented in Scoping.
Array Area	The area offshore within the PEIR Boundary within which the generating stations (including wind turbine generators (WTG) and inter array cables), offshore accommodation platforms, offshore transformer substations and associated cabling are positioned.
Baseline	The status of the environment at the time of assessment without the development in place.
Cumulative effects	The combined effect of the Project acting cumulatively with the effects of 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 the Project.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP) from the Secretary of State (SoS) for Department for Energy Security and Net Zero (DESNZ).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact in question with the sensitivity of the receptor in question, in accordance with defined significance criteria.
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 Environmental Impact Assessment (EIA) Regulations, including the publication of an Environmental Statement (ES).
EIA Directive	European Union 2011/92/EU of 13 December 2011 (as amended in 2014 by Directive 2014/52/EU)
EIA Regulations	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Embedded mitigation	Mitigation that is embedded in the Project design
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 Statement (ES).
Environmental Statement (ES)	The suite of documents that detail the processes and results of the Environmental Impact Assessment (EIA).
Evidence Plan	A voluntary process of stakeholder consultation with appropriate Expert Topic Groups (ETGs) that discusses and where possible agrees the detailed approach to the Environmental Impact Assessment (EIA) and information to support Habitats Regulations Assessment (HRA) for those relevant topics included in the process, undertaken during the pre-application period.

Term	Definition
Export Cable Corridor	The areas(s) where 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) and compensatory measures.
Impact	An impact to the receiving environment is defined as any change to its baseline condition, either adverse or beneficial.
Intertidal	Area where the ocean meets the land between high and low tides.
Landfall	The location at the land-sea interface where the offshore export cable will come ashore.
Magnitude	The extent of any interaction, the likelihood, duration, frequency and reversibility of any potential impact.
Maximum Design Scenario	The maximum design parameters of the combined project assets that result in the greatest potential for change in relation to each impact assessed
Mitigation	Mitigation measures, or commitments, are commitments made by the Project to reduce and/or eliminate the potential for significant effects to arise as a result of the Project. Mitigation measures can be embedded (part of the project design) or secondarily added to reduce impacts in the case of potentially significant effects.
National Policy Statement (NPS)	A document setting out national policy against which proposals for Nationally Significant Infrastructure Projects (NSIPs) will be assessed and decided upon
Outer Dowsing Offshore Wind (the Project)	The Project.
Offshore Export Cable Corridor (ECC)	The Offshore Export Cable Corridor (Offshore ECC) is the area within the PEIR Boundary within which the export cable running from the array to landfall will be situated.
Offshore Substation (OSS)	Platforms located within the array area which house electrical equipment and control and instrumentation systems. They also provide access facilities for work boats and helicopters.
Offshore Reactive Compensation Station (ORCP)	Platforms located outside the array area which house electrical equipment and control and instrumentation systems. They also provide access facilities for work boats.
Preliminary Environmental Information Report (PEIR)	The PEIR is written in the style of a draft Environmental Statement (ES) and provides information to support and inform the statutory consultation process in the pre-application phase. Following that consultation, the PEIR documentation will be updated to produce the Project's ES that will accompany the application for the Development Consent Order (DCO).

Term	Definition
PEIR Boundary	The PEIR Boundary is outlined in Figure 3.1 of Volume 1, Chapter 3: Project Description and comprises the extent of the land and/or seabed for which the PEIR assessments are based upon.
Project Design Envelope	A description of the range of possible elements that make up the Project's design options under consideration, as set out in detail in the project description. This envelope is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known. This is also often referred to as the "Rochdale Envelope" approach.
Receptor	A distinct part of the environment on which effects could occur and can be the subject of specific assessments. Examples of receptors include species (or groups) of animals or plants, people (often categorised further such as 'residential' or those using areas for amenity or recreation), watercourses etc.
Study area	Area(s) within which environmental impact may occur.
The Planning Inspectorate	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
The Project	Outer Dowsing Offshore Wind including proposed onshore and offshore infrastructure.
Transboundary impacts	Transboundary effects arise when impacts from the development within one European Economic Area (EEA) state affects the environment of another EEA state(s).
Subsea	Subsea comprises everything existing or occurring below the surface of the sea.
Wind Turbine Generator (WTG)	All the components of a wind turbine, including the tower, nacelle, and rotor.

11 Marine Mammals

11.1 Introduction

11.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents the results to date of the Environmental Impact Assessment (EIA) process for the potential impacts of Outer Dowsing Offshore Wind ("the Project") on marine mammals. Specifically, this chapter considers the potential impact of the Project seaward of Mean High Water Springs (MHWS) during the construction, operation and maintenance, and decommissioning phases.

11.1.2 GTR4 Limited (trading as Outer Dowsing Offshore Wind) hereafter referred to as 'the Applicant', is proposing to develop the Project. The Project will be located approximately 54km from the Lincolnshire coastline in the southern North Sea. The Project will include both offshore and onshore infrastructure including an offshore generating station (windfarm), export cables to landfall, onshore cables, and connection to the electricity transmission network, and ancillary and associated development. (see Volume 1, Chapter 3: Project Description for full details).

11.1.3 This chapter has been informed by the following chapters:

- Volume 1, Chapter 3: Project Description;
- Volume 1, Chapter 7: Marine Processes;
- Volume 1, Chapter 8: Marine Water Quality;
- Volume 1, Chapter 10: Fish and Shellfish Ecology;
- Volume 2, Appendix 3.2: Underwater Noise Assessment;
- Volume 2, Appendix 11.1: Marine Mammal Technical Baseline;
- Supplementary Document 8.4: Outline Marine Mammal Mitigation Protocol; and
- Document 7.1: Report to Inform Appropriate Assessment.

11.2 Statutory and Policy Context

11.2.1 This section identifies legislation and national and local policy of relevance to marine mammal ecology. The Planning Act 2008 and Marine Works (Environmental Impact Assessment; EIA) Regulations 2007 (as amended) and Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (referred to as "the EIA Regulations") are considered along with the legislation relevant to marine mammal ecology.

11.2.2 The following section provides information regarding the legislative context surrounding the assessment of potential effects in relation to marine mammal ecology. Full details of all policy and legislation relevant to the Project application are provided within un, Chapter 2: Need, Policy and Legislative Context. A summary of the current policy and legislation is provided below, the Applicant has ensured that the assessment adheres to the relevant legislation. In undertaking the assessment, the following policy and legislation has been considered:

- The EIA Regulations (2017);

- The Planning Act (2008);
- The Marine Works (Environmental Impact Assessment) Regulations 2007 (as amended);
- The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention; 1979);
- EU Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the 'Habitats Directive');
- EU Directive 2008/56/EC Marine Strategy Framework Directive;
- The Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended);
- The Conservation of Habitats and Species Regulations 2017;
- Marine and Coastal Access Act 2009;
- The Wildlife and Countryside Act 1981 (as amended);
- OSPAR Convention 1992;
- The Convention on the Conservation of Migratory Species of Wild Animals 1979;(the Bonn Convention);
- The UK Biodiversity Action Plan and UK Post-2010 Biodiversity Framework (2012);
- The Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) 1994;
- Convention of International Trade in Endangered Species (CITES) 1975; and
- The Conservation of Seals Act 1970.

11.2.3 The relevant legislation and planning policy for offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to marine mammals is outlined in Table 11.1 below. New draft NPS's are being consulted on currently for implementation later this year.

Table 11.1: Legislation and policy context

Legislation/policy	Key provisions	Section where comment addressed
National Policy Statement for Renewable Energy Infrastructure (NPS EN-1) (DECC, 2011a)	"Where the development is subject to EIA the applicant should ensure that the Environmental Statement (ES) 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. The applicant should provide environmental information proportionate to the infrastructure where EIA is not required to help the IPC consider thoroughly the potential effects of a proposed project." - Paragraph 5.3.3	The potential effects of the Project have been assessed in regard to international, national and local sites designated for ecological or geological features of conservation importance (see section 11.7). Direct or indirect effects on features of relevant Special Area of Conservation (SAC) and Special Protection Area (SPA) sites were also considered in the Habitats Regulations Assessment Screening Report and where relevant have been included in the Report to Inform Appropriate Assessment (RIAA). Important protected areas for marine mammals within their respective Management Units (MUs) are detailed in Volume 2, Appendix 11.1: Marine Mammal Technical Baseline.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-1) (DECC, 2011a)	"Many individual wildlife species receive statutory protection under a range of legislative provisions" -Paragraph 5.3.16	Relevant marine mammal policy and legislation has been listed in section 11.2. All species are protected under the Habitats Regulations 2017, Offshore Habitats Regulations 2017 and the Wildlife and Countryside Act 1981. Seal species are also protected under the Conservation of Seals Act 1970 and all species of cetaceans are listed as European Protected Species (EPS).

Legislation/policy	Key provisions	Section where comment addressed
National Policy Statement for Renewable Energy Infrastructure (NPS EN-1) (DECC, 2011a)	"Other species and habitats have been identified as being of principal importance for the conservation of biodiversity in England and Wales and thereby requiring conservation action. The Secretary of State should ensure that these species and habitats are protected from the adverse effects of development by using requirements or planning obligations." -Paragraph 5.3.17	All species receptors, including those of principal importance for the conservation of biodiversity in England are summarised in section 11.4. Full details are provided in Volume 2, Appendix 11.1: Marine Mammal Technical Baseline.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-1) (DECC, 2011a)	"The applicant should include appropriate mitigation measures as an integral part of the proposed development. In particular, the applicant should demonstrate that: ▪ During construction, they will seek to ensure that activities will be confined to the minimum areas required for the works; ▪ During construction and operation best practice will be followed to ensure that risk of disturbance or damage to species or habitats is minimised, including as a consequence of transport access arrangements; ▪ Habitats will, where practicable, be restored after construction works have finished." - Paragraph 5.3.18	Embedded mitigation relevant for marine mammals to be adopted as part of the project have been detailed in section 11.5.4.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b)	"Assessment of offshore ecology and biodiversity should be undertaken by the applicant for all stages of the lifespan of the proposed Offshore Windfarm (OWF) and in accordance with the appropriate policy for OWF EIAs." -Paragraph 2.6.64	Construction, operation and maintenance, and decommissioning phases of the Project have been assessed in section 11.7.

Legislation/policy	Key provisions	Section where comment addressed
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate." -Paragraph 2.6.65	Consultations with relevant statutory and non-statutory stakeholders have been conducted throughout the Project (see Table 11.2 for a summary of consultation with regards to marine mammals).
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational OWFs should be referred to where appropriate." - Paragraph 2.6.66	Relevant data collected during post construction monitoring from other OWF projects has informed the assessment of the Project in section 11.7
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"The assessment should include the potential of the scheme to have both positive and negative effects on marine ecology and biodiversity." -Paragraph 2.6.67	The assessment methodology for marine mammals includes the provision for assessment of both positive and negative effects presented within section 11.6.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"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	The potential effects on marine mammal ecology are presented within this chapter, with the assessment of effects presented within section 11.7.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"Mitigation may be possible in the form of careful design of the development itself and the construction techniques employed -Paragraph 2.6.70	Embedded mitigation relevant for marine mammals is detailed in Table 11.8: Embedded mitigation relating to marine mammals
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"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."	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).

Legislation/policy	Key provisions	Section where comment addressed
	-Paragraph 2.6.71	
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	Where necessary, 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 the potentially disturbing activity including cumulative/in-combination effects with other plans or projects; baseline noise levels; predicted noise levels in relation to mortality, permanent threshold shift (PTS) and temporary threshold shift (TTS); soft-start noise levels according to proposed hammer and pile design; and operational noise." -Paragraph 2.6.92	All of the specified marine mammal ecology details are included in this chapter. Construction, operational and decommissioning noise impacts and their likely effects on marine mammal behaviour and ecology have been assessed (see Section 11.7). This assessment also considers the cumulative impacts of the Project and other relevant plans or projects (see Section 11.8).
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"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 as described in 2.6.91 above, the applicant should look at possible alternatives or appropriate mitigation before applying for an EPS licence." -Paragraph 2.6.93	The project design includes various foundation options, including those which are "noiseless" such as suction buckets. A decision on the final foundation type to be used for the Project will be made once further site investigation works and engineering has taken place post-consent. In the event that piling is required, mitigation measures, including those outlined in Table 11.8 and the Outline MMMP (document reference 8.4) will be

Legislation/policy	Key provisions	Section where comment addressed
		implemented, as appropriate, to minimise impacts to European Protected Species.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"The Infrastructure Planning Commission (IPC) should be satisfied that the preferred methods of construction, in particular the construction method needed for the proposed foundations and the preferred foundation type, where known at the time of application, are designed so as to reasonably minimise significant disturbance effects on marine mammals. Unless suitable noise mitigation measures can be imposed by requirements to any development consent the IPC may refuse the application." -Paragraph 2.6.94	The Project has considered different foundation options, hammer energies and ramp-ups. Mitigation methods are considered within the Outline MMMP (document reference 8.4). The details of the final MMMP will be agreed once the final project design is known (Table 11.8). Compliance with the MMMP will be secured within the DCO.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"Fixed submerged structures such as foundations are likely to pose little collision risk for marine mammals and the IPC is not likely to have to refuse to grant consent for a development on the grounds that offshore windfarm foundations pose a collision risk to marine mammals." -Paragraph 2.6.96	The potential for collision risk with vessels has been assessed in section 11.7.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"Monitoring of the surrounding area before and during the piling procedure can be undertaken." -Paragraph 2.6.97	Monitoring to be conducted as part of the mitigation measures during the piling is described in the Outline MMMP (document reference 8.4). The details of the final MMMP will be agreed once the final project design is known (Table 11.8).

Legislation/policy	Key provisions	Section where comment addressed
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"During construction, 24-hour working practices may be employed so that the overall construction programme and the potential for impacts to marine mammal communities is reduced in time." -Paragraph 2.6.98	The Applicant can confirm that 24-hour working practices will be employed for the construction works. The predicted project time frame is discussed in Table 11.7.
National Policy Statement for Renewable Energy Infrastructure (NPS EN-3) (DECC, 2011b).	"Soft start procedures during pile driving may be implemented. This enables marine mammals in the area disturbed by the sound levels to move away from the piling before significant adverse impacts are caused." -Paragraph 2.6.99	Mitigation methods are considered within the Outline MMMP (document reference 8.4). The details of the final MMMP will be agreed once the final project design is known (Table 11.8).
Marine Policy Statement (HM Government, 2011)	The Marine Policy Statement 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"	The potential effects of the construction, operation, and decommissioning phases and cumulative effects of the Proposed Development on marine mammals have been assessed in the impact assessment in sections 11.7 and 11.8.

Legislation/policy	Key provisions	Section where comment addressed
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"Construction activities, including installing wind turbine foundations by pile driving, geophysical surveys, and clearing the site and cable route of unexploded ordinance (UXOs) may reach noise levels which are high enough to cause disturbance, injury, or even death to marine mammals. All marine mammals are protected under Part 3 of the Habitats Regulations. In addition, whales, dolphins and porpoises (collectively known as cetaceans) are legally protected species. If construction and associated noise levels are likely to lead to an offence under Part 3 of the Habitats Regulations (which would include deliberately disturbing, injuring or killing), an application will have to be made for a wildlife licence[1] to allow the activity to take place." -Paragraph 3.8.139 - 141	Injury and disturbance from construction activities, including piling, geophysical surveys and UXO clearance has been assessed in section 11.7 as part of the assessment of construction impacts on marine mammals. The Project are not seeking to licence UXO in the DCO. All appropriate licencing requirements will be met post-consent.
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"The development of offshore windfarms can also impact fish species (see paragraphs 2.8.129 – 2.8.133), which can have indirect impacts on marine mammals if those fish are prey species. There is also the risk of collision with construction and maintenance vessels and potential entanglement risks from floating wind structures." -Paragraph 3.8.142- 143	Impacts to marine mammals arising from changes to prey availability and vessel collision risk have been assessed in sections section 11.7. There is no risk of entanglement with floating wind structures as there are no floating elements to the Project (see Volume 1, Chapter 3: Project Description)

[1] See https://www.gov.uk/guidance/understand-marine-wildlife-licences-and-report-an-incident

Legislation/policy	Key provisions	Section where comment addressed
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"Where necessary, assessment of the effects on marine mammals should include details of: ▪ likely feeding areas and impacts on prey species and prey habitat; ▪ known birthing areas / haul out sites for breeding and pupping; ▪ migration routes; ▪ protected areas; ▪ baseline noise levels; ▪ predicted construction and soft start noise levels in relation to mortality, permanent threshold shift (PTS), temporary threshold shift (TTS) and disturbance; ▪ operational noise; ▪ duration and spatial extent of the impacting activities including cumulative/in-combination effects with other plans or projects; ▪ collision risk; ▪ entanglement risk; and ▪ barrier risk." -Paragraph 3.8.144	Throughout the EIA and HRA all relevant impacts have been identified, discussed, analysed and mitigated for if necessary (see paragraph 11.5.4 and sections 11.7)
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"The scope, effort and methods required for marine mammal surveys should be discussed with the relevant statutory nature conservation body." -Paragraph 3.8.145	Communication with SNCBs has been consistent throughout the Project, targeted ETGs have occurred as discussed in section 11.3.

Legislation/policy	Key provisions	Section where comment addressed
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"The applicant should discuss any proposed noisy activities with the relevant body and must reference the JNCC and SNCB underwater noise guidance[2] in relation to noisy activities (alone and in-combination with other plans or projects) within HRA sites, in addition to the JNCC mitigation guidelines to piling[3], explosive use, and geophysical surveys. Where assessment shows that noise from construction and UXO clearance may reach noise levels likely to lead to noise thresholds being exceeded (as detailed in the JNCC guidance) or an offence as described in paragraph 2.8.138 above, the applicant should look at possible alternatives or appropriate mitigation. The applicant should develop a Site Integrity Plan (SIP) to allow the cumulative impacts of underwater noise to be reviewed closer to the construction date, when there is more certainty in other plans and projects." -Paragraph 3.8.146 - 148	This has been assessed in the RIAA (document reference 7.1) and EIA impacts from underwater noise assessed in sections 11.7 of this document. An Outline SIP will be submitted alongside DCO application and a final SIP submitted in post-consent stage.
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"Monitoring of the surrounding area before and during the piling procedure can be undertaken by various methods including marine mammal observers and passive acoustic monitoring. Active displacement of marine mammals outside potential injury zones can be undertaken using equipment such as acoustic deterrent devices" -Paragraph 3.8.254	Details have been provided in see Outline MMMP (document reference 8.4), see Table 11.8 for more details.

[2] See https://hub.jncc.gov.uk/assets/2e60a9a0-4366-4971-9327-2bc409e09784

[3] See https://jncc.gov.uk/our-work/marine-mammals-and-noise-mitigation/

Legislation/policy	Key provisions	Section where comment addressed
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"Soft start procedures during pile driving may be implemented. This enables marine mammals in the area disturbed by the sound levels to move away from the piling before physical or auditory injury is caused" -Paragraph 3.8.254	Mitigation measures are detailed in the Outline MMMP (document reference 8.4), see Table 11.8 for more details.
Draft National Policy Statement for Renewable Energy Infrastructure (EN-3), (DESNZ, 2023)	"Where noise impacts cannot be reduced be avoided, other mitigation should be considered, including alternative installation methods and noise abatement technology, spatial/temporal restrictions on noisy activities, alternative foundation types. Applicants should take a review of up-to-date research should be undertaken and all potential mitigation options presented as part of the application, having consulted the relevant JNCC mitigation guidelines[4]" -Paragraph 3.8.255 - 256	Mitigation is discussed in the Outline MMMP (document reference 8.4), see Table 11.8 for more details. Updates to noise abatement recommendations for other projects will be closely monitored and researched.

[4] See https://jncc.gov.uk/our-work/marine-mammals-and-noise-mitigation/

11.2.4 The approach to this PEIR chapter will follow the approach outlined in Volume 1, Chapter 5: EIA Methodology. In addition to the guidance outlined Volume 1, Chapter 5, the assessment of marine mammals will also comply with the following guidance documents where they are specific to the topic:

- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards. Phase I: Expectations for pre-application baseline data for designated nature conservation and landscape receptors to support offshore wind applications (Natural England, 2021);
- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards. Phase III: Expectations for data analysis and presentation at examination for offshore wind applications (Natural England, 2022);
- Marine environment: UXO clearance joint interim position statement[5] compiled by Defra, the Department for Business, Energy and Industrial Strategy (BEIS, now DESNZ), the MMO, the JNCC, Natural England, the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED), the Department of Agriculture, Environment and Rural Affairs (DAERA), NatureScot and Marine Scotland (Defra *et al*., 2021);
- Marine Mammal Noise Exposure Criteria: Assessing the severity of marine mammal behavioural responses to human noise (Southall *et al*., 2021);
- Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects (Southall *et al*., 2019);
- The protection of marine European Protected Species from injury and disturbance. Guidance for the marine area in England and Wales and the UK offshore marine area (JNCC *et al*., 2010);
- The Planning Inspectorate (hereafter referred to as the Inspectorate) Advice Note 7: EIA: Process, Preliminary Environmental Information and Environmental Statements (The Inspectorate, 2020);
- Updated cumulative effects assessment tier system (Natural England, 2022);
- Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2019);
- Oslo Paris Convention (OSPAR) Guidance on Environmental Considerations for OWF Development (OSPAR, 2008);
- Environmental Impact Assessment for offshore renewable energy projects – guide (British Standards Institute, 2015);
- Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments (Macleod *et al*., 2010);

[5] https://www.gov.uk/government/publications/marine-environment-unexploded-ordnance-clearance-joint-interim-position-statement

- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Judd, 2012);
- Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC, 2020);
- JNCC guidelines for minimising the risk of injury to marine mammals from using explosives (JNCC, 2010a); and
- Statutory Nature Conservation Agency Protocol for Minimising the Risk of Injury to Marine Mammals from Piling Noise (JNCC, 2010b).

11.3 Consultation

11.3.1 Consultation is a key part of the Development Consent Order (DCO) application process. Consultation regarding marine mammals has been conducted through the Evidence Plan Process (EPP) Expert Topic Group (ETG) meetings and the Scoping Process. An overview of the Project consultation process is presented within Volume 1, Chapter 6: Consultation Process.

11.3.2 A summary of the key issues raised during consultation to date, specific to marine mammals, is outlined in Table 11.2 below, together with how these issues have been considered in the production of this PEIR.

Table 11.2: Summary of consultation relating to marine mammals

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
19/01/22 Pre-scoping Evidence Plan meeting	The uncertainty around bottlenose dolphin population expansion into English waters from the established Scottish population was highlighted.	The approach taken for bottlenose dolphin population densities has been outlined in paragraph 11.4.7, with further details on the population provided in Volume 2, Appendix 11.1: Marine Mammal Technical Baseline.
19/01/22 Pre-scoping Evidence Plan meeting	It was agreed a 5km EDR is acceptable for established low order techniques where sufficient data is available.	The justification for a 5 km EDR for low order UXO clearance is provided in paragraph 11.6.34. An assessment of PTS-onset and disturbance from low order clearance is provided in section 11.7.
19/01/22 Pre-scoping Evidence Plan meeting	A number of animals which could be affected by TTS to be presented within the EIA assessment. However, it was agreed that it would be inappropriate to assess the significance of TTS.	An assessment of the number of individuals impacted by TTS is presented in 11.7, however it does not include an assessment of significance.
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 2.1.4	The Inspectorate notes the intention to seek consent for Unexploded ordnance (UXO) removal through a future Marine Licence application but that the effects of removal of UXO will be considered as part of the EIA process for the Development Consent Order (DCO) application. The ES should address any cumulative effects from the construction of the Proposed Development with the likely effects from the UXO clearance.	Consideration of underwater noise effects from UXO on marine mammals can be found within section 11.7.
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.1	The Scoping Report proposes to scope out accidental pollution resulting from all phases of the Proposed Development. The Inspectorate agrees that such effects are capable of being mitigated through standard management practices and can be scoped out of the assessment. The ES should provide details of the proposed mitigation measures to be included in the PEMP and its constituent MPCP, and/or	Accidental pollution has been scoped out of the assessment due to the commitment of a Marine Pollution Contingency Plan (MPCP) and Outline CoCP (see paragraph 11.5.2). Details on pollution prevention are provided in Table 11.8.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	appropriate Code of Construction Practice (CoCP). The ES should also explain how such measures will be secured.	
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.2	The Scoping Report lists a number of studies which evidence that the presence of operational OWFs does not, in the longer term, preclude the presence of marine mammals. The Scoping Report concludes that that "while disturbance leading to temporary displacement may occur, this is expected to be spatially and temporally small scale and thus it is not expected that any stage of the Project will result in a permanent barrier to the movement of marine mammals in the area." The Inspectorate is content that barrier effects to marine mammals during operation will be small scale and short lived and unlikely to result in significant effects. The Inspectorate therefore agrees this can be scoped out of the impact assessment.	Barrier effects have been scoped out of the assessment, see paragraph 11.5.2
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.3	The Scoping Report references evidence that dates from 2018 that supports a position that there is no evidence of EMF from marine renewable devices having any impact (either positive or negative) on marine mammals. Furthermore, the only marine mammal stated to show any response to EMF is the Guiana dolphin (*Sotalia guianesi*), which are not reported as being present within the scoping area. EMF effects to marine mammals are therefore proposed to be scoped out. The Inspectorate is content to scope this matter out on this basis.	EMF has been scoped out of the assessment, see paragraph 11.5.2.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.4	Construction activities resulting in disturbance to seals at haul-out sites are proposed to be scoped out on the basis of the distances to haul-outs (5-6km from the AoS) and the nature of the construction activities relative to activities which are generally reported to cause disturbance to seals at haul-outs (e.g. kayaks and fast-moving vessels within a few hundred metres). The Inspectorate notes the absence of information in the Scoping Report with regards to likely ports to be used as a source of vessel movements and thus whether vessels would be transiting from a closer location to seal haul-outs. As such, the Inspectorate does not agree that this matter can be scoped out of the assessment at this stage. The Inspectorate expects the ES to provide an assessment of impacts and resulting effects on seal haul-out sites, or robust evidence to support the conclusion that significant effects are unlikely. The Vessel Management Plan (VMP) should consider measures to reduce disturbance to marine mammals including seals at haul-out sites, as applicable. The Applicant should make effort to agree the evidence required in the ES with relevant consultation bodies, including Natural England, as part of the EPP.	Disturbance at seal haul-outs has been assessed for construction, operation and decommissioning phases in section 11.7.
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.5	It is recommended the Applicant use the latest version of the Inter Agency Marine Mammal Working Group (IAMMWG) reports (dated March 2022) to inform the impact assessment.	The IAMMWG reports (IAMMWG, 2022) have been used to inform the population sizes for harbour porpoise, white beaked dolphin, bottlenose dolphin and minke whale MUs (see Table 11.4). These figures have been taken forward into the impact assessment in sections 11.7 and 11.8.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.6	The ES should clearly explain and justify the selection of the site-specific survey area for all marine mammals as 'the array area plus a 4km buffer', with reference to agreements sought through the EPP.	The site-specific area is defined as the survey area plus a 4km buffer as is standard in baseline survey data collection (see paragraph 11.4.1). This was agreed in Marine Mammal ETG dated 19th January 2022.
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.7	The Inspectorate considers that the ES should also assess effects on the minke whale feature of the Sea of the Hebrides MPA (Nature Conservation), where significant effects are likely to occur.	The minke whale feature of the Sea of Hebrides MPA has been included in the assessment and the site is identified as a relevant designated site in Table 11.5.
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.8	The ES should present the TTS impact ranges and the number of animals predicted to be at risk. The Applicant's attention is directed to the comments of the MMO and Natural England at Appendix 2 to this Opinion. The Applicant should seek to agree the approach to the assessment of PTS and TTS-onset on marine mammals with the relevant consultation bodies, including the MMO and Natural England, through the EPP.	TTS ranges have been presented in section 11.7. There is only the presentation of impact ranges, areas and number of individuals and no assessment of significance as agreed in the Marine Mammal ETG dated 26th September 2022.
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.9	The Applicant's attention is directed to the comments of the MMO and Natural England at Appendix 2 to this Opinion with regards to use of TTS-onset as proxy for disturbance and also the use of the Effective Deterrence Range (EDR). The ES should clearly state the evidence base used to determine the approach to assessing disturbance from UXO clearance and other activities and justify the approach selected. The Applicant should seek to agree the approach to the assessment of UXOs and disturbance of marine mammals with the relevant consultation bodies through the EPP, including the MMO and Natural England.	The evidence for assessing disturbance from UXO is provided in paragraph 11.6.42 Discussion around the approach to assessment of UXOs has been discussed at the ETG on 23rd January 2023.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
09/09/22 Scoping Opinion (The Inspectorate, 2022) Comment ID: 3.5.10	Mitigation measures The ES should include consideration of measures to manage potential cumulative disturbance in the event that there is multiple piling or other noisy activities taking place simultaneously in the Southern North Sea Special Area of Conservation (SAC). It is also recommended an outline Site Integrity Plan (SIP) be provided with the Application.	The draft Report to Inform Appropriate Assessment (RIAA) includes full consideration of any necessary mitigation measures required to avoid an adverse effect on the integrity of the Southern North Sea Special Area of Conservation, including the need for a Site Integrity Plan to manage in-combination effects. An Outline SIP will be submitted alongside DCO application and outlines the proposed mitigation measures which could be utilised for the Project.
26/08/2022 Scoping Opinion (The Inspectorate, 2022) MMO Comment ID: 3.4.11	The MMO supports the use of soft-start procedures on commencement of piling. A 20-minute soft-start in accordance with Joint Nature Conservation Committee (JNCC) protocol for minimising the risk to injury to marine mammals and other fauna from piling noise (JNCC, 2010). Should piling cease for a period greater than 10 minutes, then the soft-start procedure must be repeated.	Embedded mitigation measures have been detailed in Table 11.8. Further details on the soft-start and other measures are detailed in Outline MMMP (document reference 8.4).
26/08/2022 Scoping Opinion MMO Comment ID: 3.7.1	The primary potential impacts in relation to underwater noise have been adequately identified for marine mammals and the methods described are sufficient to inform a robust impact assessment.	Noted. The impact assessment for impacts from underwater noise are assessed in section 11.7.
26/08/2022 Scoping Opinion (The Inspectorate, 2022) MMO Comment ID: 3.7.2	The MMO considers it appropriate that the thresholds presented in Southall *et al*., (2019) will be used in the impact assessment. However, it is worth noting that the noise exposure criteria will evolve over time, so the assessment should use the most current, peer-reviewed guidance available. It is also appropriate that both the instantaneous peak Sound Pressure Level (SPL_{peak}) and cumulative Sound Exposure Level (SEL_{cum}) over 24-hours will be assessed.	The hearing thresholds presented are from Southall *et al*., (2019) which remains the current best available criteria for a noise assessment) and have been used in the impact assessment, see section 11.7. Both SPL_{peak} and SEL_{cum} have been modelled in Volume 2, Appendix 3.2: Underwater Noise Assessment and assessed in section 11.7.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
26/08/2022 Scoping Opinion (The Inspectorate, 2022) MMO Comment ID: 3.7.3	With reference to paragraph 7.5.40 of the Scoping Report, the MMO, in consultation with Cefas, does not agree that there should be no requirement to assess the potential significance of Temporary Threshold Shift (TTS). Although TTS is by definition both recoverable and temporary, it is nevertheless an injury to the sensory capability of the animal which has the potential for serious consequences. As agreed with other projects, as a minimum, the TTS impact ranges and the number of animals predicted to be at risk should be presented. Therefore, the MMO recommends including both the TTS effect ranges and number of animals predicted to be at risk.	TTS ranges have been presented in section 11.7. There is only the presentation of impact ranges, areas and number of individuals and no assessment of significance as agreed in the Marine Mammal ETG dated 26th September 2022.
26/08/2022 Scoping Opinion (The Inspectorate, 2022) MMO Comment ID: 3.7.4	Furthermore, it is not appropriate to use the TTS-onset thresholds as a proxy for disturbance. TTS occurs at much higher sound exposure, and so will underestimate the risk of disturbance. The 26km Effective Deterrence Range (EDR) for other species should be used or evidence should be presented for review to support a different distance on the basis of behavioural response studies. The Unexploded Ordnance (UXO) blast signal (for high-order detonation) is a particularly loud signal, so applying caution is necessary in this case. It could be argued that the harbour porpoise EDRs are likely to be conservative because porpoise are sensitive to noise, so they are a good starting point and a reasonable option in the absence of other data.	The 26km EDR has been applied to all marine mammal species for disturbance from UXO clearance as requested in the Scoping Opinion response, see Table 11.17. However, an alternative disturbance threshold in which TTS-onset has been used as a proxy for disturbance has also been presented (see Table 11.19:) alongside the 26km EDR assessment. For additional details see paragraph 11.6.33.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
26/08/2022 Scoping Opinion (The Inspectorate, 2022) MMO Comment ID: 3.7.5	Embedded mitigation measures are listed in paragraph 7.5.50 of the Scoping Report and include the development of, and adherence to, a Vessel Management Plan, implementation of a Marine Mammal Mitigation Protocol (MMMP) for piling, UXO geophysical survey work, as well as a decommissioning MMMP. These measures are in keeping with other windfarm developments and can provide a suitable means for managing and mitigating potential effects of the Project. The MMO expects details of the MMMPs, and specific mitigation measures will be discussed and agreed with the MMO and SNCBs, once project parameters have been defined, and the noise modelling has been undertaken.	Details of embedded mitigation measures are presented in Table 11.8. MMMPs will be discussed with SNCBs once project parameters and noise modelling confirmed, as part of the EPP. An Outline MMMP (document reference 8.4) will be submitted alongside PEIR.
26/08/2022 Scoping Opinion (The Inspectorate, 2022) MMO Comment ID: 3.7.6	The underwater noise assessment should include full details of the noise modelling methodology and model parameters and assumptions, including: ▪ Acoustic source level spectra and how they were derived (e.g., conversion from hammer strike energy, backpropagation from measurements). ▪ Specifications of the propagation model, including equations if appropriate, or references to the peer-reviewed scientific literature in which they are contained. ▪ The environmental conditions (local area bathymetry, seabed and water column properties) and how these have been parameterised in the model. ▪ Any assumptions or simplifications such as averaging in depth, space or time.	The full details of the underwater noise assessment are presented in Volume 2, Appendix 3.2: Underwater Noise Assessment.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	▪ The parameters of a fleeing model.	
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 70	Natural England agrees with the proposed MUs for marine mammals but suggest that the latest version of the IAMMWG reports is used (March 2022) and that the reference for seal MUs is included in the future.	The IAMMWG reports (IAMMWG, 2022) have been used to inform the population sizes for harbour porpoise, white beaked dolphin, bottlenose dolphin and minke whale MUs (see Table 11.4). Seal MUs have been used to inform the population sizes of both harbour and grey seals (SCOS, 2022). These figures have been taken forward into the impact assessment in sections 11.7 and 11.8.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 71	Natural England are broadly satisfied with the key datasets listed to inform the marine mammal baseline. Carter *et al.*, (2022) should be used, as the peer reviewed and slightly amended version of Carter *et al.*, (2020). Consideration should be given to inclusion of data from other nearby windfarms e.g., Hornsea zone.	Volume 2, Appendix 11.1: Marine Mammal Technical Baseline has included Carter *et al.*, (2022) for the density reference for grey and harbour seals, which has been taken forward into the impact assessment in section 11.7. The marine mammal baseline data that exist for the study are presented in Table 11.3.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 72	Natural England considers that most of the relevant marine mammal protected areas have been identified. The only site in a relevant MU that has been omitted is the Sea of Hebrides (NC)MPA for minke whales. Natural England recommends that the applicant reference the Sea of the Hebrides (NC)MPA, which lists minke whale.	The marine nature conservation designations with relevance to marine mammals features in The Project are presented in Table 11.5.
30/08/22 Scoping Opinion Natural England Comment ID: 73	The list of guidance document is comprehensive and relevant for the marine mammal assessment.	Noted. The list of guidance documents have been provided in paragraph 11.2.4.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 74	For reference, Natural England considers that there is insufficient evidence to demonstrate noise reduction from 'low yield' clearance of UXOs.	Noted. For the purposes of this assessment, "low order" is considered to be referring to deflagration only.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 75	Natural England do not agree that the TTS onset thresholds should be used as a proxy for disturbance given that TTS occurs at higher sound exposures, and so will underestimate the risk of disturbance.	The 26km EDR has been applied to all marine mammal species for disturbance from UXO clearance as requested in the Scoping Opinion response, see Table 11.17. However, an alternative disturbance threshold in which TTS-onset has been used as a proxy for disturbance has also been presented (see Table 11.19:) alongside the 26km EDR assessment. For additional details see paragraph 11.6.33.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 76	The 5km EDR referenced here is only applicable for harbour porpoises. If it is to be applied to other species, further evidence is required.	A 5km EDR has been assumed for low-order UXO clearance for all species (as per the Sofia Offshore Windfarm Marine Licence application for UXO detonation) and based on the difference between the expected sound levels of low order and high order UXO clearance, rather than specifically the sensitivity of different species. There is currently no advised EDR for low-order detonations so until empirical data are available 5km is the assumed EDR (see paragraph 11.6.34 for more detail). However, an alternative disturbance threshold in which TTS-onset has been used as a proxy for disturbance has also been presented (see Table 11.19:) alongside the 26km EDR assessment. For additional details see paragraph 11.6.33.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 77	Natural England agrees that the listed embedded mitigation protocols are relevant to the marine mammal assessment, however we advise that more measures may be required to manage disturbance in the SNS SAC in the event that construction takes place simultaneously with other OWF construction or noisy activities in the SAC. These plans and contingencies will need to be outlined in detail as part of the ES. Furthermore, a Site Integrity Plan (SIP) will need to be produced which will specify exactly how these plans will be implemented as part of marine licence. We reserve the right to comment on the suitability of these documents in mitigating impacts when they are submitted as part of the consultation process	The draft Report to Inform Appropriate Assessment (RIAA) includes full consideration of any necessary mitigation measures required to avoid an adverse effect on the integrity of the Southern North Sea Special Area of Conservation, including the need for a Site Integrity Plan to manage in-combination effects. An Outline SIP will be submitted alongside DCO application and outlines the proposed mitigation measures which could be utilised for the Project.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 78	Natural England agrees with the proposed impacts scoped into the assessment.	The scope of the assessment has been presented in paragraph 11.5.1.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 79	Underwater noise from UXO clearance and other construction activities: Please refer to our comments above in regard to TTS onset as a proxy for disturbance and 5km EDR range for low order detonation for other species	The 26km EDR has been applied to all marine mammal species for disturbance from UXO clearance as requested in the Scoping Opinion response, see Table 11.17. However, an alternative disturbance threshold in which TTS-onset has been used as a proxy for disturbance has also been presented (see Table 11.19:) alongside the 26km EDR assessment. For additional details see paragraph 11.6.33.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
		A 5km EDR has been assumed for low-order UXO clearance for all species based on the Sofia Offshore Windfarm Marine Licence application for UXO detonation. There is currently no advised EDR for low-order detonations so until empirical data are available 5km is the assumed EDR (see paragraph 11.6.34 for more detail).
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 80	Vessel collision and disturbance: Although not of concern, we found the proposed approach for assessment unclear thus we welcome further details on this at future EWG.	The assessment of vessel collision and disturbance for construction, operation and decommissioning phases is provided in section 11.7. The assessment of cumulative vessel disturbance is presented in section 11.8. The assessment of vessel collision and disturbance was discussed in the Marine Mammal ETG on the 23rd January 2023 including vessel routes to be assumed.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 81	We agree with the Applicant's earlier statement (Paragraph 7.5.48) that the final list of impacts scoped into the CEA cannot be determined at the Scoping stage. As such we do not advise that any impacts are scoped out at this stage e.g., indirect impacts.	Based on the Scoping Opinion and consultation the list of impacts to be scoped in has been updated, see paragraph 11.5.1.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 82	Natural England agrees that accidental pollution, barrier effects (operation) and EMF should be scoped out of assessment. However, we do not agree that the disturbance at haul-outs can be scoped out at this stage without knowledge of vessel movements and ports during the various phases. The Vessel Management Plan should	Accidental pollution, barrier effects and EMF have been scoped out, see paragraph 11.5.2. Disturbance at haul-out sites has been scoped in (see paragraph 11.5.1) and assessed in section 11.7.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	consider measures to reduce disturbance to marine mammals including hauled out seals.	
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 83	Natural England are broadly satisfied with the key datasets listed to inform the marine mammal baseline; however, we have provided several references above to be included in future documents.	The suggested references have been included in Table 11.3 to strengthen the information provided in the marine mammal baseline for PEIR.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 84	Natural England considers that most of the relevant marine mammal protected areas have been identified, however, we recommend that the applicant also reference and include due consideration within the assessment to the Sea of the Hebrides (NC)MPA, which lists minke whale as a protected feature. Natural England advise that further review of the list of receptors will be required once the full results of the site-specific surveys have been analysed.	The marine nature conservation designations with relevance to marine mammals features in The Project are presented in Table 11.5.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 85	Natural England believes that all of the likely impact pathways have been identified. However, we reserve the right to amend our advice once more information is provided	The scope of the assessment is presented in paragraph 11.5.1.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 86	Natural England agrees that barrier effects (operation) and EMF should be scoped out of assessment. However, we do not agree that accidental pollution and disturbance at haul-outs can be scoped out at this stage without knowledge of vessel movements and ports during the various phases and mitigations measures put in place for pollution incidents are secured. The Vessel Management Plan should consider	Barrier effects and EMF have been scoped out, see paragraph 11.5.2. Disturbance at haul-out sites has been scoped in (see paragraph 11.5.1) and assessed in section 11.7. Accidental pollution has been scoped out due to the implementation of mitigation (PEMP and MPCP)

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	measures to reduce disturbance to marine mammals including hauled out seals.	
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 87	Please refer to our comments above in regard to TTS onset as a proxy for disturbance and 5km EDR range for low order detonation for other species. Vessel collision and disturbance: Although not of concern, we found the proposed approach for assessment unclear thus we welcome further details on this at future EWG. We support the proposal by the applicant to review the list of impacts in the CEA after the Project alone assessment is complete	A 5km EDR has been assumed for low-order UXO clearance for all species based on the Sofia Offshore Windfarm Marine Licence application for UXO detonation. There is currently no advised EDR for low-order detonations so until empirical data are available 5km is the assumed EDR (see paragraph 1.6.34 for more detail). This approach was agreed at the Marine Mammal ETG dated 23rd January 2023.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 88	Natural England agrees that the listed embedded mitigation protocols are relevant to the marine mammal assessment, however more measures will be required to manage disturbance in the event that there are multiple pilling programmes underway in the Southern North Sea SAC and these need to be outlined in in the ES, we also advise including a Site Integrity Plan (SIP) to the list of documents to be included as part of the Application. We reserve the right to comment on the suitability of these documents in mitigating impacts when they are submitted as part of the consultation process.	Mitigation measures for the SNS SAC will be detailed within the ES. An Outline SIP will be submitted alongside DCO application.
30/08/22 Scoping Opinion (The Inspectorate, 2022) Natural England Comment ID: 89	Natural England do not agree that the TTS-onset thresholds should be used as a proxy for disturbance given that TTS occurs at higher sound exposures, and so will underestimate the risk of disturbance. We advise that the applicant review the evidence base to determine an appropriate approach to assessing disturbance from UXO clearance and other activities. The 5km EDR referenced is only applicable for	The 26km EDR has been applied to all marine mammal species for disturbance from UXO clearance, see Table 11.17. However, an alternative disturbance threshold in which TTS-onset has been used as a proxy for disturbance have also been presented (see Table 11.19:) alongside the 26km EDR assessment. For additional details see paragraph 11.6.33.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	harbour porpoises, so if it is to be applied to other species, further evidence is required. Natural England refers the applicant to section 6.5.2 of the Best Practice: Phase III document in relation to the Soloway & Dahl (2014) methodology for assessment of impact ranges of UXO disposal.	A 5km EDR has been assumed for low-order UXO clearance for all species based on the Sofia Offshore Windfarm Marine Licence application for UXO detonation. There is currently no advised EDR for low-order detonations so until empirical data are available 5km is the assumed EDR (see paragraph 11.6.34 for more detail). Please see paragraph 11.7.6 and Volume 2, Appendix 3.2: Underwater Noise Assessment for details on how Soloway and Dahl (2014) has been incorporated into the UXO assessment.
25/08/2 Scoping Opinion (The Inspectorate, 2022) Lincolnshire Wildlife Trust	LWT strongly disagrees with the scoping out of project disturbances at haul-out sites, particularly at Donna Nook. This important haul-out site receives over 2,000 adult grey seals annually and serves as birthing grounds for roughly 2,000 pups each year (recent count data from 2021; lincstrust.co.uk). Given that grey seals are a qualifying feature for the Humber Estuary SAC, due diligence is demanded with regards to potential negative impacts from marine development. Furthermore, LWT believes that the Project is overestimating distances between project/construction activities and large concentrations of grey seals, given that adults will range in and use surrounding waters near haul-out sites. Further details of LWT's stance on the scoping out of disturbance to haul-out sites is detailed below in Appendix A.	Disturbance at haul out sites has been scoped in and assessed, see section 11.7. The impacts on the Humber Estuary SAC are detailed in the RIAA (document reference 7.1).

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
25/08/2 Scoping Opinion (The Inspectorate, 2022) Lincolnshire Wildlife Trust	LWT does not agree with the proposed buffer range of 4km that is sighted in the scoping report for marine mammals. Recent marine noise research suggests that impulsive noise signals, such as those arising from pile driving and marine construction, can propagate over substantial distances (~37km; Hastie *et al*., 2019). Furthermore, the impulsive nature of a sound is likely to be a complex interaction of several parameters (e.g., duty cycle, recovery periods, and sound levels) that will strongly affect the risk of hearing damage in marine mammals. Ultimately, more research regarding auditory damage that explicitly considers ranges from noise sources is needed before safe distances can be determined. Until more is known about this complex issue, LWT would recommend reconsideration in favour of more conservative buffer zones to ensure that marine mammals are safeguarded from negative impacts.	The site-specific area is defined as the survey area plus a 4km buffer as is standard in baseline survey data collection (see paragraph 11.4.1). This was agreed in Marine Mammal ETG dated 19th January 2023. The study areas have been clarified in section 11.411.4 and in Volume 2, Appendix 11.1: Marine Mammal Technical Baseline.
25/08/2 Scoping Opinion (The Inspectorate, 2022) Lincolnshire Wildlife Trust	LWT agrees with the inclusion of noise modelling and the methods outlined in Southall *et al*., (2019). However, it would be prudent to include appropriate spatiotemporal scales, seasonality, and a range of individual responses in the modelling process. While a dose response risk assessment may help determine proportional risk to marine mammal populations, such an approach would be limited in quantifying impacts over space and time. There are alternative approaches (e.g., individual-based modelling; Nabe-Nielsen *et al*., 2018) that may offer more detailed, quantifiable insight on noise-related impacts and help assess opportunities for effective mitigation. Furthermore, a ready-	A species-specific dose-response approach has been used to assess disturbance from piling (see paragraphs 11.6.16 to 11.6.27). For disturbance form UXO detonation three behavioural disturbance thresholds have been considered: 26km EDR for high-order clearance, 5km EDR for low-order clearance, and a fixed noise threshold for TTS-onset (see paragraphs 11.6.28 to 11.6.39). Information on alternative population models has been provided in paragraphs 11.8.29 and 11.8.30 to support the approach to modelling undertaken in the impact assessment.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	made model exists for the North Sea harbour porpoise that could be adapted to properly assess noise impacts to his and other marine mammal species as a result of the Project (Nabe-Nielsen *et al*., 2018).	
25/08/2 Scoping Opinion (The Inspectorate, 2022) Lincolnshire Wildlife Trust	Lastly, LWT recommends that vessel noise be scoped into the Project and included in noise modelling for the impacts of project-related noise (Erbe *et al*., 2019).	Vessel noise has been assessed as part of vessel disturbance impact for construction, operation and decommissioning (see impact 10 in section 11.7). Additionally, impact ranges for vessel noise from Southall at al., (2019) are presented in Volume 2, Appendix 3.2: Underwater Noise Assessment.
25/08/2 Scoping Opinion (The Inspectorate, 2022) Lincolnshire Wildlife Trust	Given the dense concentration of adult grey seals during reproductive/haul-out months at Donna Nook (2,000+ adults reported in 2021; lincstrust.org.uk) and subsequent pups birthed (2,000+ pups birthed at Donna Nook in 2021; lincstrust.org.uk), LWT firmly disagrees that potential impacts to haul-outs can be scoped out of the Project and that the developers are making a blind assumption when stating that 'it is not expected that activities during construction will directly impact seal haul-outs'. First, the distance to Donna Nook from the boundary of the ECC AoS (5 to 6km according to the Scoping Report) is too short to be scoped out considering that noise signals from marine construction still have a 0.5 mean probability of exceeding marine mammal risk criteria at ranges >3.5km (Hastie *et al*., 2019). While LWT appreciates that noise impacts to seals are scoped in, the importance of haul-out sites to reproduction and population stability require deliberate and careful consideration with regards to potential anthropogenic	Disturbance at haul out sites has been scoped in and assessed, see section 11.7.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	disturbance. Second, the Project's assumed 'safe' distance of construction activity relative to Donna Nook does not account for important in water activity by seals near haul-outs. While the distance to Donna Nook from the ECC AoS boundary may be 5 to 6km, there is likely to be a high concentration of grey seals ranging in and using nearby waters for foraging forays during haul-out months. This means that the distance of construction activity relative to large concentrations of grey seals has potentially been overestimated and therefore requires reconsideration and proper evaluation in the PEIR and ES.	
23/01/23 Pre-PEIR submission Evidence Plan meeting	It was queried whether cumulative effects of non-oil and gas pre-construction surveys and Carbon Capture Storage are captured in the CEA.	The offshore construction schedules for the projects included in the CEA have been investigated using publicly available information. No information on planned surveys in the timescales associated with Project are available, however an assumption regarding a likely number of surveys based on historical data has been used within the assessment.
23/01/23 Pre-PEIR submission Evidence Plan meeting	The ICES marine noise registry should be reviewed to inform assumptions, including military UXO and sonar, in the CEA.	The marine noise registry has been consulted and used to inform the CEA, see section 11.8.
23/01/23 Pre-PEIR submission Evidence Plan meeting	It was queried whether the CEA was undertaken on an annual or seasonal basis.	The level of information is not fine scale enough so the assumption have been made that the levels of activity will be consistent throughout a year, see section 11.8.

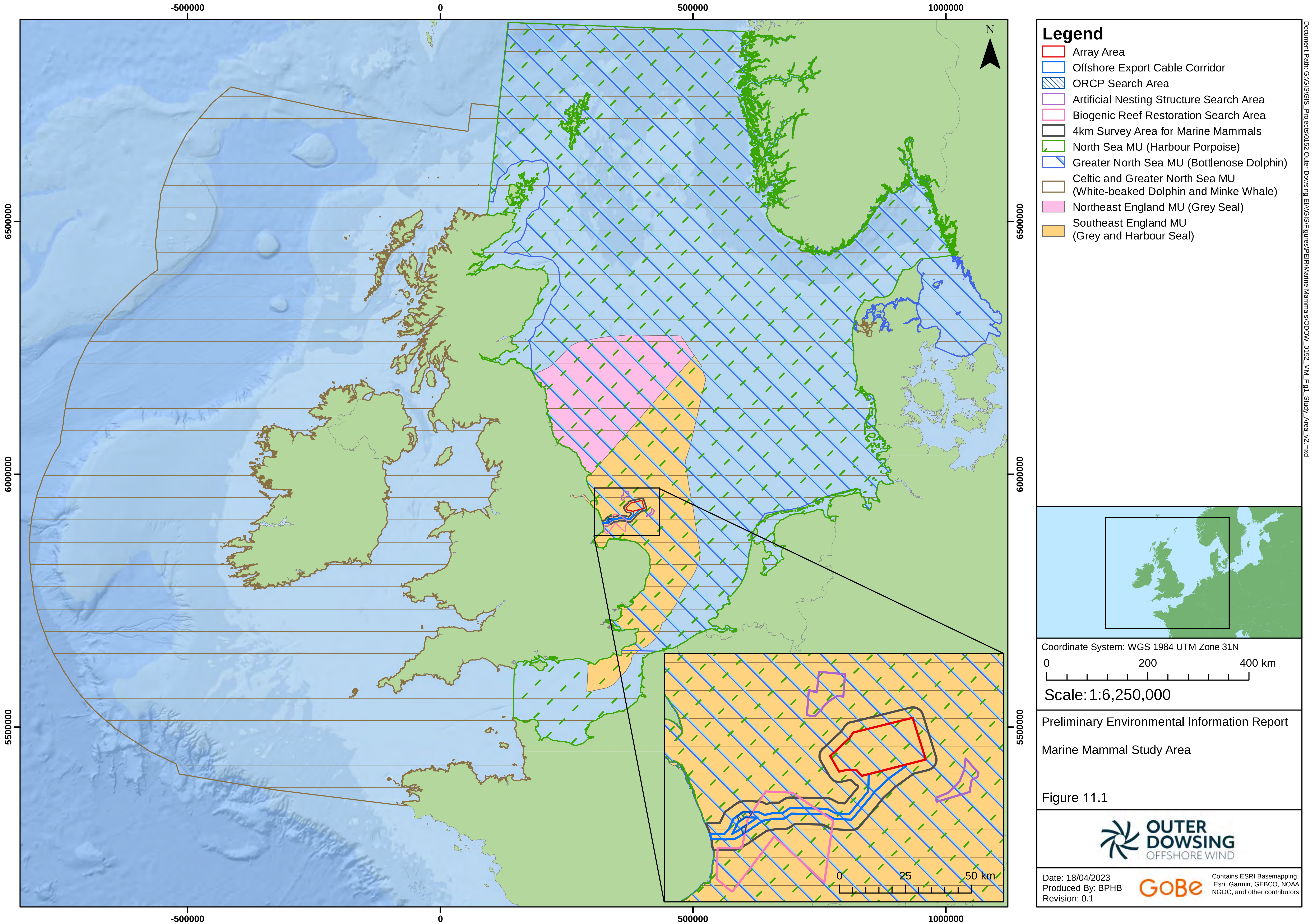
11.3.3 As identified in Volume 1, Chapter 4: Site Selection and Consideration of Alternatives and Volume 1, Chapter 3: Project Description, the Project design envelope has been refined and will be refined further prior to DCO submission. This process is reliant on stakeholder consultation feedback.

11.4 Scope

Study Area

11.4.1 The Project marine mammal study area varies depending on the species, considering individual species ecology and behaviour (Figure 11.1). The marine mammal study area has been defined at two spatial scales:

- The Management Unit (MU) study area: provides a wider geographic context in terms of species present and their estimated densities and abundance. This scale defines the appropriate reference populations for the assessment. The regional study area for each species is as follows:
  - Harbour porpoise: North Sea MU;
  - White-beaked dolphin: Celtic and Greater North Seas MU;
  - Bottlenose dolphin: Greater North Sea MU;
  - Minke whale: Celtic and Greater North Seas MU;
  - Grey seals: Southeast England MU and Northeast England MU; and
  - Harbour seals: Southeast England MU.
- The Project study area: the survey area for the Project site-specific aerial surveys (carried out between March 2021 and February 2023 as part of the ornithological aerial surveys – survey area comprised the Project array areas and a 4km buffer as described in Volume 1, Chapter 12: Offshore and Intertidal Ornithology) to provide an indication of the local densities of each species across the windfarm and offshore Area of study (AoS) and associated impact footprints.


Legend
Array Area
Offshore Export Cable Corridor
ORCP Search Area
Artificial Nesting Structure Search Area
Biogenic Reef Restoration Search Area
4km Survey Area for Marine Mammals
North Sea MU (Harbour Porpoise)
Greater North Sea MU (Bottlenose Dolphin)
Celtic and Greater North Sea MU (White-beaked Dolphin and Minke Whale)
Northeast England MU (Grey Seal)
Southeast England MU (Grey and Harbour Seal)
Coordinate System: WGS 1984 UTM Zone 31N
0 200 400 km
Scale: 1:6,250,000
Preliminary Environmental Information Report
Marine Mammal Study Area
Figure 11.1
OUTER DOWSING OFFSHORE WIND
Date: 18/04/2023
Produced By: BPHB
Revision: 0.1
GoBe
Contains ESRI Basemapping; Esri, Garmin, GEBCO, NOAA NGDC, and other contributors
0 25 50 km
-500000 0 500000 1000000
6500000 6000000 5500000
N

Data sources

11.4.2 Table 11.3 outlines the baseline datasets that exist for the study area.

Table 11.3: Marine Mammal Baseline Datasets

Source	Summary	Spatial Coverage
Site-specific surveys (HiDef, 2022)	HiDef digital aerial surveys (March 2021 – February 2023). Note: only March 2021 – February 2022 data were available for PEIR.	Array area plus 4km buffer.
Site-specific geophysical surveys	MMO and PAM detections during surveys conducted between August 2021 – January 2022	Array area plus 500m buffer. Plus, coverage of the Silver Pit area to the west of the array.
Seal habitat preference maps (Carter *et al*., 2020, 2022)	Density surface based on telemetry and count data.	UK waters.
Small Cetaceans in European Atlantic waters and the North Sea (SCANS) III (Hammond *et al*., 2021)	Aerial and vessel visual surveys for cetaceans, June and July 2016.	All European Atlantic waters. The Project is located in block O.
Joint Cetacean Protocol (JCP) Phase III (Paxton *et al*., 2016)	Aerial, vessel and land-based surveys, 1994 - 2010.	UK waters. Nearest areas of commercial interest for which data are available are: Norfolk Bank and South Dogger Bank.
Harbour porpoise densities (Heinänen and Skov, 2015)	Vessel and aerial surveys, 1994 – 2011.	UK waters.
Seal telemetry data provided by the Sea Mammal Research Unit (SMRU)	Data on movement of both harbour and grey seals from tagged individuals.	UK wide.
The Wildlife Trust (TWT) data	Unknown at this stage. TWT will be contacted to obtain any marine mammal data for the relevant area.	
Sea Watch Foundation data	The Sea watch Foundation have been approached and no data has been provided.	
Nearby OWFs	Site-specific data collated at nearby OWFs: Dudgeon & Sheringham Shoal Extensions Race Bank Triton Knoll Sheringham Shoal Dudgeon Docking Shoal Lincs	Offshore windfarm array areas plus buffer (varies by site).

Source	Summary	Spatial Coverage
	Lynn Inner Dowsing Hornsea Project One Hornsea Project Two Hornsea Project Three Hornsea Project Four Humber Gateway Westermost Rough	

Existing Environment

11.4.3 The existing environment for marine mammals is detailed in Volume 2, Appendix 11.1, with a summary provided here. This PEIR chapter should therefore be read alongside the detailed Volume 2, Appendix 11.1: Marine Mammal Technical Baseline which assesses the range of species and the abundance and density of marine mammals that could potentially be impacted by the Project, informed by data collected across previous offshore windfarm projects and surveys covering the marine mammal MUs that include the Project array area.

11.4.4 The data available (see section 11.4.2 for details of data sources) have confirmed the likely presence of harbour porpoise, minke whale, white beaked dolphin, bottlenose dolphin, grey seal and harbour seal in the vicinity of the Project and, therefore, these species should be considered within the quantitative impact assessment. The most robust and relevant density estimates within each MU were determined for each species, with harbour porpoise estimated to have the highest density within its respective MU (Table 11.4).

Table 11.4: Marine mammal MU and density estimates (#/km^2) taken forward to impact assessment

Species	MU	MU size	MU ref	Density (individuals/km^2)	Density ref
Harbour porpoise	North Sea	346,601	IAMMWG (2022)	2.375 (average monthly)	HiDef, (2022)
White beaked dolphin	Celtic and Greater North Sea	43,951	IAMMWG (2022)	0.002	HiDef, (2022) site-specific surveys and Hammond *et al.*, (2021)[6]
Bottlenose dolphin	Greater North Sea	2,022	IAMMWG (2022)	0.002 0.110[7]	Lacey *et al.*, (2022) and Hammond *et al.*, (2021)
Minke whale	Celtic and Greater North Sea	20,118	IAMMWG (2022)	0.010	Hammond *et al.*, (2021) and Royal Haskoning DHV (2021)[8]
Harbour seal	Southeast England	4,852	SCOS (2022) counts scaled to account for seals at sea using Longeran *et al.*, (2013)	Grid cell specific	Carter *et al.*, (2020, 2022)
Grey seal	Southeast England and Northeast	63,464	2019 counts for seals at sea	Grid cell specific	Carter *et al.*, (2020, 2022)

11.4.5 Harbour porpoise within the North Sea MU have an estimated abundance of 346,601 (95% CI: 289,498 – 419,967, CV: 0.09) (IAMMWG, 2022). They have an overall conservation status of ‘unknown’ and an overall trend of ‘unknown’ (JNCC, 2019a). Harbour porpoise have a widespread distribution within the MU and were observed at the Project site during the 12 months of site-specific surveys that have been analysed to date (March 2021 – February 2022). The site-specific surveys obtained an average monthly harbour porpoise density estimate of 2.375 porpoise/km^2.

[6] HiDef surveys and SCANS-III resulted in the same density estimate for white-beaked dolphins of 0.002 animals/km^2
[7] Only present within 2km of the coastline
[8] Dudgeon and Sheringham Shoal Extension projects

11.4.6 A single MU has been assigned for white-beaked dolphins, the Celtic and Greater North Sea with an estimated abundance of 43,951 (95% CI: 28,439 – 67,924, CV: 0.22) (IAMMWG, 2022). White-beaked dolphins are wide-spread across the continental shelf and three were observed in March 2021 during the first year of Project site-specific surveys. The average site-specific monthly estimate has been calculated as 0.002 individuals/km^2 which aligns with the SCANS III block O density abundance (Hammond *et al*., 2021).

11.4.7 The Project is located in the Greater North Sea MU for bottlenose dolphins which has an estimated abundance of 2,022 (95% CI: 548 – 7,453, CV: 0.75) (IAMMWG, 2022). No bottlenose dolphins were identified in the first 12 months of site-specific surveys (March 2021 – February 2022) and neither were any identified in block O of the SCANS III survey (Hammond *et al*., 2021). The SCANS III data has been used to obtain predicted density surfaces (Lacey *et al*., 2022) and data extracted from these density surfaces showed there was a maximum density of 0.002 bottlenose dolphin/km^2 in both the array area and ECC. Additionally, consideration has been provided for densities closer to the coast as the east coast Scottish population has been recorded ranging further south into the coast of northeast England. As there is no reliable estimate for bottlenose dolphin densities in the vicinity of the Project, a highly precautionary estimate of 0.110 dolphins/km^2 within 2km of the coast of northeast England has been assumed. Therefore, the quantitative impact assessment will present results assuming the two different density estimates: 0.002 dolphins/km^2 (throughout entire impact range) and 0.110 dolphins/km^2 (2km from coast).

11.4.8 A single MU is implemented for Minke whales in UK waters, the Celtic and Greater North Seas MU with an estimated 20,118 (95% CI: 14,061 – 28,786, CV: 0.18) (IAMMWG, 2022). No minke whales were sighted in the first year of site-specific surveys (March 2021 – February 2022). SCANS III estimated a total of 603 minke whales (95% CI: 109-1,670, CV: 0.675) in block O, with an estimated density of 0.010 whales/km^2. This density was also recorded at nearby Sheringham Shoal and Dudgeon Extension site-specific surveys so has been taken forward to the quantitative impact assessment.

11.4.9 The latest August haul-out data for harbour seals within the Southeast England MU from the 2016-2019 dataset resulted in an estimated abundance of 3,494 (SCOS, 2022). In Volume 2, Appendix 11.1: Marine Mammal Technical Baseline the 2019 count has been scaled by the estimated proportion hauled out (0.72, 95% CI: 0.54-0.88) (Lonergan *et al*., 2013) to provide an estimate of 4,852 harbour seals in the Southeast England MU in 2019 (95% CI: 3,970 – 6,470). A total of 24 harbour seals have been sighted in the first year of site-specific surveys (March 2021 – February 2022).

11.4.10 The latest August haul-out data for grey seals within the Southeast England MU from the 2016-2019 dataset resulted in an estimated abundance of 8,667 (SCOS, 2022). Given the wide ranging nature of grey seals (frequently travelling over 100km between haul out sites) (SCOS, 2021) and the large degree of movement between the north east and south east of England, it is not appropriate to consider the Southeast England MU as a discrete population unit in isolation. Therefore, the relevant population against which to assess impacts should be the combined Southeast and Northeast England MUs. In Volume 2, Appendix 11.1: Marine Mammal Technical Baseline the 2019 count data for the Southeast England MU and combined with the Northeast England MU 2019 count data (13,327 total) has been scaled by the estimated proportion hauled out (0.2515, 95% CI: 0.2145-0.2907) (SCOS, 2022) to produce an estimate of 52,990 grey seals in the Southeast and Northeast England MUs combined (95% CI: 45,845 – 62,131). A total of 40 grey seals were recorded during the sight-specific surveys (March 2021 – February 2022).

Compensation Areas

11.4.11 Two areas of search for the delivery of potential compensation measures (if required through the Habitats Regulations Assessment (HRA) process) have been identified for the Project (Figure 11.1). These will fall in the Project survey area for all species; therefore, the baseline will be as described above (see paragraphs 11.4.3 to 11.4.10).

11.4.12 The potential impacts arising from the compensation measures (once defined) will be assessed within the ES following refinement of the proposed areas and once details of the works to be undertaken have been finalised.

Designated sites

11.4.13 A separate HRA draft Report to Inform Appropriate Assessment (RIAA) has been completed for the Project (RIAA document reference 7.1) which includes details on the designated sites screened into the HRA for each marine mammal species. This section outlines the Special Areas of Conservation (SACs) within the assessment MUs for each marine mammal species (Table 11.5).

11.4.14 The Project array area is partly located within the summer area of the Southern North Sea SAC and is in close proximity to the Wash and North Norfolk Coast SAC for harbour seals and the Humber Estuary SAC for grey seals. Further from the Project there is the Berwickshire and North Northumberland Coast SAC for grey seals, the Southern Trench MPA and Sea of Hebrides MPA for minke whale, and the Moray Firth SAC for bottlenose dolphins.

Table 11.5: Marine nature conservation designations with relevance to marine mammals in the Project

Protected Area	Designation	Species	Minimum distance from the Project array area (km)
Southern North Sea	SAC	Harbour porpoise (primary reason)	Partially overlaps
The Wash	SAC	Harbour seal (primary reason)	48km
Humber Estuary	SAC	Grey seal (qualifying feature)	55km
Berwickshire and North Northumberland Coast	SAC	Grey seal (primary reason)	260km
Southern Trench	MPA	Minke whale (primary reason)	450km
Moray Firth	SAC	Bottlenose dolphin (primary reason)	580km
Sea of the Hebrides	MPA	Minke whale (primary reason)	910km

Future Baseline

11.4.15 The EIA Regulations require that:

"A description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge"

is included within the ES (EIA Regulations, Schedule 4, Paragraph 3). From the point of assessment, over the course of the development and operational lifetime of the Project (operational lifetime anticipated to be up to 30 years from first power), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that the Project is not constructed, using available information and scientific knowledge of marine mammal ecology.

11.4.16 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 is the cause of the recent exponential growth of grey seals in the North Sea (Russell *et al*., 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.

11.4.17 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 11.6. For grey seals the long-term trends in population size were categorised as increasing and the assessment resulted in a conclusion of the species having favourable future prospects. 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 Unfavourable - Inadequate future prospects. Harbour porpoise are considered to have an Unknown conservation status, however the UK harbour porpoise population has been assessed as having Favourable future prospects. White-beaked dolphin, bottlenose dolphin and minke whale are Unknown future prospects and Unknown overall trend.

Table 11.6: Summary of the conservation status of each marine mammal species (FV = Favourable, XX = Unknown, + = Improving, U1 = Unfavourable - Inadequate)

Species	Range	Population	Habitat	Future prospects	Conservation status	Overall trend	Reference
Harbour porpoise	FV	XX	XX	FV	XX	XX	JNCC (2019a)
White-beaked dolphin	FV	XX	XX	XX	XX	XX	JNCC (2019b)
Bottlenose dolphin	FV	XX	XX	XX	XX	XX	JNCC (2019c)

Species	Range	Population	Habitat	Future prospects	Conservation status	Overall trend	Reference
Minke whale	FV	XX	XX	XX	XX	XX	JNCC (2019d)
Grey seal	FV	FV	FV	FV	FV	+	JNCC (2019e)
Harbour seal	FV	U1	XX	U1	U1	XX	JNCC (2019f)

11.5 Basis of Assessment

Scope of the Assessment

Impacts Scoped In for Assessment

11.5.1 The following impacts have been scoped into the assessment:

- Construction:
  - Impact 1: UXO Clearance - PTS;
  - Impact 2: UXO Clearance - Disturbance;
  - Impact 3: Pile driving - PTS;
  - Impact 4: Pile Driving – TTS;
  - Impact 5: Pile driving - Disturbance;
  - Impact 6: PTS from other construction activities;
  - Impact 7: TTS from other construction activities;
  - Impact 8: Disturbance from other construction activities;
  - Impact 9: Vessel collisions
  - Impact 10: Vessel disturbance;
  - Impact 11: Indirect impacts on prey;
  - Impact 12: Water quality impacts; and
  - Impact 13: Disturbance at seal haul-outs.
- Operation:
  - Impact 14: Operational noise;
  - Impact 15: Vessel collisions;
  - Impact 16: Vessel disturbance; and
  - Impact 17: Indirect impacts on prey.

- Decommissioning:
  - Impact 18: Underwater noise from decommissioning;
  - Impact 19: Vessel collisions;
  - Impact 20: Vessel disturbance;
  - Impact 21: Indirect impact on prey; and
  - Impact 22: Water quality impacts.

Impacts Scoped Out for Assessment

11.5.2 In line with the Scoping Opinion (The Inspectorate, 2022), and based on the receiving environment, expected parameters of the Project (Volume 1, Chapter 3: Project Description), and expected scale of impact/potential for effect on the environment, the following impacts have been scoped out of the assessment:

- Construction and decommissioning:
  - Accidental pollution due to the implementation of mitigation measures in PEMP and MPCP.
- Operation:
  - Accidental pollution;
  - Barrier effects as during operation they will be small scale and short lived so unlikely to result in significant effects; and
  - EMF as there is no likely significant effect (LSE) on the species identified in the baseline.
- Decommissioning:
  - Accidental pollution.

Realistic Worst Case Scenario

11.5.3 The following section identifies the MDS in environmental terms, defined by the Project design envelope (Table 11.7).

Table 11.7: Maximum design scenario for marine mammals for the Project alone

Potential effect	Maximum design scenario assessed	Justification
Construction		
Impact 1 and 2: Underwater noise from UXO clearance	Maximum number of clearance events within 24 hours: 2 Indicative duration: 25 days MDS clearance method: high-order detonation Expected to occur prior to foundation installation. Max charge size: 800kg + donor Low order (deflagration) charge: 0.5kg	Estimated maximum design. A detailed UXO survey will be completed prior to construction. The type, size and number of possible detonations and duration of UXO clearance operations is not known at this stage. The Applicant is not seeking to license the disposal of UXO in this application, but it is included in the impact assessment.
Impact 3, 4 and 5: Underwater noise from piling	Monopile WTG: ▪ 93 WTG foundations ▪ Max 13m pile diameter ▪ Max hammer energy: 6,600kJ ▪ Max 8 hours per pile ▪ Max 12 hours piling per day ▪ Max 2 simultaneous piling events ▪ Max 2 monopiles/day = 47 piling days Monopile other structures: ▪ Max 5 OP foundations within array area ▪ Max 2 Offshore Reactive Compensation Platforms (ORCPs) within the Offshore ECC ▪ Max pile diameter 14m ▪ Max hammer energy 6,600kJ ▪ Max 8 hours piling per monopile ▪ Max 2 monopiles per day = 4 piling days	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). The maximum number of piled foundations, and the maximum number of piling days would represent the temporal maximum design scenario for disturbance. The maximum predicted impact range for underwater noise for piled foundations would

Potential effect	Maximum design scenario assessed	Justification
	Multi-leg pin-piled jacket WTG: ▪ Max 93 WTG foundations ▪ 4 legs per foundation ▪ Max 372 legs in total ▪ Max pin pile diameter 5m ▪ Max hammer energy 3,500kJ ▪ Max 24 hours piling per day ▪ Max 2 simultaneous piling events ▪ Max 8 pin-piles installed per day ▪ Average 2 leg (4 pin-piles) per day = 186 piling days Multi-leg pin piled jacket OP: ▪ Max 5 OP foundations within array area ▪ Max 2 Offshore Reactive Compensation Platforms (ORCPs) within the Offshore ECC ▪ Max 8 legs per platform ▪ 3 pin-piles per leg ▪ Number pin piles total 168 ▪ Max pin pile diameter 5m ▪ Max hammer energy 3,500kJ ▪ Average 2 legs per day = 6 days Foundation installation: 2027-2029 Total monopiles (WTG + OPs): up to 100 Total pin piles (WTG + OPs): up to 540 Piling construction duration: 1 year	represent the spatial maximum design scenario for disturbance. The ORCPs will be positioned within the Offshore ECC ORCP Search Area – there will be no simultaneous piling between the ORCP foundations and foundations in the array area.

Potential effect	Maximum design scenario assessed	Justification
Impact 6, 7 and 8: Underwater noise from other construction activities	Seabed preparation: levelling and/or dredging of soft mobile sediments Cable route clearance methods: mass flow excavation, dredging Cable burial methods: jet trenching, pre-cut and post-lay ploughing, mechanical trenching, dredging, max flow excavation, vertical injection and rock cutting Offshore construction indicative dates: 2027 - 2029	Maximum potential for underwater noise impacts from pre-construction works.
Impact 9: Collision risk from vessels	Max total construction vessels: 131 Max total round trips: 4,471 Indicative peak vessels on-site in a given $5km^2$ area simultaneously: eight Offshore construction indicative dates: 2027-2029 Max round trips over 3 years: 13,413	The maximum numbers of vessels and associated vessel movements represents the maximum potential for collision risk and disturbance
Impact 10: Disturbance from vessels		
Impact 11: Indirect impacts from prey	Assessment is based on the MDS presented in Volume 1, Chapter 10: Fish and Shellfish Ecology.	
Impact 12: Water quality impacts	Maximum amount of suspended sediment released during construction activities and associated duration - see Volume 1, Chapter 7: Marine Processes and Volume 1 Chapter 8: Marine Water Quality.	
Impact 13: Disturbance at haul out sites	Assessment is based on distances to vessel transit routes and landfall	
Operation and Maintenance		

Potential effect	Maximum design scenario assessed	Justification
Impact 14: Operational noise	Operational noise from offshore windfarms to date has been found to be not significant for marine mammals. However, the size of WTGs planned at the Proposed Development do not have empirical data for operational noise and therefore operational noise has been scoped in as a precaution. An updated assessment of predicted SPL from 16MW and 30MW turbines (proposed for the Project) presented in Volume 1, Appendix 3.2: Underwater Noise Report.	
Impact 15: Collision risk from vessels Impact 16: Disturbance from vessels	Total: 28 Annual round trips: 2,216 Peak vessel quantities: 28	The maximum numbers of vessels and associated vessel movements represents the maximum potential for collision risk and disturbance.
Impact 17: Indirect impacts on prey	Assessment is based on the MDS presented in Volume 1, Chapter 10: Fish and Shellfish Ecology.	
Decommissioning		
Impact 18: Underwater noise	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 solutions assumed to be cut off at or below seabed	
Impact 19: Collision risk from vessels Impact 20: Disturbance from vessels	Assumed to be similar vessel types, numbers and movements to construction phase (or less).	The maximum numbers of vessels and associated vessel movements represents the maximum potential for collision risk and disturbance.
Impact 21: Indirect impacts from prey	Assessment is based on the MDS presented in Volume 1, Chapter 10: Fish and Shellfish Ecology.	
Impact 22: Water quality impacts	Maximum amount of suspended sediment released during decommissioning activities and associated duration - see Volume 1, Chapter 7: Marine Processes and Volume 1 Chapter 8: Marine Water Quality.	
Cumulative impacts		
See Table 11.38		

Embedded Mitigation

11.5.4 Mitigation measures that were identified and adopted as part of the evolution of the Project design (embedded into the Project design) and that are relevant to marine mammals are listed in Table 11.8. General mitigation measures, which would apply to all parts of the Project, are set out first. Thereafter mitigation measures that would apply specifically to marine mammal issues associated with the construction, operation and decommissioning, are described separately.

Table 11.8: Embedded mitigation relating to marine mammals

Project phase	Mitigation measures embedded into the Project design
General	
Project Environment Management Plan (PEMP)	A Project Environmental Management Plan (PEMP) (for the construction and operation phases) and Decommissioning Plan (for the decommissioning phase) will be produced and followed. This will include a Marine Pollution Contingency Plan (MPCP) which will safeguard the marine environment in the event of accidental pollution occurring as a result of ODOW operations. Plans will also highlight key organisations and contact details in the event of a spill (e.g. Environment Agency, Marine Management Organisation, Natural England and the Maritime and Coastguard Agency (MCA)).
Construction	
Project design	Identification of maximum hammer energy to be used during pile driving (6,600 kJ for monopile, 3,500 kJ for pin-pile). Inclusion of soft-start and ramp up procedures for pile driving. Maximum of 2 simultaneous piling events.
Marine Mammal Mitigation Protocol (MMMP) for piling	Implementation of a piling Marine Mammal Mitigation Protocol (MMMP) (to minimize the risk of auditory injury to negligible levels);
MMMP for UXO	Implementation of a UXO MMMP (to minimize the risk of auditory injury to negligible levels);
MMMP for geophysical surveys	Implementation of a geophysical survey MMMP (to minimize the risk of auditory injury to negligible levels);
Vessel Management Plan (VMP)	Development of, and adherence to, a Vessel Management Plan (VMP) (including defined vessel navigational routes, a vessel code of conduct to reduce collision risk and minimize disturbance and identification and avoidance of sensitive areas where practicable).
Decommissioning	
Decommissioning Plan	A decommissioning plan will be prepared in line with any updated guidance and environmental assessments.
Decommissioning MMMP	Implementation of a decommissioning MMMP (to minimize the risk of auditory injury to negligible levels);

11.6 Assessment Methodology

11.6.1 Determining the significance of effect is a two-stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts (see Volume 1, Chapter 5: EIA Methodology).

11.6.2 Information about the Project and the Project activities for all stages of the Project life cycle (construction, O&M and decommissioning) have been combined with information about the environmental baseline to identify the potential interactions between the Project and the environment. These potential interactions are known as potential impacts. The potential impacts are then assessed to give a level of significance of effect upon the receiving environment/receptors.

11.6.3 The outcome of the assessment is to determine the significance of these effects against predetermined criteria.

Magnitude of impact

11.6.4 The magnitude of potential impacts is defined by a series of factors including the spatial extent of any interaction, the likelihood, duration, frequency and reversibility of a potential impact. The magnitude of the impact is defined in Table 11.9.

Table 11.9: Impact magnitude definitions

Magnitude	Description/reason
High	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).
Medium	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 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).
Low	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 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).

Sensitivity of receptors

11.6.5 The sensitivities of marine mammal receptors are defined by both their potential vulnerability to an impact from the proposed development, and their recoverability. The sensitivity/importance of the receptor is defined in Table 11.10.

Table 11.10: Sensitivity of the receptor

Receptor sensitivity	Definition
High	▪ No ability to adapt behaviour so that survival and reproduction rates are affected; ▪ No tolerance – Effect will cause a change in both reproduction and survival rates; and ▪ No ability for the animal to recover from any impact on vital rates (reproduction and survival rates).
Medium	▪ Limited ability to adapt behaviour so that survival and reproduction rates may be affected; ▪ Limited tolerance – Effect may cause a change in both reproduction and survival of individuals; and ▪ Limited ability for the animal to recover from any impact on vital rates (reproduction and survival rates).
Low	▪ Ability to adapt behaviour so that reproduction rates may be affected but survival rates not likely to be affected; ▪ Some tolerance – Effect unlikely to cause a change in both reproduction and survival rates; and ▪ Ability for the animal to recover from any impact on vital rates (reproduction and survival rates).
Negligible	▪ Receptor is able to adapt behaviour so that survival and reproduction rates are not affected.

11.6.6 Assessment of the significance of potential effects is described in Table 11.11. The magnitude of the impact is correlated against the sensitivity of the receptor to provide a level of significance. On this basis, potential impacts are assessed as Negligible, Minor, Moderate or Major (definitions are provided in Volume 1, Chapter 5: EIA Methodology).

11.6.7 For the purposes of this assessment, any effects with a significance level of major and/or moderate have been deemed significant in EIA terms, while those of minor or negligible are deemed non-significant.

Table 11.11: Matrix to determine effect significance

		Magnitude of impact			
		Negligible	Low	Medium	High
Sensitivity of receptor	Negligible	Negligible (Not significant)	Negligible (Not significant)	Minor (Not significant)	Minor (Not significant)
	Low	Negligible (Not significant)	Minor (Not significant)	Minor (Not significant)	Moderate (Significant)
	Medium	Minor (Not significant)	Minor (Not significant)	Moderate (Significant)	Major (Significant)
	High	Minor (Not significant)	Moderate (Significant)	Major (Significant)	Major (Significant)

Injury (Permanent Threshold Shift)

11.6.8 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 permanent (PTS). The PTS-onset thresholds used in this assessment are those presented in Southall *et al*., 2019) (Table 11.12). The method used to calculate PTS-onset impact ranges for both 'instantaneous' PTS (SPL_{peak}), and 'cumulative' PTS (SEL_{cum}, over 24 hours) are detailed in Volume 2, Appendix 3.2: Underwater Noise Assessment.

Table 11.12: PTS-onset thresholds for impulsive noise (from Southall *et al*., 2019).

Hearing group	Species	Cumulative PTS (SEL_{cum} dB re 1µPa^{2}s weighted)	Instantaneous PTS (SPL_{peak} dB re 1µPa unweighted)
Very High Frequency (VHF) Cetacean	Harbour porpoise	155	202
High Frequency (HF) Cetacean	Bottlenose dolphin White-beaked dolphin	185	230
Low Frequency (LF) Cetacean	Minke whale	183	219
Phocid (PCW)	Grey seal Harbour seal	185	218

11.6.9 In calculating the received noise level that animals are likely to receive during the whole piling sequence, all HF and VHF cetaceans were assumed to start moving away at a swim speed of 1.5 m/s once the piling has started (based on reported sustained swimming speeds for harbour porpoises; Otani *et al.*, 2000). Minke whales which are assumed to swim at a speed of 3.25 m/s (Blix and Folkow, 1995). The calculated PTS-onset impact ranges therefore represent the minimum starting distances from the piling location for animals to escape and prevent them from receiving a dose higher than the threshold (Table 11.13).

Table 11.13: Marine mammal swimming speed used in the cumulative PTS-onset assessment.

Hearing group	Species	Speed (m/s)
Very High Frequency (VHF) Cetacean	Harbour porpoise	1.5
High Frequency (HF) Cetacean	Bottlenose dolphin White-beaked dolphin	1.5
Low Frequency (LF) Cetacean	Minke whale	3.25
Phocid (PCW)	Grey seal Harbour seal	1.5

11.6.10 Southall (2019) propose the SPL_{peak} (being either unweighted or flat weighted across the entire frequency band of a hearing group). This is because the direct mechanical damage to the auditory system that is associated with high peak sound pressures is not frequency dependent (i.e., restricted to the audible frequency range of a species).

11.6.11 The physiological damage that sound energy can cause is mainly restricted to energy occurring in the frequency range of a species' hearing range. Therefore, for the cumulative sound exposure level (SEL_{cum}), sound has been weighted based on species group specific weighting curves given in Southall (2019) (Figure 11.2).

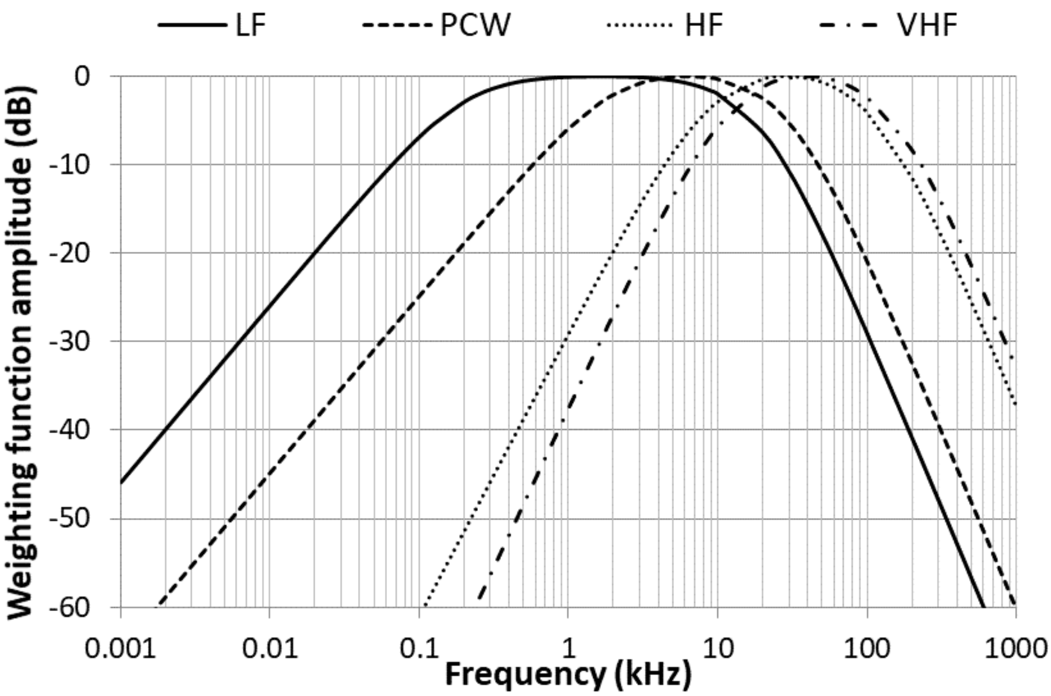


Figure 11.2: Auditory weighting functions for low frequency (LF), high frequency (HF) and very high frequency (VHF) cetaceans as well as phocid (PCW) pinnipeds in water taken from to Southall *et al.* (2019).

PTS – pile driving

11.6.12 To quantify the impact of noise with regard to PTS, the PTS-onset impact range (the area around the piling location within which the noise levels exceed the PTS-onset threshold) will be determined using the recent threshold presented by Southall (2019) (see Table 11.13). Based on agreed density estimates for each species presented in Volume 2, Appendix 3.2: Underwater Noise Assessment, the number of animals expected within the PTS onset impact range has been calculated and presented as a proportion of the relevant (estimated) population size.

11.6.13 The SEL_{cum} threshold for PTS-onset considers the sound exposure level received by an animal and the duration of exposure, accounting for the accumulated exposure over the duration of an activity within a 24-hour period. Southall (2019) recommends the application of SEL_{cum} for the individual activity alone (i.e., not for multiple activities occurring within the same area or over the same time). To inform this impact assessment, sound modelling has considered the SEL_{cum} over a piling event. Concurrent piling scenarios where 2 piling events occur within 24 hours, have also be modelled.

PTS – UXO clearance

11.6.14 The recent Southall (2019) (see Table 11.13) has been used to assess the PTS onset impact from UXO detonation from a range of charge sizes. The number of animals expected in the PTS onset impact range has been calculated and presented as a proportion of the relevant population size.

PTS – other construction activities

11.6.15 In the absence of specific guidance on the PTS onset thresholds that should be used to assess the noise impacts from non-piling noise, noise modelling has been undertaken using the Southall (2019) thresholds. include vessel activity, dredging, trenching and rock dumping. Full results are presented in Volume 2, Appendix 3.2: Underwater Noise Assessment to estimate the number and range of animals predicted to experience PTS from other construction activities.

Disturbance - pile driving

11.6.16 The assessment of disturbance from pile driven foundations was based on the current best practice methodology, making use of the best available scientific evidence. This incorporates the application of a species-specific dose-response approach rather than a fixed behavioural threshold approach.

11.6.17 For example, the latest guidance provided in Southall (2019) is that:

"Apparent patterns in response as a function of received noise level (sound pressure level) highlighted a number of potential errors in using all-or-nothing "thresholds" to predict whether animals will respond. Tyack and Thomas (2019) subsequently and substantially expanded upon these observations. The clearly evident variability in response is likely attributable to a host of contextual factors, which emphasizes the importance of estimating not only a dose-response function but also characterizing response variability at any dosage".

11.6.18 Noise contours at 5dB intervals were generated by noise modelling and were overlain on species density surfaces to predict the number of animals potentially disturbed. This allowed for the quantification of the number of animals that will potentially respond.

11.6.19 Compared with the EDR and fixed noise threshold approaches, the application of a dose-response curve allows for more realistic assumptions about animal response varying with dose, which is supported by a growing number of studies. A dose-response function is used to quantify the probability of a response from an animal to a dose of a certain stimulus or stressor (Dunlop *et al.*, 2017) and is based on the assumption that not all animals in an impact zone will respond. The dose can either be determined using the distance from the sound source or the received weighted or unweighted sound level at the receiver (Sinclair *et al.*, 2021).

Harbour porpoise dose-response function

11.6.20 To estimate the number of porpoise predicted to experience behavioural disturbance as a result of pile driving, this impact assessment uses the porpoise dose-response function presented in Graham (2017a) (Figure 11.3). The Graham *et al.* (2017a) dose-response function was developed using data on harbour porpoise collected during the first six weeks of piling during Phase 1 of the Beatrice Offshore Windfarm monitoring program. Changes in porpoise occurrence (detection positive hours per day) were estimated using 47 CPODs[9] placed around the windfarm site during piling and compared with baseline data from 12 sites outside of the windfarm area prior to the commencement of operations, to characterise this variation in occurrence. Porpoise were considered to have exhibited a behavioural response to piling when the proportional decrease in occurrence was greater than 0.5. The probability that porpoise occurrence did or did not show a response to piling was modelled along with the received single-pulse sound exposure levels piling source levels based on the received noise levels (Graham *et al.*, 2017a).

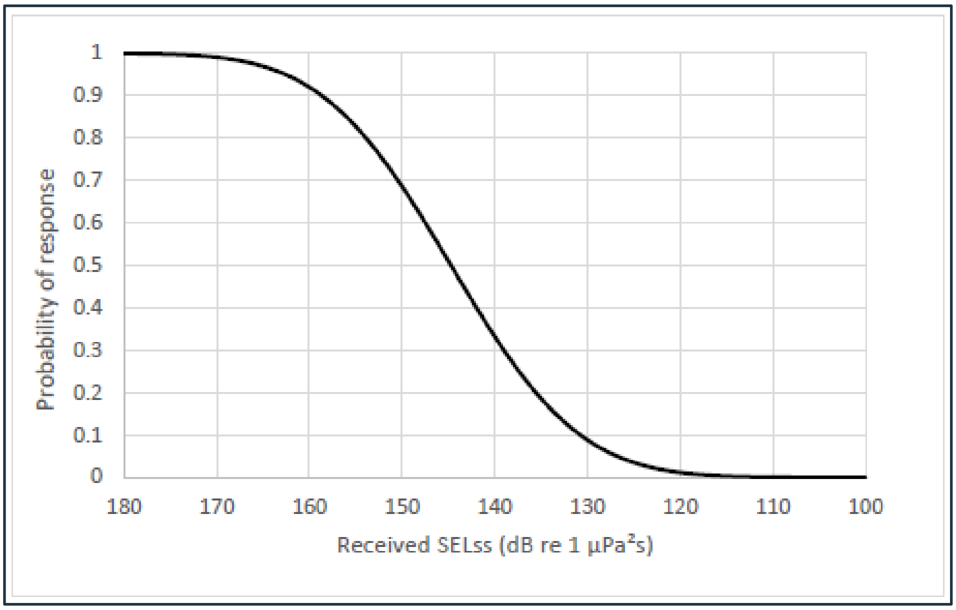


Figure 11.3: Relationship between the proportion of porpoise responding and the received single strike SEL (SEL_{ss}) (Graham *et al*., 2017a).

11.6.21 Since the initial development of the dose-response function in 2017, additional data from the remaining pile driving events at Beatrice Offshore Windfarm have been processed, and are presented in Graham (2019). The passive acoustic monitoring showed a 50% probability of porpoise response (a significant reduction in detection relative to baseline) within 7.4km at the first location piled, with decreasing response levels over the construction period to a 50% probability of response within 1.3km by the final piling location (Figure 11.4) (Graham *et al*., 2019). Therefore, using the dose-response function derived from the initial piling events for all piling events in the impact assessment is precautionary, as evidence shows that porpoise response is likely to diminish over the construction period.

[9] CPODs monitor the presence and activity of toothed cetaceans by the detection within the CPOD app of the trains of echolocation clicks that they make. See https://www.chelonia.co.uk/index.html

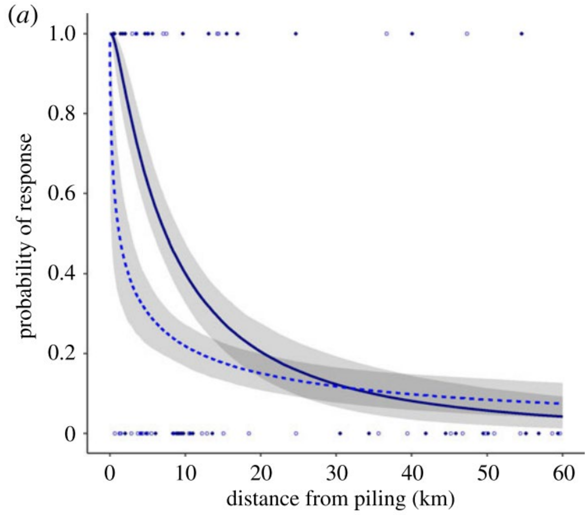


Figure 11.4: The probability of a harbour porpoise response (24 h) in relation to the partial contribution of distance from piling (solid navy line) and the final location piled (dashed blue line). Obtained from Graham *et al.* (2019)[10].

11.6.22 In the absence of species-specific data on bottlenose dolphins, common dolphins, Risso's dolphins or minke whales, this dose-response function has been adopted for all cetaceans, however it is considered that the application of the porpoise dose-response function to other cetacean species is highly over precautionary. Porpoise are considered to be particularly responsive to anthropogenic disturbance, with playback experiments showing avoidance reactions to very low levels of sound (Tyack, 2009) and multiple studies showing that porpoise respond (avoidance and reduced vocalisation) to a variety of anthropogenic noise sources to distances of multiple kilometres (e.g., Brandt *et al.*, 2013; Thompson *et al.*, 2013; Tougaard *et al.*, 2013; Brandt *et al.*, 2018; Sarnocinska *et al.*, 2019; Thompson *et al.*, 2020; Benhemma-Le Gall *et al.*, 2021).

11.6.23 Various studies have shown that other cetacean species show comparatively less of a disturbance response from underwater noise compared with harbour porpoise. For example, through an analysis of 16 years of marine mammal observer data from seismic survey vessels, Stone (2017) found a significant reduction in porpoise detection rates when large seismic airgun arrays were actively firing, but not for bottlenose dolphins. While the strength and significance of responses varied between porpoise and other dolphin species for different measures of effect, the study emphasised the sensitivity of the harbour porpoise (Stone *et al.*, 2017). In the Moray Firth, bottlenose dolphins have been shown to remain in the impacted area during both seismic activities and pile installation activities (Fernandez-Betelu *et al.*, 2021) which highlights a lack of complete displacement response. Likewise, other high-frequency cetacean species, such as striped and common dolphins, have been shown to display less of a response to underwater noise signals and construction-related activities compared with harbour porpoise (e.g. Kastelein *et al.*, 2006; Culloch *et al.*,

[10] Predicted assuming the number of AIS vessel locations within 1km; confidence intervals (shaded areas) estimated for uncertainty in fixed effects only. Harbour porpoise occurrence was considered to have responded to piling when the proportional decrease in occurrence (DPH) exceeded a threshold of 0.5. Points show actual response data for the first location piled (filled navy circles) and the final location piled (open blue circles).

2016).

11.6.24 There is no disturbance threshold (effective disturbance range or dose-response function) for any other cetacean species included in this assessment. Therefore, in the complete absence of an alternative, the assessment for all cetacean species has used the porpoise dose-response function. This is considered highly precautionary and as such the number of animals predicted to experience behavioural disturbance is considered to be an over-estimate and should be interpreted with a large degree of caution.

Seal dose-response function

11.6.25 For grey seals, the dose-response function adopted was based on the data presented in Whyte (2020) (Figure 11.5). The Whyte *et al.* (2020) study updates the initial dose-response information presented in Russell *et al.* (2016b) and Russell and Hastie (2017), where the percentage change in harbour seal density was predicted at the Lincs offshore windfarm. The original study used telemetry data from 25 harbour seals tagged in the Wash between 2003 and 2006, in addition to a further 24 harbour seals tagged in 2012, to estimate levels of seal usage in the area in order to assess how seal usage changed in relation to the pile driving activities at the Lincs Offshore Windfarm in 2011-2012.

11.6.26 In the Whyte (2020) dose-response function it has been assumed that all seals are displaced at sound exposure levels above 180dB re 1µPa^{2}s. This is a conservative assumption since there were no data presented in the study for harbour seal responses at this level. It is also important to note that the percentage decrease in response in the categories 170≤175 and 175≤180dB re 1µPa^{2}s is slightly anomalous (higher response at a lower sound exposure level) due to the small number of spatial cells included in the analysis for these categories (n = 2 and 3 respectively). Given the large confidence intervals on the data, this assessment presents the mean number of seals predicted to be disturbed alongside the 95% confidence intervals (CI), for context.

11.6.27 There are no corresponding data for grey seals and, as such, the harbour seal dose-response function is applied to the grey seal disturbance assessment. This is considered to be an appropriate proxy for grey seals, since both species are categorised within the same functional hearing group. However, it is likely that this over estimates the grey seal response, since grey seals are considered to be less sensitive to behavioural disturbance than harbour seals and could tolerate more days of disturbance before there is likely to be an effect on vital rates (Booth *et al.*, 2019). 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 (Aarts *et al.*, 2018). Likewise, if the impacted area is considered to be a high quality foraging patch, it is likely that some grey seals may show no behavioural response at all, given their motivation to remain in the area for foraging (Hastie *et al.*, 2021). Therefore, the adoption of the harbour seal dose-response function for grey seals is considered to be precautionary as it will likely over-estimate the potential for impact on grey seals.

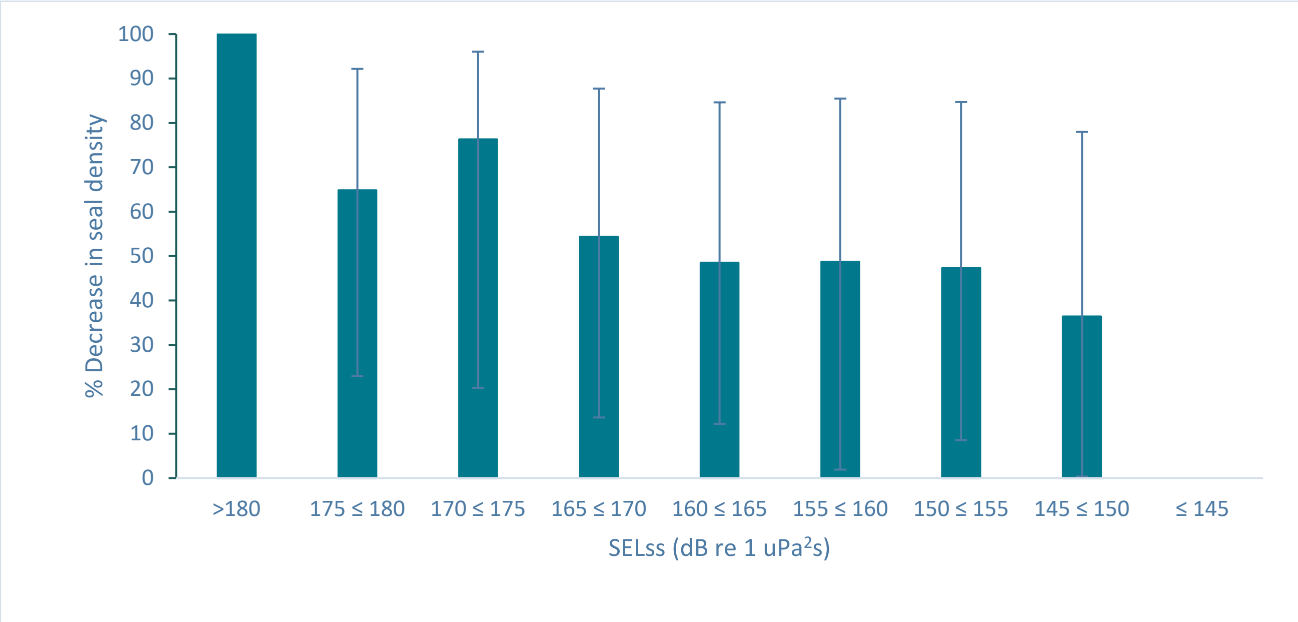


Figure 11.5: Predicted decrease in seal density as a function of estimated sound exposure level, error bars show 95% CI (Whyte *et al.*, 2020).

Disturbance - UXO clearance

11.6.28 While there are empirically-derived dose-response relationships for pile driving; these are not directly applicable to the assessment of UXO detonation due to the very different nature of the sound emission. While both sound sources (piling and explosives) are categorised as "impulsive" sound sources, they differ drastically in the number of pulses and the overall duration of the noise emission, both of which will ultimately drive the behavioural response. While one UXO-detonation is anticipated to result in a one-off startle-response or aversive behaviour, the series of pulses emitted during pile driving will more or less continuously drive animals out of the impacted area, giving rise to a measurable and quantifiable dose-response relationship. For UXO clearance, there are no dose-response functions available that describe the magnitude and transient nature of the behavioural impact of UXO detonation on marine mammals.

11.6.29 Since there is no dose-response function available that appropriately reflects the behavioural disturbance from UXO detonation, other behavioural disturbance thresholds have been considered instead. These alternatives are summarised in the sections below.

EDR - 26km for high order UXO clearance

11.6.30 There is guidance available on the EDR that should be applied to assess the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs in England, Wales & Northern Ireland (JNCC, 2020). This guidance advises that an effective deterrence range of 26km around the source location is used to determine the impact area from high-order UXO detonation (neutralisation of the UXO through full detonation of the original explosive content) with respect to disturbance of harbour porpoise in SACs.

11.6.31 The recommendation for the 26km EDR comes from a report by Tougaard *et al*., (2013) which calculates the EDR using data from the Dahne *et al*., (2013) study. The Dahne *et al*., (2013) study was conducted at the first OWF in German waters, where 12 jacket foundations were piled using a Menck MHU500T hydraulic hammer with up to 500 kJ hammer energy to install piles of 2.4m to 2.6m diameter up to 30m penetration depth. The JNCC (2020) guidance itself acknowledges that this EDR is based on the EDR recommended for pile driving of monopiles, since there is no equivalent data for explosives. The guidance states that:

"The 26km EDR is also to be used for the high order detonation of unexploded ordnance (UXOs) despite there being no empirical evidence of harbour porpoise avoidance." (JNCC, 2020).

11.6.32 The guidance also acknowledges that the disturbance resulting from a single explosive detonation would likely not cause the more wide-spread prolonged displacement that has been observed in response to pile driving activities:

"… a one-off explosion would probably only elicit a startle response and would not cause widespread and prolonged displacement…" (JNCC, 2020).

11.6.33 In the Scoping Opinion responses (The Inspectorate, 2022) both the MMO and Natural England advised that the 26km EDR is applied not only to harbour porpoise, but to all marine mammal species. While this has been presented here as requested, it is important to acknowledge that there is no evidence to support the assumption that marine mammal species respond the same way to a high-order UXO clearance as harbour porpoise do to the pile driving of jacket foundations using 500 kJ hammer energy (Dähne *et al.*, 2013). Therefore, an alternative approach to the disturbance threshold (TTS-onset as a proxy for disturbance) has been provided alongside the 26km EDR approach.

EDR - 5km for low order UXO clearance

11.6.34 Unlike the recommended 26km EDR for disturbance around high-order detonations (JNCC, 2020), there is no currently advised equivalent for low-order detonations (neutralisation of the UXO without full detonation of the original explosive material). In the absence of empirical data with which to set a threshold, the Sofia Offshore Windfarm Marine Licence Application for UXO detonation assumed a 5km EDR for low-order detonations. This assumed EDR was based on the fact that data has shown that low-order deflagration detonations produce underwater noise that is over 20dB lower than high-order detonation (Robinson *et al*., 2020). Note, the Sofia Offshore Windfarm Limited committed to undertaking noise monitoring of low-order detonations to confirm this proportionally lower noise level however, the data are not yet available. Until such time as empirical data are available to inform the EDR for low-order detonations, the 5km EDR suggested by Sofia Offshore Windfarm has been assumed.

Fixed noise threshold – TTS-onset

11.6.35 Recent assessments of UXO clearance activities have used the TTS-onset threshold to indicate the level at which a 'fleeing' response may be expected to occur in marine mammals (e.g. Seagreen, Neart na Goithe and Awel y Mor). This is a result of discussion in Southall *et al*. (2007) which states that in the absence of empirical data on responses, the use of the TTS-onset threshold may be appropriate for single pulses (like UXO detonation):

"Even strong behavioral responses to single pulses, other than those that may secondarily result in injury or death (e.g., stampeding), are expected to dissipate rapidly enough as to have limited long-term consequence. Consequently, upon exposure to a single pulse, the onset of significant behavioral disturbance is proposed to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e., TTS-onset). We recognize that this is not a behavioral effect per se, but we use this auditory effect as a de facto behavioral threshold until better measures are identified. Lesser exposures to a single pulse are not expected to cause significant disturbance, whereas any compromise, even temporarily, to hearing functions has the potential to affect vital rates through altered behavior." (Southall et al., 2007)."

"Due to the transient nature of a single pulse, the most severe behavioral reactions will usually be temporary responses, such as startle, rather than prolonged effects, such as modified habitat utilization. A transient behavioral response to a single pulse is unlikely to result in demonstrable effects on individual growth, survival, or reproduction. Consequently, for the unique condition of a single pulse, an auditory effect is used as a de facto disturbance criterion. It is assumed that significant behavioral disturbance might occur if noise exposure is sufficient to have a measurable transient effect on hearing (i.e., TTS-onset). Although TTS is not a behavioral effect per se, this approach is used because any compromise, even temporarily, to hearing functions has the potential to affect vital rates by interfering with essential communication and/or detection capabilities. This approach is expected to be precautionary because TTS at onset levels is unlikely to last a full diel cycle or to have serious biological consequences during the time TTS persists." (Southall et al., 2007).

11.6.36 Therefore, an estimation of the extent of behavioural disturbance can be based on the sound levels at which the onset of TTS is predicted to occur from impulsive sounds. TTS-onset thresholds are taken as those proposed for different functional hearing groups by Southall (2019).

11.6.37 In the Scoping Opinion Responses (The Inspectorate, 2022), both the MMO and Natural England advised that it is not appropriate to use TTS-onset thresholds as a proxy for disturbance from UXOs. However, TTS-onset as a proxy for disturbance has been presented alongside the 26km EDR approach in acknowledgement that there is no empirically based threshold to assess disturbance from high-order UXO clearance currently available.

Summary

11.6.38 In the absence of agreed thresholds to assess the potential for behaviour disturbance in marine mammals from UXO detonations, the Project impact assessment presents results for each of the following behavioural disturbance thresholds:

- 26km EDR for high-order detonations;
- 5km EDR for low-order detonations; and
- TTS-onset thresholds for both high and low-order detonations.

11.6.39 While the Applicant acknowledges that there is no empirical data to validate these thresholds as appropriate for behavioural disturbance from UXO detonations, these thresholds do cover our understanding of the range of potential behavioural responses from impulsive sound sources, and, as such, provide the best indication as to the potential level of impact.

11.6.40 It is important for the impact assessment to acknowledge that our understanding of the effect of disturbance from UXO detonation is very limited, and as such the assessment can only provide an indication of the number of animals potentially at risk of disturbance given the limited evidence available.

Disturbance – other construction activities

11.6.41 There is currently no guidance on the thresholds to be used to assess disturbance of marine mammals from other construction activity. Therefore, this impact assessment provides a qualitative assessment for these impacts. The assessment is based on the limited evidence that is available in the existing literature for that impact pathway and species combination, where available. The majority of available evidence on the impact of disturbance of marine mammals from other construction activities focuses on the impact of vessel activity and dredging. Both these activities are of relevance during the construction of the Project, with dredging potentially being required for seabed preparation work for foundations as well as for export cable, array cable and interconnector cable installations.

Assumptions and Limitations

11.6.42 There are uncertainties relating to the underwater noise modelling and impact assessment. 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-onset Assumptions

11.6.43 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 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 (6dB), and assumes that PTS occurs from exposures resulting in 40dB or more of TTS measured approximately four minutes after exposure (NMFS, 2018).

Proportion Impacted

11.6.44 It is 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 (2017) to develop their dose response function implemented into the SAFESIMM (Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna) 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, since they assume that all animals are impacted.

Exposure to Noise

11.6.45 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 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.

11.6.46 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 the position of receptors 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 windfarm construction are not specifically addressed. The dose-response functions for porpoise include behavioural responses at noise levels down to 120dB SEL_{ss} which may be indistinguishable from ambient noise at the ranges these levels are predicted.

Cumulative PTS

11.6.47 The cumulative sound exposure level (SEL_{cum}) is energy based and is a measure of the accumulated sound energy an animal is exposed to over an exposure period. An animal is considered to be at risk of experiencing “cumulative PTS” if the SEL_{cum} exceeds the energy based threshold. The calculation of SEL_{cum} is undertaken with frequency-weighted sound levels, using species group-specific weighing functions to reflect the hearing sensitivity of each functional hearing group. To assess the risk of cumulative PTS, it is necessary to make assumptions on how animals may respond to noise exposure, since any displacement of the animal relative to the noise source will affect the sound levels received. For this assessment, it was assumed that animals would flee from the pile foundation at the onset of piling. A fleeing animal model was therefore used to determine the cumulative PTS impact ranges, to determine the minimum distance to the pile site at which an animal can start to flee, without the risk of experiencing cumulative PTS.

11.6.48 There is much more uncertainty associated with the prediction of the cumulative PTS impact ranges than with those for the instantaneous PTS. One reason is that the sound levels an animal receives, and which are cumulated over a whole piling sequence are difficult to predict over such long periods of time, as a result of uncertainties about the animal’s (responsive) movement in terms of its changing distance to the sound source and the related speed, and its position in the water column.

11.6.49 Another reason is that the prediction of the onset of PTS (which is assumed to be at the SEL_{cum} threshold values provided by Southall (2019)) is determined with the assumptions that:

- 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 (i.e., with a single bout of sound) or in several smaller doses spread over a longer period (called the equal-energy hypothesis); and
- the sound keeps its impulsive character, regardless of the distance to the sound source.

11.6.50 However, in practice:

- there is a recovery of a threshold shift caused by the sound energy if the dose is applied in several smaller doses (e.g., between pulses during pile driving or in piling breaks) leading to an onset of PTS at a higher energy level than assumed with the given SEL_{cum} threshold; and
- pulsed sound loses its impulsive characteristics while propagating away from the sound source, resulting in a slower shift of an animal's hearing threshold than would be predicted for an impulsive sound.

11.6.51 Both assumptions, therefore, lead to a conservative determination of the impact ranges and are discussed in further detail in the sections below.

11.6.52 Modelling the SEL_{cum} impact ranges of PTS with a 'fleeing animal' model, as is typical in noise impact assessments, are subject to both above-mentioned uncertainties and the result is a highly precautionary prediction of impact ranges. As a result of these and the uncertainties on animal movement, model parameters, such as swim speed, are generally highly conservative and, when considered across multiple parameters, this precaution is compounded therefore the resulting predictions are very precautionary and very unlikely to be realised.

Equal Energy Hypothesis

11.6.53 The equal-energy hypothesis assumes that exposures of equal energy are assumed to produce equal amounts of noise-induced threshold shift, regardless of how the energy is distributed over time. However, a continuous and an intermittent noise exposure of the same SEL will produce different levels of TTS (Ward, 1997). Ward (1997) highlights that the same is true for impulsive noise, giving the example of simulated gunfires of the same SEL_{cum} exposed to human, where 30 impulses with an SPL_{peak} of 150dB re 1m Pa result in a TTS of 20dB, while 300 impulses of a respectively lower SPL_{peak} did not result in any TTS.

11.6.54 Finneran (2015) showed that several marine mammal studies have demonstrated that the temporal pattern of the exposure does in fact affect the resulting threshold shift (e.g., Kastak *et al.*, 2005; Mooney *et al.*, 2009; Finneran *et al.*, 2010; Kastelein *et al.*, 2013a). Intermittent noise allows for some recovery of the threshold shift in between exposures, and therefore recovery can occur in the gaps between individual pile strikes and in the breaks in piling activity, resulting in a lower overall threshold shift, compared to continuous exposure at the same SEL. Kastelein *et al.*, (2013a) showed that, for seals, the threshold shifts observed did not follow the assumptions made in the guidance regarding the equal-energy hypothesis. The threshold shifts observed were more similar to the hypothesis presented in Henderson (1991) whereby hearing loss induced due to noise does not solely depend upon the total amount of energy, but on the interaction of several factors such as the level and duration of the exposure, the rate of repetition, and the susceptibility of the animal. Therefore, the equal-energy hypothesis assumption behind the SEL_{cum} threshold is not valid, and as such, models will overestimate the level of threshold shift experienced from intermittent noise exposures.

11.6.55 Another detailed example to give is the study of (Kastelein *et al.*, 2014), where a harbour porpoise was exposed to a series of 1-2kHz sonar down-sweep pulses of 1-second duration of various combinations, with regard to received sound pressure level, exposure duration and duty cycle (% of time with sound during a broadcast) to quantify the related threshold shift. The porpoise experienced a 6 to 8dB lower TTS when exposed to sound with a duty cycle of 25% compared to a continuous sound (Figure 11.6). A one second silent period in between pulses resulted in a 3 to 5dB lower TTS compared to a continuous sound (Figure 11.6).

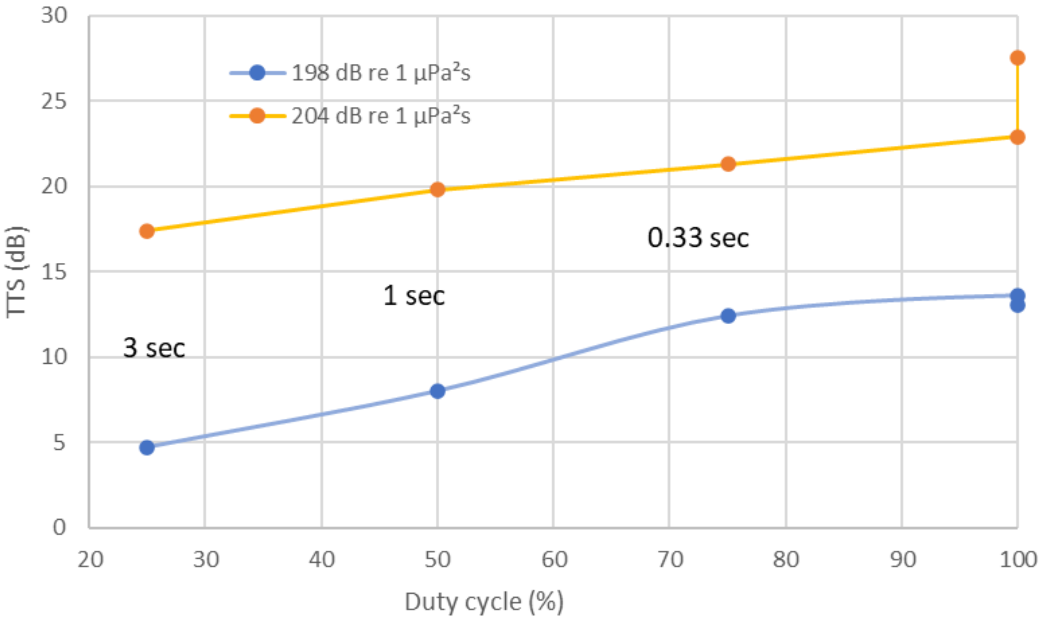


Figure 11.6: Temporary threshold shift (TTS) elicited in a harbour porpoise by a series of 1-2kHz sonar down-sweeps of 1 second duration with varying duty cycle and a constant SEL_{cum} of 198 and 204dB re1 μPa²s, respectively. Also labelled is the corresponding 'silent period' in-between pulses. Data from Kastelein *et al.*, (2014).

11.6.56 Kastelein (2015b) showed that the 40dB hearing threshold shift (the PTS-onset threshold) for harbour porpoise, is expected to be reached at different SEL_{cum} levels depending on the duty cycle: for a 100% duty cycle, the 40dB hearing threshold shift is predicted to be reached at a SEL_{cum} of 196dB re 1μPa^{2}s, but for a 10% duty cycle, the 40dB hearing threshold shift is predicted to be reached at a SEL_{cum} of 206dB re 1μPa^{2}s (thus resulting in a 10dB re 1μPa^{2}s difference in the threshold).

11.6.57 Pile strikes are relatively short signals; the signal duration of monopile pile strikes may range between 0.1 seconds (De Jong and Ainslie, 2008) and approximately 0.3 seconds (Dähne *et al.*, 2017) measured at a distance of 3.3km to 3.6km. Duration will however increase with increasing distance from the pile site.

11.6.58 For the pile driving at the Project, the soft start is 10 blows/min and the ramp-up is 30 blows per minute. Assuming a signal duration of around 0.5 seconds for a pile strike, the soft start has been an 8.3% duty cycle (0.5 seconds pulse followed by 5.5 seconds silence) and the ramp-up has been a 25% duty cycle (0.5 second pulse followed by 1.5 second silence). In the study of Kastelein *et al.*, (2014), a silent period of 3 seconds corresponds to a duty cycle of 25%. The reduction in TTS at a duty cycle of 25% is 5.5-8.3dB. Assuming similar effects to the hearing system of marine mammals in the Project array area, the PTS-onset threshold would be expected to be around 2.4dB higher than that proposed by Southall (2019) and used in the current assessment, as reasoned in the following section.

11.6.59 Southall (2009) calculates the PTS-onset thresholds based on the assumption that a TTS of 40dB will lead to PTS, and that an animal's hearing threshold will shift by 2.3dB per dB SEL received from an impulsive sound. This means, if the same SEL elicits a ≥5.5dB lower TTS at 25% duty cycle compared to 100% duty cycle, to elicit the same TTS as a sound of 100% duty cycle, a ≥2.4dB (≥5.5dB/2.3) higher SEL is needed with a 25% duty cycle than with a 100% duty cycle. The threshold at which PTS-onset is likely is therefore, expected to be a minimum of 2.4dB higher than the PTS-onset threshold proposed by Southall *et al.* (2019).

11.6.60 If a 2 or 3dB increase in the PTS-threshold is assumed, then this can make a significant difference to the maximum predicted impact range for cumulative PTS. Table 11.14 summarises the difference in the predicted PTS impact ranges using the current and adjusted thresholds. In summary, if the threshold accounts for recovery in hearing between pulses, the PTS impact ranges for the NE location decreases from 3.35km for harbour porpoise to 2.175km (+2dB) or 1.657km (+3dB). For minke whale the PTS impact ranges for the NE location decreases from 5.4km to 3.9km (+2dB) or 3.175km (+3dB).

11.6.61 Therefore, accounting for recovery in hearing between pulses by increasing the PTS onset threshold by 2 or 3dB significantly decreases the predicted PTS-onset impact ranges. This approach to modelling cumulative PTS is in development and has not yet been fully assessed or peer reviewed. Therefore, the Project impact assessment will present the cumulative PTS impact ranges using the current Southall (2019) PTS-onset impact threshold. While more research needs to be conducted to understand the exact magnitude of this effect in relation to pile driving sound, this study proves a significant reduction in the risk of PTS even through short silent periods for TTS recovery as found in pile driving.

Table 11.14: Difference in predicted cumulative PTS impact ranges if recovery between pulses is accounted for and the PTS-onset threshold is increased by 2 or 3 dB[11].

Threshold		Max impact range (km)	Reduction in impact range (km)
Minke whale			
PTS	183 SEL_{cum}	5.400	-
PTS + 2dB	185 SEL_{cum}	3.900	1.500

[11] Note: PTS-onset impact ranges for dolphins are seals were <0.1 km so are not considered here

Threshold		Max impact range (km)	Reduction in impact range (km)
PTS + 3dB	186 SEL_{cum}	3.175	2.225
Harbour porpoise			
PTS	155 SEL_{cum}	3.350	-
PTS + 2dB	157 SEL_{cum}	2.175	1.175
PTS + 3dB	158 SEL_{cum}	1.675	1.675

Impulsive Characteristics

11.6.62 Southall (2019) calculated the PTS-onset thresholds based on the assumption that an animal's hearing threshold will shift by 2.3dB per dB SEL received from an impulsive sound, but only 1.6dB per dB SEL when the sound received is non impulsive. The PTS-onset threshold for non-impulsive sound is, therefore, higher than for impulsive sound, as more energy is needed to cause PTS with non-impulsive sound compared to impulsive sound. Consequently, an animal subject to both types of sound has been at risk of PTS at an SEL_{cum} that lies somewhere between the PTS onset thresholds of impulsive and non-impulsive sound.

11.6.63 Southall (2019) acknowledges that, as a result of propagation effects, the sound signal of certain sound sources (e.g. impact piling) 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 (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).

11.6.64 Using the criteria of signal duration[12], rise time[13], crest factor[14] and peak pressure[15] divided by signal duration[16], Hastie (2019) estimated the transition from impulsive to non-impulsive characteristics of impact piling noise during the installation of offshore wind turbine foundations at the Wash and in the Moray Firth. Hastie (2019) showed that the noise signal experienced a high degree of change in its impulsive characteristics with increasing distance. Southall (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 (2019), the rise-time and peak pressure may be the most appropriate indicators to determine the impulsive/non-impulsive transition.

[12] Time interval between the arrival of 5% and 95% of total energy in the signal.
[13] Measured time between the onset (defined as the 5th percentile of the cumulative pulse energy) and the peak pressure in the signal.
[14] 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.
[15] The greatest absolute instantaneous sound pressure within a specified time interval.
[16] Time interval between the arrival of 5% and 95% of total energy in the signal.

11.6.65 Based on this data it is expected that the probability of a signal being defined as "impulsive" (using the criteria of rise time being less than 25 milliseconds) reduces to only 20% between ~2 and 5km from the source. Predicted PTS impact ranges based on the impulsive noise thresholds may 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.

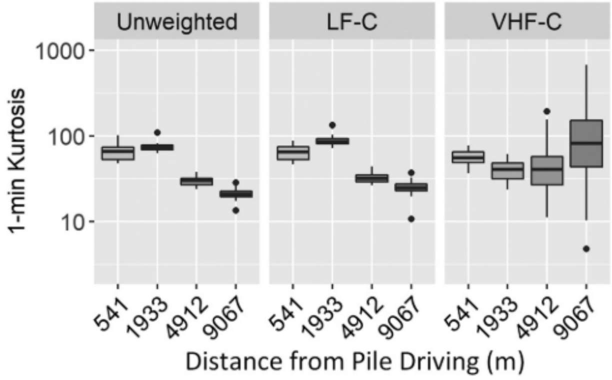
11.6.66 It is acknowledged that the Hastie (2019) study is an initial investigation into this topic, and that further data are required in order to set limits to the range at which impulsive criteria for PTS are applied.

11.6.67 Since the Hastie (2019) study, Martin *et al.* (2020) investigated the sound emission of different sound sources to test techniques for distinguishing between the sound being impulsive or non-impulsive. For impulsive sound sources, they included impact pile driving of four 4-legged jacket foundation installed at around 20m water depth (at the Block Island Windfarm in the USA). For the impact piling sound, they recorded sound at four distances between ~500m and 9km, recording the sound of 24 piling events. To investigate the impulsiveness of the sound, they used three different parameters and suggested the use of kurtosis[17]to further investigate the impulsiveness of sound. Hamernik *et al.* (2007) showed a positive correlation between the magnitude of PTS and the kurtosis value in chinchillas, with an increase in PTS for a kurtosis value from 3 up to 40 (which in reverse also means that PTS decreases for the same SEL with decreasing kurtosis below 40). Therefore, Martin *et al.* (2020) argued that:

- Kurtosis of 0-3 = continuous sinusoidal signal (non-impulsive);
- Kurtosis of 3-40 = transition from non-impulsive to impulsive sound; and
- Kurtosis of 40 = fully impulsive.

11.6.68 For the evaluation of their data, Martin (2020) used unweighted as well as LF-Cetacean (C) and VHFC weighted sound, based on the species-specific weighting curves in Southall *et al.* (2019) to investigate the impulsiveness of sound. Their results for pile driving are shown in Figure 11.7: The range of kurtosis weighted by LF-C and VHF-C Southall *et al.* (2019) auditory frequency weighting functions for 30 min of impact pile driving data measured in 25m of water at the Block Island Windfarm. Boxplots show the median value (horizontal lines), interquartile range (boxes) and outlier values (dots). Boxplots reproduced from Martin *et al.* (2020); adjacent table shows approximate median values extracted from the boxplot.. For the unweighted and LFC weighted sound, the kurtosis value was >40 within 2km from the piling site. Beyond 2km, the kurtosis value decreased with increasing distance. For the VHFC weighted sound, kurtosis factor is more inconclusive with the median value >40 for the 500m and 9km measuring stations, and at 40 for the stations in between. However, the variability of the kurtosis value for the VHFC weighted sound increased with distance.

[17] Kurtosis is a measure of the asymmetry of a probability distribution of a real-valued variable.



	Median value (1-min kurtosis)		
Distance (km)	Unweighted	LF-C	VHF-C
0.541	65	65	60
1.933	70	85	40
4.912	30	30	40
9.067	20	25	80

Figure 11.7: The range of kurtosis weighted by LF-C and VHF-C Southall *et al.* (2019) auditory frequency weighting functions for 30 min of impact pile driving data measured in 25m of water at the Block Island Windfarm. Boxplots show the median value (horizontal lines), interquartile range (boxes) and outlier values (dots). Boxplots reproduced from Martin *et al.* (2020); adjacent table shows approximate median values extracted from the boxplot.

11.6.69 From these data, Martin (2020) conclude that the change to non-impulsiveness

> *"is not relevant for assessing hearing injury because sounds retain impulsive character when SPLs are above EQT [effective quiet threshold[18]]"*

11.6.70 (i.e., the sounds they recorded retain their impulsive character while being at sound levels that can contribute to auditory injury). However, we interpret their results differently. Figure 11.7: The range of kurtosis weighted by LF-C and VHF-C Southall *et al.* (2019) auditory frequency weighting functions for 30 min of impact pile driving data measured in 25m of water at the Block Island Windfarm. Boxplots show the median value (horizontal lines), interquartile range (boxes) and outlier values (dots). Boxplots reproduced from Martin *et al.* (2020); adjacent table shows approximate median values extracted from the boxplot. clearly shows (for unweighted and LF-C weighted sound) that piling sound loses its impulsiveness with increasing distance from the piling site - the kurtosis value decreases with increasing distance and therefore the sound loses its harmful impulsive characteristics. Based on this study and the study by Hastie (2019), we argue that the predicted PTS impact ranges based on the impulsive noise thresholds will over-estimate the risk of PTS-onset in cases and at ranges where the likelihood increases that an animal is exposed to sound with much reduced impulsive characteristics.

[18] From Martin (2020): The proposed effective quiet threshold (EQT) is the 1-min auditory frequency weighted SPL that accumulates to this 1-min SEL, which numerically is 18dB below the 1-min SEL [because $10 \cdot \log_{10}(1\ \text{min}/1\ \text{s})$dB¼17.7dB]. Thus, the proposed level for effective quiet is equivalently a 1-min SPL that is 50dB below the numeric value of the auditory frequency-weighted Southall *et al.*, (2019) daily SEL TTS threshold for non-impulsive sources.,

11.6.71 There are points that need consideration before adopting kurtosis as an impulsiveness measure, with the recommended threshold value of 40. Firstly, this value was experimentally obtained for chinchillas that were exposed to noise for a five-day period under controlled conditions. Caution may need to be taken to directly adopt this threshold-value (and the related dose-response of increasing PTS with increasing kurtosis between 3 and 40) to marine mammals in the wild, especially given that the PTS guidance considers time periods of up to 24 hours. Secondly, kurtosis is recommended to be computed over at least 30 seconds, which means that it is not a specific measure that can be used for single blows of a piling sequence. Instead, kurtosis has been recommended to evaluate steady-state noise in order to include the risk from embedded impulsive noise (Goley *et al.*, 2011). Metrics used by Hastie *et al.* (2019) computed for each pile strike (e.g. risetime) may be more suitable to be included in piling impact assessments, as, for each single pile strike, the sound exposure levels received by an animal are considered. It is currently unknown which metric is the most useful and how they correlate with the magnitude of auditory injury in (marine) mammals.

11.6.72 Southall (2021) points out that:

"at present there are no properly designed, comparative studies evaluating TTS for any marine mammal species with various noise types, using a range of impulsive metrics to determine either the best metric or to define an explicit threshold with which to delineate impulsiveness".

11.6.73 Southall (2021) proposes that the presence of high-frequency noise energy could be used as a proxy for impulsiveness, as all currently used metrics have in common that a high frequency spectral content result in high values for those metrics. This suggestion is an interim approach:

"the range at which noise from an impulsive source lacks discernable energy (relative to ambient noise at the same location) at frequencies ≥ 10kHz could be used to distinguish when the relevant hearing effect criteria transitions from impulsive to nonimpulsive".

11.6.74 Southall (2021), however, notes that:

"it should be recognized that the use of impulsive exposure criteria for receivers at greater ranges (tens of kilometers) is almost certainly an overly precautionary interpretation of existing criteria".

11.6.75 Considering that an increasing proportion of the sound emitted during a piling sequence will become less impulsive (and thereby less harmful) while propagating away from the sound source, and this effect starts at ranges below 5km in all above mentioned examples, the cumulative PTS-onset threshold for animals starting to flee at 5km should be higher than the Southall *et al.*, (2021) threshold adopted for this assessment (i.e., the risk of experiencing PTS becomes lower), and any impact range estimated beyond this distance should be considered as an unrealistic over-estimate, especially when they result in very large distances.

11.6.76 For the purpose of presenting a precautionary assessment, the quantitative impact assessment for the Project is based on fully impulsive thresholds, but the potential for overestimation should be noted.

Animal Depth

11.6.77 Empirical data on SEL_{ss} levels recorded during piling construction at the Lincs offshore windfarm have been compared to estimates obtained using the Aquarius pile driving model[19] (Whyte *et al.*, 2020). This has demonstrated that measured recordings of SEL_{ss} levels made at 1m depth were all lower than the model predicted single-strike sound exposure levels for the shallowest depth bin (2.5m). In contrast, measurements made at 9m depth were much closer to the model predicted single-strike sound exposure levels. This highlights the limitations of modelling exposure using depth averaged sound levels, as the acoustic model can overpredict exposure at the surface. This is important to note since animals may conduct shorter and shallower dives when fleeing (e.g. van Beest *et al.*, 2018).

Cumulative PTS Conclusion

11.6.78 Given the above, SMRU Consulting considers that the calculated SEL_{cum} PTS-onset impact ranges are highly precautionary and that the true extent of effects (impact ranges and numbers of animals experiencing PTS) will likely be considerably less than that assessed here.

Density

11.6.79 There are uncertainties relating to the ability to predict the responses of animals to underwater noise and the number 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 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.

Predicting response

11.6.80 In addition, there are limited empirical data available to inform predictions of 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 Windfarm and therefore uses the most recent and site-specific information on disturbance to harbour porpoise as a result of pile driving noise.

[19] From more information on the Aquarius model see: de Jong, C., Binnerts, B., Prior, M., Colin, M., Ainslie, M., Mulder, I., and Hartstra, I. (2019). "Wozep – WP2: update of the Aquarius models for marine pile driving sound predictions," TNO Rep. (2018), number R11671, The Hague, Netherlands, p. 94. Retrieved from https://www.noordzeeloket.nl/publish/pages/160801/update_aquarius_models_pile_driving_sound_predeictions_tno_2019.pdf

11.6.81 There is also a lack of information on how observed effects (e.g. short-term displacement around impact piling activities) manifest themselves in terms of effects on individual fitness, and ultimately population dynamics (see the section 11.6.27 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.

Duration of Impact

11.6.82 The duration of disturbance is another uncertainty. Studies at Horns Rev 2 demonstrated that porpoises returned to the area between one and three days after piling (Brandt *et al.*, 2011) and monitoring at the Dan Tysk Windfarm as part of the Disturbance Effects on the Harbour Porpoise Population in the North Sea (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 windfarm 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 porpoise detections were reduced between one and two days after piling (Brandt *et al.*, 2018).

11.6.83 Analysis of data from monitoring of marine mammal activity during piling of jacket pile foundations at Beatrice Offshore Windfarm (Graham *et al.*, 2017a, Graham *et al.*, 2019) provides 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.

TTS Limitations

11.6.84 It is recognised that TTS is a temporary impairment of an animal's hearing ability with potential consequences for the animal's ability to escape predation, forage and/or communicate, supporting the statement of Kastelein *et al.*, (2012c) that

> *"the magnitude of the consequence is likely to be related to the duration and magnitude of the TTS"*

11.6.85 An assessment of the impact based on the TTS thresholds as currently given in Southall (2019) or the former NMFS (2016) guidelines and Southall *et al.* (2007) guidance) would lead to a substantial overestimate of the potential impact of TTS. Furthermore, the prediction of TTS impact ranges, based on the sound exposure level (SEL) thresholds, are subject to the same inherent uncertainties as those for PTS, and in fact the uncertainties may be considered to have a proportionately larger effect on the prediction of TTS. These concepts are explained in detail below based on the thresholds detailed by Southall *et al.* (2019), as these are based upon the most up-to-date scientific knowledge.

11.6.86 It is SMRU Consulting's expert opinion that basing any impact assessment on the impact ranges for TTS using current TTS thresholds would overestimate the potential for an ecologically significant effect. This is because the species-specific TTS thresholds in Southall (2019) describe those thresholds at which the onset of TTS is observed, which is, per their definition, a 6dB shift in the hearing threshold, usually measured four minutes after sound exposure, which is considered as

"the minimum threshold shift clearly larger than any day-to-day or session-to-session variation in a subject's normal hearing ability", and which "is typically the minimum amount of threshold shift that can be differentiated in most experimental conditions"

11.6.87 The time hearing recovers back to normal (the recovery time) for such small threshold shifts is expected to be less than an hour, and, therefore, unlikely to cause any major consequences for an animal.

11.6.88 A large shift in the hearing threshold near to values that may cause PTS may however require multiple days to recover (Finneran, 2015). For TTS induced by steady-state tones or narrowband noise, Finneran (2015) describes a logarithmic relationship between recovery rate and recovery time, expressed in dB/decade (with a decade corresponding to a ratio of 10 between two time intervals, resulting in steps of 10, 100, 1000 minutes and so forth). For an initial shift of 5 to 15dB above hearing threshold, TTS reduced by 4 to 6dB per decade for dolphins, and 4 to 13dB per decade for harbour porpoise and harbour seals. Larger initial TTS tend to result in faster recovery rates, although the total time it takes to recover is usually longer for larger initial shifts (summarised in Finneran, 2015). While the rather simple logarithmic function fits well for exposure to steady-state tones, the relationship between recovery rate and recovery time might be more complex for more complex broadband sound, such as that produced by pile driving noise.

11.6.89 For small threshold shifts of 4 to 5dB caused by pulsed noise, Kastelein (2016) demonstrated that porpoises recovered within one hour from TTS. While the onset of TTS has been experimentally validated, the determination of a threshold shift that would cause a longer-term recovery time and is therefore potentially ecologically significant, is complex and associated with much uncertainty.

11.6.90 The degree of TTS and the duration of recovery time that may be considered severe enough to lead to any kind of energetic or fitness consequences for an individual, is currently undetermined, as is how many individuals of a population can suffer this level of TTS before it may lead to population consequences. There is currently no set threshold for the onset of a biologically meaningful TTS, and this threshold is likely to be well above the TTS-onset threshold, leading to smaller impact ranges (and consequently much smaller impact areas, considering a squared relationship between area and range) than those obtained for the TTS-onset threshold. One has to bear in mind that the TTS-onset thresholds as recommended first by Southall (2007) and further revised by Southall *et al.* (2019) were determined as a means to be able to determine the PTS-onset thresholds and represents the smallest measurable degree of TTS above normal day to day variation. A direct determination of PTS-onset thresholds would lead to an injury of the experimental animal and is therefore considered as unethical. Guidelines such as National Academies of Sciences Engineering and Medicine (2017) and Southall (2007) therefore rely on available data from humans and other terrestrial mammals that indicate that a shift in the hearing threshold of 40dB may lead to the onset of PTS.

11.6.91 For pile driving for offshore windfarm foundations, the TTS and PTS-onset thresholds for impulsive sound are the appropriate thresholds to consider. These consist of a dual metric, a threshold for the peak sound pressure associated with each individual hammer strike, and one for the cumulative sound exposure level (SEL_{cum}), for which the sound energy over successive strokes is summated. The SEL_{cum} is based on the assumption that each unit of sound energy an animal is exposed to leads to a certain amount of threshold shift once the cumulated energy raises above the TTS-onset threshold. For impulsive sound, the threshold shift that is predicted to occur is 2.3dB per dB noise received; for non-impulsive sound this rate is smaller (1.6dB per dB noise) (Southall *et al.*, 2007). Please see the section above for further details on the limitations of SEL_{cum} thresholds (the same limitations apply to TTS as PTS).

11.6.92 Modelling the SEL_{cum} impact ranges of PTS with a 'fleeing animal' model (as is typical during in noise impact assessments) are subject to both of these precautions. Modelling the SEL_{cum} TTS impact ranges will inherit the same uncertainties, however, over a longer period of time, and over greater ranges as the TTS impact ranges are expected to be larger than those of PTS. Therefore, these uncertainties and conservativisms will have a relatively larger effect on predictions of TTS ranges.

11.6.93 It is also important to bear in mind that the quantification of any impact ranges in the environmental assessment process, is done to inform an assessment of the potential magnitude and significance of an impact. Because the TTS thresholds are not universally used to indicate a level of biologically meaningful impact of concern per se but are used to enable the prediction of where PTS might occur, it would be very challenging to use them as the basis of any assessment of impact significance.

11.6.94 All the data that exists on auditory injury in marine mammals is from studies of TTS and not PTS. SMRU Consulting agrees with the studies' conclusion that we may be more confident in our prediction of the range at which any TTS may occur. However, this is not necessarily very useful for the impact assessment process. We accept that scientific understanding of the degree of exposure required to elicit TTS may be more empirically based than our ability to predict the degree of sound required to elicit PTS, it does not automatically follow that our ability to determine the consequences of a stated level of TTS for individuals is any more certain than our ability to determine the consequences of a stated level of PTS for individuals. It could even be argued that we are more confident in our ability to predict the consequences of a permanent effect than we are to predict the consequences of a temporary effect of variable severity and uncertain duration.

11.6.95 It is important to consider that predictions of PTS and TTS are linked to potential changes in hearing sensitivity at particular hearing frequencies, which for piling noise are generally thought to occur in the 2-10kHz range and are not considered to occur across the whole frequency spectrum. Studies have shown that exposure to impulsive pile driving noise induces TTS in a relatively narrow frequency band in harbour porpoise and harbour seals (reviewed in Finneran, 2015), with statistically significant TTS occurring at 4 and 8kHz (Kastelein *et al.*, 2016) and centred at 4kHz (Kastelein *et al.*, 2012a; Kastelein *et al.*, 2012b; Kastelein *et al.*, 2013b; Kastelein *et al.*, 2017).Our understanding of the consequences of PTS within this frequency range to an individual’s survival and fecundity is limited, and therefore our ability to predict and assess the consequences of TTS of variable severity and duration is even more difficult to do.

11.7 Impact Assessment

Construction

11.7.1 This section presents the assessment of impacts arising from the construction phase of the Project.

Impact 1: UXO Clearance - PTS

11.7.2 If UXO are found, a risk assessment will be undertaken and items of UXO will either be avoided, removed or detonated in situ. Recent advancements in the available methods for UXO clearance mean that high-order detonation may be avoided. The methods of UXO clearance considered for the Project would follow the mitigation hierarchy:

- Avoidance;
- Removal/relocation;
- Low-order clearance (deflagration); and
- High-order detonation;

11.7.3 As the detailed pre-construction surveys have not yet been completed, it is not possible at this time to determine how many items of UXO will require clearance. As a result, a separate Marine Licence will be applied for post-consent for the clearance (where required) of any UXO identified. The Project is located in the vicinity of historical industrial and commercial coastal towns which may have been subject to bombing during World War Two and, therefore, UXOs may be present in these areas. Furthermore, Lincolnshire was also home to a large number of military airfields during World War Two which increases the likelihood of encountering UXOs in the region. Despite this, much of the Project area is classified as Low Risk for UXOs.

11.7.4 Current advice from the SNCBs (Natural England and the MMO) is that the Southall *et al.*, (2019) criteria for impulsive sounds should be used for assessing the impact of PTS from UXO detonation on marine mammals. Whilst this is currently considered the recommended method to use for assessment, the suitability of these criteria for UXO is under discussion due to the lack of empirical evidence from UXO detonations using these metrics, in particular the range-dependent characteristics of the impulsiveness of the sound, and whether current propagation models can accurately predict the range at which these thresholds are reached.

11.7.5 An estimation of the source level and predicted PTS-onset impact ranges were calculated for a range of expected UXO sizes. The maximum charge weight for the potential UXO devices that could be present within the Project site boundary has been estimated as 800kg. This has been modelled alongside a range of smaller high-order charges at 25, 55, 120, 240, 525 and 700kg. In addition, a low-order deflagration has been assessed, which assumes that the donor or shaped-charge (charge weight 0.5kg[20]) detonates fully but without the follow-up detonation of the UXO. No mitigation measures have been considered for the modelling of the range and number of animals predicted to be disturbed by the detonation of high-order and low-order charges.

11.7.6 Full details of the underwater noise modelling and the resulting PTS-onset impact areas and ranges are detailed in Volume 2, Appendix 3.2: Underwater Noise Assessment. The source level of each UXO charge weight was calculated in accordance with Soloway and Dahl (2014), which follows Arons (1954) and Barett (1996), and using conservative calculation parameters that result in the upper estimate of the source level for each charge size. This is therefore considered to be an indication of the potential maximum noise output from each charge size and, as such, likely results in an overestimate of PTS-onset impact ranges, especially for larger charge sizes and low order clearance. More recent models developed by Robinson (2022) were found to agree reasonably well with the experimental characterisation of explosive noise sources in shallow water environments used by Soloway and Dahl (2014).

11.7.7 In line with the recommendations outlined within the recent position statement on UXO clearance (DEFRA *et al.*, 2021) this impact assessment includes an assessment for high-order detonations, though this is considered unlikely to occur in practice. The results for PTS from UXO clearance are presented in Table 11.15.

[20] It should be noted that a charge weight of 0.5kg is considered highly conservative for a low order charge based on the results of Robinson *et al.,* (2022)

Table 11.15: PTS-onset impact ranges and number of animals predicted to experience PTS-onset for UXO detonation. All charge sizes listed are in kg. For all charge sizes above 25kg a donor of 0.5kg is assumed

Species	Threshold	Metric	Charge size 0.5	25	55	120	240	525	700	800
Unweighted SPL_{peak} (dB re 1µPa)										
Harbour porpoise	202dB (VHF)	Range (km)	1.2	4.6	6.0	7.8	9.8	12.0	14.0	14.0
		# animals	11	158	269	454	717	1,074	1,462	1,462
		% MU	<0.01	0.05	0.08	0.13	0.21	0.31	0.42	0.42
Bottlenose dolphin &	230dB (HF)	Range (km)	0.07	0.26	0.34	0.45	0.56	0.73	0.81	0.84
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-beaked dolphin		Range (km)	0.07	0.26	0.34	0.45	0.56	0.73	0.81	0.84
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minke whale	219dB (LF)	Range (km)	0.22	0.82	1.0	1.3	1.7	2.2	2.4	2.6
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbour seal	218dB (PCW)	Range (km)	0.24	0.91	1.1	1.5	1.9	2.5	2.7	2.8
		# animals	0	0	0	1	1	3	3	3
		% MU	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.07
Grey seal		Range (km)	0.24	0.91	1.1	1.5	1.9	2.5	2.7	2.8
		# animals	0	2	3	6	10	17	19	21
		% MU	0.00	<0.01	0.01	0.01	0.02	0.03	0.04	0.04
Weighted SEL_{ss} (dB re 1µPa²s)										
Harbour porpoise	155dB (VHF)	Range (km)	0.11	0.57	0.74	0.95	1.1	1.4	1.5	1.5
		# animals	0	2	4	7	9	15	17	17
		% MU	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bottlenose dolphin		Range (km)	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.06	0.06

Species	Threshold	Metric	Charge size							
			0.5	25	55	120	240	525	700	800
	185dB (HF)	# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-beaked dolphin		Range (km)	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	0.06	0.06
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minke whale	183dB (LF)	Range (km)	0.32	2.2	3.2	4.7	6.5	9.5	10.0	11.0
		# animals	0	0	0	1	1	3	3	4
		% MU	0.00	0.00	0.00	<0.01	0.01	0.01	0.02	0.02
Harbour seal	185dB (PCW)	Range (km)	0.06	0.39	0.57	0.83	1.1	1.6	1.9	2.0
		# animals	0	0	0	0	0	1	1	2
		% MU	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03
Grey seal		Range (km)	0.06	0.39	0.57	0.83	1.1	1.6	1.9	2.0
		# animals	0	0	0	0	0	1.0	1.0	2.0
		% MU	0.00	<0.01	<0.01	<0.01	0.01	0.01	0.02	0.02

Sensitivity

11.7.8 Most of the acoustic energy produced by a high-order detonation is below a few hundred Hz, decreasing on average by about SEL 10dB per decade above 100 Hz, and there is a pronounced drop-off in energy levels above ~5-10kHz (von Benda-Beckmann *et al.*, 2015; Salomons *et al.*, 2021). Therefore, the primary acoustic energy from a high-order UXO detonation is below the region of greatest sensitivity for most marine mammal species considered here (porpoise, dolphins and seals) (Southall *et al.*, 2019). If PTS were to occur within this low frequency range, it would be unlikely to result in any significant impact to vital rates of porpoise, dolphins and seals. Therefore, most marine mammals (porpoise, dolphins and seals) have been assessed as having a Low sensitivity to PTS from UXO clearance.

11.7.9 Recent acoustic characterisation of UXO clearance noise has shown that there is more energy at lower frequencies (<100 Hz) then previously assumed (Robinson *et al.*, 2022). Given the lower frequency components of the sound produced by UXO clearance, it is more precautionary to assess minke whales as having a Medium sensitivity to PTS from UXO clearance.

Harbour porpoise

Magnitude

11.7.10 At the largest modelled charge size of 800kg + a 25kg donor charge, the impact range for harbour porpoise using unweighted SPL_{peak} is expected to be 14km, resulting in PTS-onset in 1,462 harbour porpoise, equating to 0.42% of the MU (Table 11.15). Using weighted SEL_{ss}, the maximum impact range calculated for harbour porpoise was 1.5km, impacting 17 harbour porpoise, equating to <0.01% of the MU.

11.7.11 As part of any future consent for UXO removal the Project will be required to implement a UXO-specific MMMP to ensure that the effect significance of PTS is negligible. The exact mitigation measures contained with the UXO MMMP are yet to be determined and will be agreed with NE. However, multiple measures are available and have been implemented elsewhere for UXO clearance, such as the use of Acoustic Deterrent Device (ADDs) displace animals to beyond the PTS impact range, or noise abatement techniques where appropriate. The magnitude of this impact is, therefore, considered to be reduced to Negligible (adverse) for harbour porpoise with the implementation of embedded mitigation.

Significance

11.7.12 The sensitivity of harbour porpoise to PTS-onset from UXO clearance has been assessed as Low.

11.7.13 The magnitude of PTS-onset to harbour porpoise from UXO clearance has been assessed as Negligible (adverse).

11.7.14 Therefore, the effect significance of PTS-onset to harbour porpoise from UXO clearance is **Negligible** (**not significant)** in EIA terms.

Bottlenose dolphin

Magnitude

11.7.15 At the largest modelled charge size, the impact range for bottlenose dolphin using unweighted SPL_{peak} is expected to be 0.84km, resulting in no predicted PTS-onset in bottlenose dolphin (Table 11.15). Using weighted SEL_{ss}, the maximum impact range calculated for bottlenose dolphin was 0.06km, also resulting in no predicted PTS-onset (Table 11.15). The magnitude of this impact is, therefore, considered to be Negligible (adverse) for bottlenose dolphin.

Significance

11.7.16 The sensitivity of bottlenose dolphin to PTS-onset from UXO clearance has been assessed as Low.

11.7.17 The magnitude of PTS-onset to bottlenose dolphin from UXO clearance has been assessed as Negligible (adverse).

11.7.18 Therefore, the effect significance of PTS-onset to bottlenose dolphin from UXO clearance is **Negligible** (**not significant)** in EIA terms.

White-beaked dolphin

Magnitude

11.7.19 At the largest modelled charge size, the impact range for white-beaked dolphin using unweighted SPL_{peak} is expected to be 0.84km, resulting in no predicted PTS-onset in white-beaked dolphin (Table 11.15). Using weighted SEL_{ss}, the maximum impact range calculated for white-beaked dolphin was 0.06km, also resulting in no predicted PTS-onset (Table 11.15). The magnitude of this impact is, therefore, considered to be Negligible (adverse) for white-beaked dolphin.

Significance

11.7.20 The sensitivity of white-beaked dolphin to PTS-onset from UXO clearance has been assessed as Low.

11.7.21 The magnitude of PTS-onset to white-beaked dolphin from UXO clearance has been assessed as Negligible (adverse).

11.7.22 Therefore, the effect significance of PTS-onset to white-beaked dolphin from UXO clearance is **Negligible (not significant)** in EIA terms.

Minke whale

Magnitude

11.7.23 At the largest modelled charge size, the impact range for minke whale using unweighted SPL_{peak} is expected to be 2.6km, resulting in no predicted PTS-onset in minke whale (Table 11.15). Using weighted SEL_{ss}, the maximum impact range calculated for minke whale was 11km, impacting 4 minke whale, equating to <0.01% of the MU (Table 11.15).

11.7.24 As mentioned previously, as part of any future consent for UXO removal the Project will be required to implement a UXO-specific MMMP to ensure that the effect significance of PTS is negligible. The magnitude of this impact is, therefore, considered to be Negligible (adverse) for minke whale.

Significance

11.7.25 The sensitivity of minke whale to PTS-onset from UXO clearance has been assessed as Medium.

11.7.26 The magnitude of PTS-onset to minke whale from UXO clearance has been assessed as Negligible (adverse).

11.7.27 Therefore, the effect significance of PTS-onset to minke whale from UXO clearance is **Minor (not significant)** in EIA terms.

Harbour seal

Magnitude

11.7.28 At the largest modelled charge size, the impact range for harbour seal using unweighted SPL_{peak} is expected to be 2.8km, resulting in PTS-onset in 3 harbour seals, equating to <0.01% of the MU (Table 11.15). Using weighted SEL_{ss}, the maximum impact range calculated for harbour porpoise was 2km, impacting 2 harbour seals, equating to <0.01% of the MU (Table 11.15). The magnitude of this impact is, therefore, considered to be Negligible (adverse) for harbour seal.

Significance

11.7.29 The sensitivity of harbour seal to PTS-onset from UXO clearance has been assessed as Low.

11.7.30 The magnitude of PTS-onset to harbour seal from UXO clearance has been assessed as Negligible (adverse).

11.7.31 Therefore, the effect significance of PTS-onset to harbour seal from UXO clearance is **Negligible (not significant)** in EIA terms.

Grey seal

Magnitude

11.7.32 At the largest modelled charge size, the impact range for grey seal using unweighted SPL_{peak} is expected to be 2.8km, resulting in PTS-onset in 21 grey seals, equating to <0.01% of the MU (Table 11.15). Using weighted SEL_{ss}, the maximum impact range calculated for harbour porpoise was 2km, impacting 2 grey seals, equating to <0.01% of the MU (Table 11.15). The magnitude of this impact is, therefore, considered to be Negligible (adverse) for grey seal.

Significance

11.7.33 The sensitivity of grey seal to PTS-onset from UXO clearance has been assessed as Low.

11.7.34 The magnitude of PTS-onset to grey seal from UXO clearance has been assessed as Negligible (adverse).

11.7.35 Therefore, the effect significance of PTS-onset to grey seal from UXO clearance is **Negligible (not significant)** in EIA terms.

UXO clearance – PTS summary

11.7.36 Table 11.16 presents a summary of the sensitivity, magnitude and significance of PTS-onset from UXO clearance for marine mammals. The significance has been assessed as Negligible for most marine mammal species (porpoise, dolphins and seals) and Minor for minke whales, which is **not significant** in EIA terms.

Table 11.16: Summary of marine mammal sensitivity, magnitude and significance of PTS from UXO clearance.

Species	Sensitivity	Magnitude	Significance
Harbour porpoise	Low	Negligible	**Negligible (Not significant)**
Bottlenose dolphin	Low	Negligible	**Negligible (Not significant)**
White-beaked dolphin	Low	Negligible	**Negligible (Not significant)**
Minke whale	Medium	Negligible	**Minor (Not significant)**
Harbour seal	Low	Negligible	**Negligible (Not significant)**
Grey seal	Low	Negligible	**Negligible (Not significant)**

Impact 2: UXO Clearance - Disturbance

11.7.37 As previously stated, there are currently no empirically-derived behavioural thresholds or dose-response functions for UXO detonation. Therefore, in the absence of agreed thresholds to assess the potential for behaviour disturbance in marine mammals from UXO detonations, the Project impact assessment presents the results for the 26km EDR (high-order; Table 11.17), 5km EDR (low-order; Table 11.18) and TTS-onset thresholds (Table 11.19:).

11.7.38 It is acknowledged that our understanding of the effect of disturbance from UXO detonation is very limited, and as such the assessment can only provide an indication of the number of animals potentially at risk of disturbance given the limited evidence available.

Table 11.17: Disturbance from high order UXO clearance using an EDR of 26km.

Species	Density (#/km^2)	Area (km^2)	# impacted	MU size	% MU
Harbour porpoise	2.375	2,123.72	5,044	346,601	1.5
Bottlenose dolphin	0.002	2,123.72	4	2,022	0.2
White-beaked dolphin	0.002	2,123.72	4	43,951	<0.1
Minke whale	0.010	2,123.72	21	20,118	0.1
Harbour seal	0.13[21]	2,123.72	276	4,852	5.7
Grey seal	0.85[22]	2,123.72	1,805	52,990	3.4

[21] Within the 50km buffer of the Project, there are predicted to be up to ~1,670 harbour seals at any one time in the foraging season, which equates to an average density of 0.13 harbour seals/km^2.

[22] Within the 50km buffer of the Project, there are predicted to be up to~11,018 grey seals at any one time in the foraging season, which equates to an average density of 0.85 grey seals/km^2.

Table 11.18: Disturbance from low order UXO clearance using an EDR of 5km.

Species	Density (#/km^2)	Area (km^2)	# impacted	MU size	% MU
Harbour porpoise	2.375	78.54	186	346,601	0.1
Bottlenose dolphin	0.002	78.54	0	2,022	0.0
White-beaked dolphin	0.002	78.54	0	43,951	0.0
Minke whale	0.010	78.54	1	20,118	<0.1
Harbour seal	0.13	78.54	10	4,852	0.2
Grey seal	0.85	78.54	67	52,990	0.1

Table 11.19: Disturbance from UXO clearance using TTS-onset as a proxy for disturbance.

Species	Threshold	Metric	Charge size							
			0.5	25	55	120	240	525	700	800
Unweighted SPL_{peak} (dB re 1µPa)										
Harbour porpoise	196dB (VHF)	Range (km)	2.3	8.5	11	14	18	23	25	26
		# animals	39	539	903	1,462	2,417	3,947	4,663	5,044
		% MU	0.01	0.16	0.26	0.42	0.70	1.14	1.35	1.46
Bottlenose dolphin	224dB (HF)	Range (km)	0.13	0.49	0.64	0.83	1.0	1.3	1.4	1.5
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-beaked dolphin		Range (km)	0.13	0.49	0.64	0.83	1.0	1.3	1.4	1.5
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minke whale	213dB (LF)	Range (km)	0.41	1.5	1.9	2.5	3.2	4.1	4.5	4.7
		# animals	0	0	0	0	0	1	1	1
		% MU	0.00	0.00	0.00	0.00	0.00	<0.01	<0.01	<0.01
Harbour seal	212dB (PCW)	Range (km)	0.45	1.6	2.1	2.8	3.5	4.6	5.0	5.3
		# animals	0	1	2	3	5	9	10	11
		% MU	0.00	0.02	0.04	0.07	0.10	0.18	0.21	0.24
Grey seal		Range (km)	0.45	1.6	2.1	2.8	3.5	4.6	5.0	5.3
		# animals	1	7	12	21	33	57	67	75
		% MU	<0.01	0.01	0.02	0.04	0.06	0.11	0.13	0.14
Weighted SEL_{ss} (dB re $1µPa^2s$)										
Harbour porpoise	140dB (VHF)	Range (km)	0.93	2.4	2.8	3.2	3.5	4.0	4.1	4.2
		# animals	6	43	58	76	91	119	125	132
		% MU	<0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04
Bottlenose dolphin	170dB (HF)	Range (km)	<0.05	0.15	0.21	0.30	0.39	0.53	0.62	0.69
		# animals	0	0	0	0	0	0	0	0

Species	Threshold	Metric	Charge size							
			0.5	25	55	120	240	525	700	800
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White-beaked dolphin		Range (km)	<0.05	0.15	0.21	0.30	0.39	0.53	0.62	0.69
		# animals	0	0	0	0	0	0	0	0
		% MU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minke whale	168dB (LF)	Range (km)	4.5	29	41	57	76	100	110	120
		# animals	1	26	53	102	181	314	380	452
		% MU	<0.01	0.13	0.26	0.51	0.90	1.56	1.89	2.25
Harbour seal	170dB (PCW)	Range (km)	0.80	5.2	7.5	10	14	19	22	23
		# animals	0	11	23	41	80	147	198	216
		% MU	0.01	0.23	0.47	0.84	1.65	3.04	4.07	4.45
Grey seal		Range (km)	0.80	5.2	7.5	10	14	19	22	23
		# animals	2	72	150	267	523	964	1,292	1,413
		% MU	<0.01	0.14	0.28	0.50	0.99	1.82	2.44	2.67

Sensitivity

11.7.39 It is noted in the JNCC (2020) guidance that, although UXO detonation is considered a loud underwater noise source, "...a one-off explosion would probably only elicit a startle response and would not cause widespread and prolonged displacement...". Whilst detonations will usually be undertaken as part of a campaign and, therefore, there may result in multiple detonations over several days (JNCC, 2020), each detonation will be of a short-term duration. Therefore, it is not expected that disturbance from a single UXO detonation would result in any significant impacts, and that disturbance from a single noise event would not be sufficient to result in any changes to the vital rates of individuals. Therefore, the sensitivity of marine mammals for disturbance from UXO clearance is expected to be Low.

Harbour porpoise

Magnitude

11.7.40 Using the 26km EDR for disturbance from high order detonations: It is anticipated that 5,044 harbour porpoise would be disturbed by high-order UXO clearance, equating to 1.5% of the MU (Table 11.17). Given the number and proportion of the MU expected to be disturbed by high-order UXO clearance, the impact is assessed as a Low (adverse) magnitude to harbour porpoise.

11.7.41 Using the 5km EDR for disturbance from low order detonations: It is anticipated that 186 harbour porpoise would be disturbed by low-order UXO clearance, equating to 0.1% of the MU (Table 11.18). Given the number and proportion of the MU expected to be disturbed by low-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude.

11.7.42 Using TTS onset as a proxy for behavioural disturbance: The impact range for harbour porpoise for the maximum UXO clearance of 800kg UXO + a 25kg donor charge using unweighted SPL_{peak} was calculated at a maximum of 26km, impacting 5,044 harbour porpoise, equating to 1.46% of the MU (Table 11.19:). Using weighted SEL_{ss}, the maximum impact range calculated for harbour porpoise was 4.2km, impacting 132 harbour porpoise, equating to 0.04% of the MU (Table 11.19:). Given the number and proportion of the MU expected to be disturbed by UXO clearance, the impact is assessed as Low (adverse) magnitude.

Significance

11.7.43 The sensitivity of harbour porpoise to disturbance from UXO clearance has been assessed as Low.

11.7.44 The magnitude of disturbance to harbour porpoise from UXO clearance has been assessed as Low (adverse) to Negligible (adverse).

11.7.45 Therefore, the effect significance of disturbance to harbour porpoise from UXO clearance is **Minor** to **Negligible (not significant)** in EIA terms.

Bottlenose dolphin

Magnitude

11.7.46 Using the 26km EDR for disturbance from high order detonations: It is anticipated that 4 bottlenose dolphins would be disturbed by high-order UXO clearance, equating to 0.2% of the MU (Table 11.17). Given the low number and proportion of the MU expected to be disturbed by high-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude to bottlenose dolphin.

11.7.47 Using the 5km EDR for disturbance from low order detonations: It is anticipated that no bottlenose dolphins within the MU would be disturbed by low-order UXO clearance (Table 11.18). Given the lack of predicted impact, the impact is assessed as a Negligible (adverse) magnitude to bottlenose dolphin.

11.7.48 Using TTS onset as a proxy for behavioural disturbance: The impact range for bottlenose dolphin for the maximum UXO clearance of 800kg UXO + a 25kg donor charge was calculated at a maximum of 1.5km, resulting in no predicted impact to bottlenose dolphin (Table 11.19:). Using weighted SEL_{ss}, the maximum impact range calculated for bottlenose dolphin was 0.69km, also resulting in no predicted impact to bottlenose dolphin (Table 11.19:). Given that there is no predicted disturbance from UXO clearance, the impact is assessed as Negligible (adverse) magnitude.

Significance

11.7.49 The sensitivity of bottlenose dolphins to disturbance from UXO clearance has been assessed as Low.

11.7.50 The magnitude of disturbance to bottlenose dolphin from UXO clearance has been assessed as Negligible (adverse).

11.7.51 Therefore, the effect significance of disturbance to bottlenose dolphins from UXO clearance is **Negligible (not significant)** in EIA terms.

White-beaked dolphin

Magnitude

11.7.52 Using the 26km EDR for disturbance from high order detonations: It is anticipated that 4 white-beaked dolphins within the MU would be disturbed by high-order UXO clearance, equating to <0.1% of the MU (Table 11.17). Given the low number and proportion of the MU expected to be disturbed by high-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude to white-beaked dolphins.

11.7.53 Using the 5km EDR for disturbance from low order detonations: It is anticipated that no white-beaked dolphins within the MU would be disturbed by low-order UXO clearance (Table 11.18). Given the lack of predicted impact, the impact is assessed as a Negligible (adverse) magnitude to white-beaked dolphins.

11.7.54 Using TTS onset as a proxy for behavioural disturbance: The impact range for white-beaked dolphin for the maximum UXO clearance of 800kg UXO + a 25kg donor charge was calculated at a maximum of 1.5km, resulting in no predicted impact to white-beaked dolphin (Table 11.19:). Using weighted SEL_{ss}, the maximum impact range calculated for white-beaked was 0.69km, also resulting in no predicted impact to bottlenose dolphin (Table 11.19:). Given that there is no predicted disturbance from UXO clearance, the impact is assessed as Negligible (adverse) magnitude.

Significance

11.7.55 The sensitivity of white-beaked dolphins to disturbance from UXO clearance has been assessed as Low.

11.7.56 The magnitude of disturbance to white-beaked dolphins from UXO clearance has been assessed as Negligible (adverse).

11.7.57 Therefore, the effect significance of disturbance to white-beaked dolphins from UXO clearance is **Negligible (not significant)** in EIA terms.

Minke whale

Magnitude

11.7.58 Using the 26km EDR for disturbance from high order detonations: It is anticipated that 21 minke whales would be disturbed by high-order UXO clearance, equating to 0.1% of the MU (Table 11.17). Given the low number and proportion of the MU expected to be disturbed by high-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude to minke whales.

11.7.59 Using the 5km EDR for disturbance from low order detonations: It is anticipated that 1 minke whale would be disturbed by low-order UXO clearance, equating to <0.1% of the MU (Table 11.18). Given the number and proportion of the MU expected to be disturbed by low-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude to minke whales.

11.7.60 Using TTS onset as a proxy for behavioural disturbance: The impact range for minke whale for the maximum UXO clearance of 800kg UXO + a 25kg donor charge was calculated at a maximum of 4.7km, impacting 1 minke whale, equating to <0.01% of the MU (Table 11.19:). Using weighted SEL_{ss}, the maximum impact range calculated for minke whale was 120km, impacting 452 minke whale, equating to 2.2% of the MU (Table 11.19:). Despite the large TTS-onset impact range presented, it should be noted that the Soloway and Dahl (2014) equation used for modelling the impact ranges in Volume 2, Appendix 3.2: Underwater Noise Assessment is not considered valid at such a distance from the noise source. Given the number and proportion of the MU expected to be disturbed by UXO clearance, the impact is assessed as Low (adverse) magnitude.

Significance

11.7.61 The sensitivity of minke whales to disturbance from UXO clearance has been assessed as Low.

11.7.62 The magnitude of disturbance to minke whales from UXO clearance has been assessed as Negligible (adverse) to Low (adverse).

11.7.63 Therefore, the effect significance of disturbance to minke whales from UXO clearance is **Minor to Negligible (not significant)** in EIA terms.

Harbour seal

Magnitude

11.7.64 Using the 26km EDR for disturbance from high order detonations: It is anticipated that 276 harbour seals would be disturbed by high-order UXO clearance, equating to 5.7% of the MU (Table 11.17). Given the number and proportion of the MU expected to be disturbed by high-order UXO clearance, the impact is assessed as a Low (adverse) magnitude to harbour seals.

11.7.65 Using the 5km EDR for disturbance from low order detonations: It is anticipated that 10 harbour seals would be disturbed by low-order UXO clearance, equating to 0.2% of the MU (Table 11.18). Given the low number and proportion of the MU expected to be disturbed by low-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude to harbour seals.

11.7.66 Using TTS onset as a proxy for behavioural disturbance: The impact range for harbour seals for the maximum UXO clearance of 800kg UXO + a 25kg donor charge was calculated at a maximum of 5.3km, impacting 11 harbour seals, equating to 0.24% of the MU (Table 11.19:). Using weighted SEL_{ss}, the maximum impact range calculated for harbour seal was 23km, impacting 216 harbour seal, equating to 4.45% of the MU (Table 11.19:). Given the number and proportion of the MU expected to be disturbed by UXO clearance, the impact is assessed as Low (adverse) magnitude.

Significance

11.7.67 The sensitivity of harbour seals to disturbance from UXO clearance has been assessed as Low.

11.7.68 The magnitude of disturbance to harbour seal from UXO clearance has been assessed as Low (adverse) to Negligible (adverse).

11.7.69 Therefore, the effect significance of disturbance to harbour seal from UXO clearance is Minor to **Negligible (not significant)** in EIA terms.

Grey seal

Magnitude

11.7.70 Using the 26km EDR for disturbance from high order detonations: It is anticipated that 1,805 grey seals would be disturbed by high-order UXO clearance, equating to 3.4% of the MU (Table 11.17). Given the number and proportion of the MU expected to be disturbed by high-order UXO clearance, the impact is assessed as a Low (adverse) magnitude to grey seals.

11.7.71 Using the 5km EDR for disturbance from low order detonations: It is anticipated that 67 grey seals would be disturbed by low-order UXO clearance, equating to 0.1% of the MU (Table 11.18). Given the low number and proportion of the MU expected to be disturbed by low-order UXO clearance, the impact is assessed as a Negligible (adverse) magnitude to grey seals.

11.7.72 Using TTS onset as a proxy for behavioural disturbance: The impact range for grey seals for the maximum UXO clearance of 800kg UXO + a 25kg donor charge was calculated at a maximum of 5.3km, impacting 75 grey seals, equating to 0.14% of the MU (Table 11.19:). Using weighted SEL_{ss}, the maximum impact range calculated for grey seal was 23km, impacting 1,413 grey seals, equating to 2.67% of the MU (Table 11.19:). Given the number and proportion of the MU expected to be disturbed by UXO clearance, the impact is assessed as Low (adverse) magnitude.

Significance

11.7.73 The sensitivity of grey seals to disturbance from UXO clearance has been assessed as Low.

11.7.74 The magnitude of disturbance to grey seals from UXO clearance has been assessed as Low (adverse) to Negligible (adverse).

11.7.75 Therefore, the effect significance of disturbance to grey seals from UXO clearance is Minor to **Negligible (not significant)** in EIA terms.

UXO clearance – disturbance summary

11.7.76 Table 11.20 presents a summary of the sensitivity, magnitude and significance of disturbance from UXO clearance for marine mammals. The significance has been assessed as Negligible for bottlenose dolphins, white-beaked dolphins, and as Minor to Negligible for harbour porpoise, minke whale, harbour seal and grey seals, which are **not significant** in EIA terms.

Table 11.20: Summary of marine mammal sensitivity, magnitude and significance of disturbance from UXO clearance.

Species	Sensitivity	Magnitude	Significance
Harbour porpoise	Low	Low to Negligible	**Minor to Negligible (Not significant)**
Bottlenose dolphin	Low	Negligible	**Negligible (Not significant)**
White-beaked dolphin	Low	Negligible	**Negligible (Not significant)**
Minke whale	Low	Low to Negligible	**Minor to Negligible (Not significant)**
Harbour seal	Low	Low to Negligible	**Minor to Negligible (Not significant)**
Grey seal	Low	Low to Negligible	**Minor to Negligible (Not significant)**

Impact 3: Pile driving – PTS

WTGs

11.7.77 The following section provides the quantitative assessment of the impact of injury (PTS) from pile driving on marine mammal species. Results are presented in Table 11.21 at the maximum hammer energy for both monopiles (6,600 kJ) and pin piles (3,500 kJ).

Table 11.21: Impact area, maximum range, number of harbour porpoise predicted to experience PTS-onset from piling[23].

Species	Location	Monopile				Pin pile			
		SW	NW	NE	NE&SW	SW	NW	NE	NE&SW
Instantaneous PTS (SPL_{peak})									
Harbour porpoise	Area (km^2)	0.39	0.79	1.1	NA	0.28	0.58	0.8	NA
	Max range (km)	0.37	0.51	0.59		0.31	0.44	0.51	
	# animals	1	2	3		1	1	2	
	% MU	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	
Bottlenose dolphin	Area (km^2)	<0.01	<0.01	<0.01	NA	<0.01	<0.01	<0.01	NA
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
White-beaked dolphin	Area (km^2)	<0.01	<0.01	<0.01	NA	<0.01	<0.01	<0.01	NA
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Minke whale	Area (km^2)	<0.01	<0.01	<0.01	NA	<0.01	<0.01	<0.01	NA
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Harbour seal	Area (km^2)	<0.01	<0.01	<0.01	NA	<0.01	<0.01	<0.01	NA
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Grey seal	Area (km^2)	<0.01	<0.01	<0.01	NA	<0.01	<0.01	<0.01	NA
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	

[23] NA for concurrent NE and SW monopile and pin pile scenarios indicates that modelled noise impact contours did not overlap and, therefore, the area and impact ranges were not modelled by Subacoustech.

Species	Location	Monopile				Pin pile			
Cumulative PTS (SEL_{cum})									
Harbour porpoise	Area (km^2)	3	11	27	310	0.7	4.3	12	270
	Max range (km)	1.4	2.2	3.4	-	0.73	1.4	2.3	-
	# animals	7	26	64	736	2	10	29	641
	% MU	<0.01	0.01	0.02	0.21	<0.01	<0.01	0.01	0.19%
Bottlenose dolphin	Area (km^2)	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	NA
	Max range (km)	<0.10	<0.10	<0.10		<0.10	<0.10	<0.10	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
White-beaked dolphin	Area (km^2)	<0.1	<0.1	<0.1	NA	0.1	0.1	0.1	NA
	Max range (km)	<0.10	<0.10	<0.10		<0.10	<0.10	<0.10	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Minke whale	Area (km^2)	1.6	17	62	480	0.1	5	29	400
	Max range (km)	1.2	2.9	5.5	-	0.3	1.7	3.9	-
	# animals	0	0	1	5	0	0	0	4
	% MU	0.00	0.00	<0.01	0.02	0.00	0.00	0.00	0.02%
Harbour seal	Area (km^2)	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	NA
	Max range (km)	<0.10	<0.10	<0.10		<0.10	<0.10	<0.10	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Grey seal	Area (km^2)	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	NA
	Max range (km)	<0.10	<0.10	<0.10		<0.10	<0.10	<0.10	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	

Harbour porpoise

Sensitivity

11.7.78 The ecological consequences of PTS for marine mammals are uncertain. At an expert elicitation workshop for the interim Population Consequences of Disturbance framework (iPCoD framework), experts in marine mammal hearing[24] discussed the nature, extent and potential consequence of PTS to UK marine mammal species arising from exposure to repeated low-frequency impulsive noise such as pile driving (Booth and Heinis, 2018). This workshop outlined and collated the best and most recent empirical data available on the effects of PTS on marine mammals. 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.

11.7.79 Southall (2007) defined the onset of TTS as *"being a temporary elevation of a hearing threshold by 6dB"* (in which the reference pressure for the dB is 1µPa). Although 6dB of TTS is a somewhat arbitrary definition of onset, it has been adopted largely because 6dB 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 6dB, 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 40dB. 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 40dB of TTS, i.e., 40dB of TTS is assumed to equate to 6dB of PTS.

11.7.80 For piling noise, most energy is between ~30 - 500Hz, with a peak usually between 100 – 300Hz and energy extending above 2kHz (Kastelein *et al.*, 2015a; Kastelein *et al.*, 2016). Studies have shown that exposure to impulsive pile driving noise induces TTS in a relatively narrow frequency band in harbour porpoise and harbour seals (reviewed in Finneran, 2015), with statistically significant TTS occurring at 4 and 8kHz (Kastelein *et al.*, 2016) and centred at 4kHz (Kastelein *et al.*, 2012a; Kastelein *et al.*, 2012b; Kastelein *et al.*, 2013b; Kastelein *et al.*, 2017). Therefore, during the expert elicitation, the experts agreed that any threshold shifts as a result of pile driving would manifest themselves in the 2 – 10kHz range (Kastelein *et al.*, 2017) and that a PTS 'notch' of 6 – 18dB in a narrow frequency band in the 2 - 10kHz region is unlikely to significantly affect the fitness of individuals (ability to survive and reproduce). The expert elicitation concluded that:

"… the effects of a 6dB PTS in the 2-10kHz band was unlikely to have a large effect on survival or fertility of the species of interest.

… for all species experts indicated that the most likely predicted effect on survival or fertility as a result of 6dB PTS was likely to be very small (i.e. <5% reduction in survival or fertility).

… the defined PTS was likely to have a slightly larger effect on calves/pups and juveniles than on mature females survival or fertility."

[24] Workshop experts included representatives from Woods Hole Oceanographic Institute, Aarhus University, National Marine Mammal Foundation, SEAMRCO, JASCO Applied Sciences, SMRU and University of Aberdeen.

11.7.81 For harbour porpoise, the predicted decline in vital rates from the impact of a 6dB PTS in the 2-10kHz band for different percentiles of the elicited probability distribution are provided in Table 11.22. The data provided in Table 11.22 should be interpreted as:

- Experts estimated that the median decline in an individual mature female harbour porpoise's survival was 0.01% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.8).
- Experts estimated that the median decline in an individual mature female harbour porpoise's fertility was 0.09% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.9).
- Experts estimated that the median decline in an individual harbour porpoise juvenile or dependent calf survival was 0.18% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.10: Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent calf harbour porpoise as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).).

Table 11.22: Predicted decline in harbour porpoise vital rates for different percentiles of the elicited probability distribution.

	Percentiles of the elicited probability distribution								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Adult survival	0	0	0	0.01	0.01	0.03	0.05	0.1	0.23
Fertility	0	0	0.02	0.05	0.09	0.16	0.3	0.7	1.35
Calf/Juvenile survival	0	0	0.02	0.09	0.18	0.31	0.49	0.8	1.46

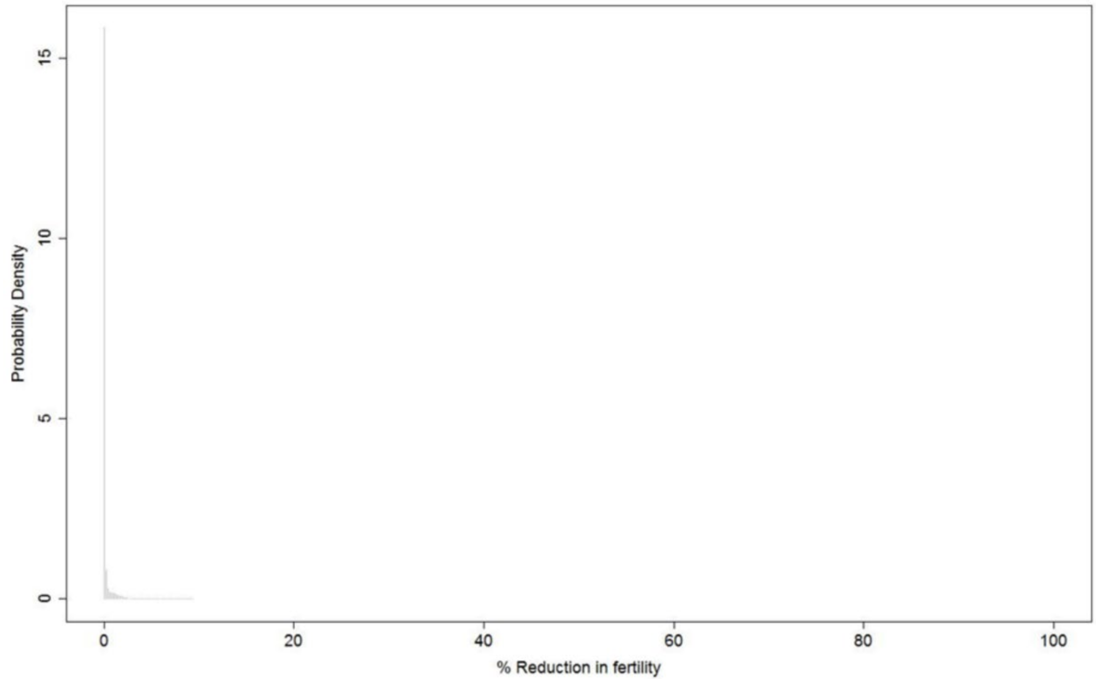


Figure 11.8: Probability distribution showing the consensus distribution for the effects on fertility of a mature female harbour porpoise as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

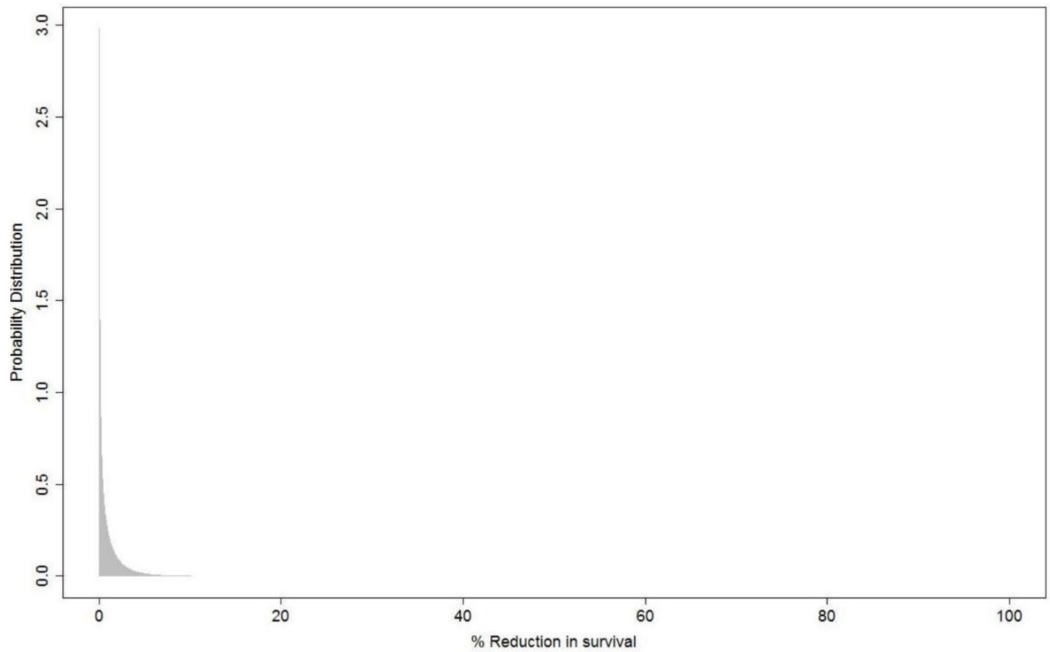


Figure 11.9: Probability distribution showing the consensus distribution for the effects on survival of a mature female harbour porpoise as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

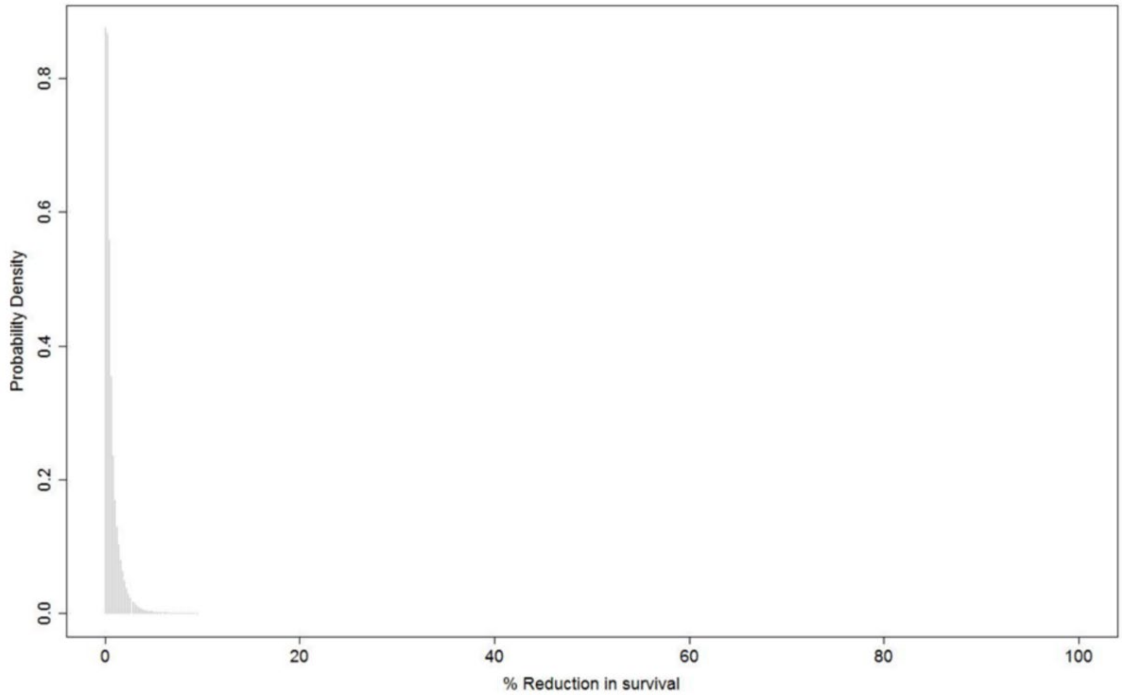


Figure 11.10: Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent calf harbour porpoise as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

11.7.82 Furthermore, 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. 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.*, 2019; Benhemma-Le Gall *et al.*, 2021). Therefore, the presence of construction related vessels 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.

11.7.83 Whilst PTS is a permanent effect which cannot be recovered from, the evidence does not suggest that PTS from piling will cause a significant impact on either survival or reproductive rates; therefore, harbour porpoise have been assessed as having a Low sensitivity to PTS.

Magnitude

11.7.84 Table 11.21 presents the PTS-onset impact area, impact range and number of harbour porpoise within the PTS-onset impact area using the maximum hammer energy. The maximum instantaneous PTS-onset impact range is predicted to occur at the NE monopile location with an impact range of 0.59km, impacting 3 harbour porpoise and equating to <0.01% of the MU.

11.7.85 For the onset of cumulative PTS, the maximum predicted impact is for a single piling event is at the NE monopile location, with a predicted impact range of 3.4km, impacting 64 harbour porpoise which equates to 0.02% of the MU (Table 11.21). Cumulative PTS was also calculated for concurrent piling at the NE and SW locations with a maximum impact area of 310km^2. It is predicted that 736 harbour porpoise could potentially experience PTS, equating to 0.21% of the MU (Table 11.21).

11.7.86 It should be noted that the predictions for PTS-onset assume that all animals within the PTS-onset range are impacted, which will overestimate the true number of impacted animals as only 18-19% of the animals are predicted to actually experience PTS at the PTS-onset threshold level. In addition, the sound is modelled as being fully impulsive irrespective of the distance to the pile which is highly precautionary and results in predictions that are unlikely to be realised (e.g., it is unlikely that the sound will be fully impulsive at 3.4km from the pile). Therefore, given this and the low number and percentage of harbour porpoise predicted to be impacted, PTS-onset is considered to be of Negligible (adverse) magnitude.

11.7.87 Although the numbers and percentage of harbour porpoise predicted to be at risk from PTS onset are low (maximum of 736 harbour porpoise and 0.21% of the MU), harbour porpoise are EPS and under EPS legislation it is an offence to injure a single individual (this includes PTS auditory injury). Therefore, a piling MMMP will be required to reduce the effect significance of PTS to negligible levels (see Table 11.8). 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. Therefore, the impact of PTS-onset from piling for harbour porpoise continues to be assessed as having a Negligible (adverse) magnitude given embedded mitigation planned during the construction of the Project.

Significance

11.7.88 The sensitivity of harbour porpoise to PTS-onset from piling has been assessed as Low.

11.7.89 The magnitude of PTS-onset to harbour porpoise from piling has been assessed as Negligible (adverse).

11.7.90 Therefore, the effect significance of PTS-onset to harbour porpoise from piling is **Negligible (not significant)** in EIA terms.

Bottlenose dolphin

Sensitivity

11.7.91 As for harbour porpoise, the ecological consequences of PTS for bottlenose dolphins are uncertain. At the same expert elicitation workshop detailed above in the porpoise section, experts in marine mammal hearing discussed the nature, extent and potential consequence of PTS to bottlenose dolphins arising from exposure to repeated low-frequency impulsive noise such as pile driving (Booth and Heinis, 2018; Fernandez-Betelu *et al.*, 2022). The predicted decline in bottlenose dolphin vital rates from the impact of a 6dB PTS in the 2-10kHz band for different percentiles of the elicited probability distribution are provided in Table 11.23. The data provided in should be interpreted as:

- Experts estimated that the median decline in an individual mature female bottlenose dolphin's fertility was 0.43% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.11).
- Experts estimated that the median decline in an individual mature female bottlenose dolphin's survival was 1.6% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.12).
- Experts estimated that the median decline in an individual bottlenose dolphin juvenile survival was 1.32% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.13).
- Experts estimated that the median decline in an individual bottlenose dolphin dependent calf survival was 2.96% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz).

11.7.92 Whilst PTS is a permanent effect which cannot be recovered from, the evidence does not suggest that PTS from piling will cause a significant impact on either survival or reproductive rates, bottlenose dolphin have been assessed as having a Low sensitivity to PTS.

Table 11.23: Predicted decline in bottlenose dolphin vital rates for different percentiles of the elicited probability distribution.

	Percentiles of the elicited probability distribution								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Adult survival	0	0.18	0.57	1.04	1.60	2.34	3.39	5.18	10.99
Fertility	0	0.04	0.13	0.26	0.43	0.85	1.66	3.49	6.22
Juvenile survival	0.01	0.11	0.35	0.75	1.32	2.14	3.30	5.19	11.24
Calf survival	0	0.29	0.93	1.77	2.96	4.96	7.81	10.69	14.79

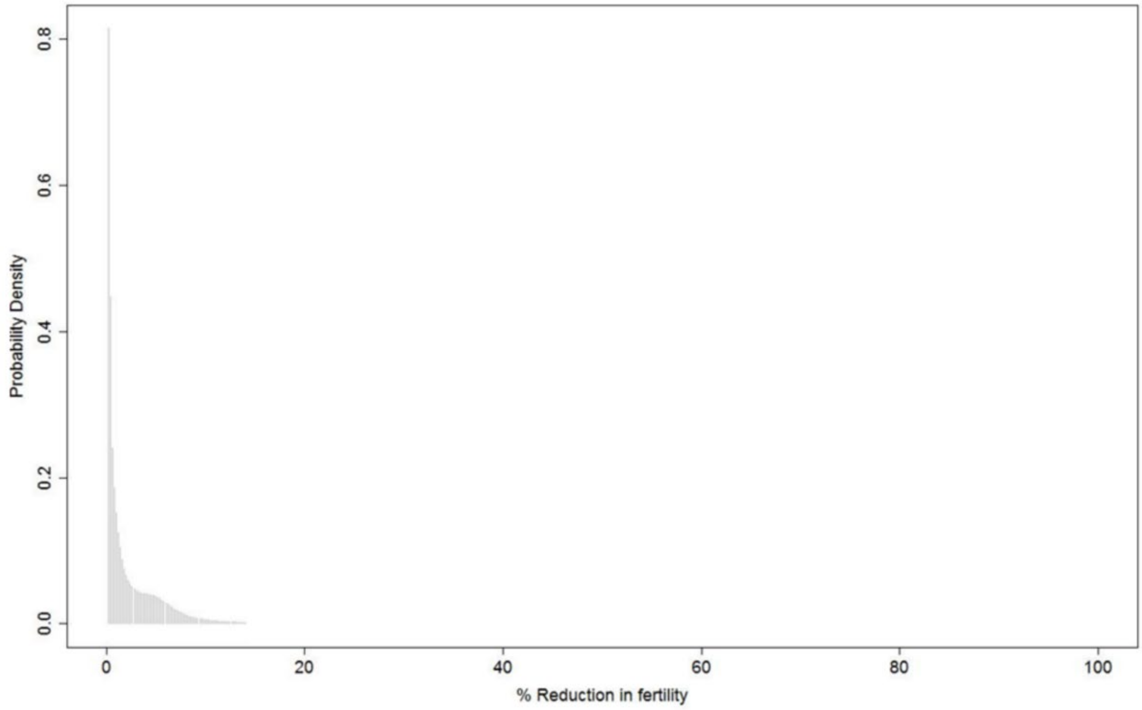


Figure 11.11: Probability distribution showing the consensus distribution for the effects on fertility of mature female bottlenose dolphin as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

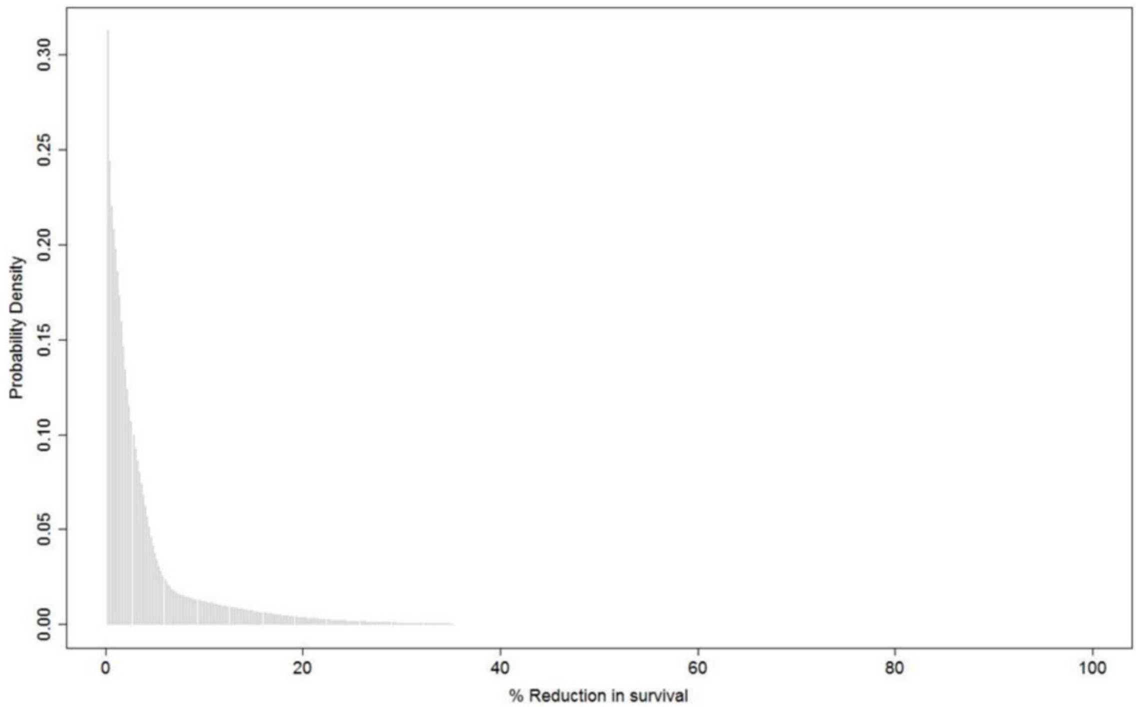


Figure 11.12: Probability distribution showing the consensus distribution for the effects on survival of mature female bottlenose dolphin as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

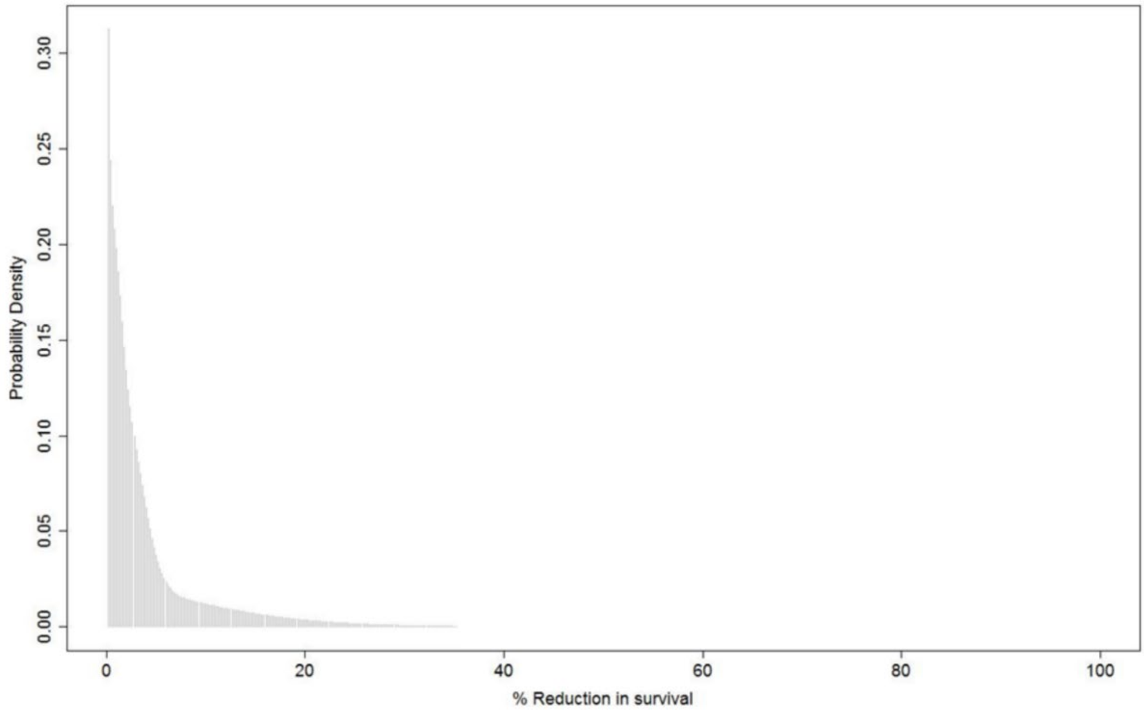


Figure 11.13: Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent calf bottlenose dolphin as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

Magnitude

11.7.93 Table 11.21 presents the PTS-onset impact area, impact range and number of bottlenose dolphin within the PTS-onset impact area using the maximum hammer energy. The maximum instantaneous PTS-onset impact range is predicted to be <0.05km at all modelled monopile and pin pile locations which results in no impact to bottlenose dolphins.

11.7.94 Table 11.21 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.10km at all modelled monopile and pin pile locations which also results in no impact to bottlenose dolphins.

11.7.95 Due to the lack of predicted impact, the magnitude of PTS onset to bottlenose dolphin from piling has been assessed as Negligible. The addition of embedded mitigation will ensure the magnitude continues to be assessed as Negligible (adverse).

Significance

11.7.96 The sensitivity of bottlenose dolphin to PTS-onset from piling has been assessed as Low.

11.7.97 The magnitude of PTS-onset to bottlenose dolphin from piling has been assessed as Negligible (adverse).

11.7.98 Therefore, the effect significance of PTS-onset to bottlenose dolphin from piling is **Negligible (not significant)** in EIA terms.

White-beaked dolphin

Sensitivity

11.7.99 As it is also a high frequency cetacean, it is anticipated that the sensitivity of white-beaked dolphin to PTS-onset from piling will be the same as that of bottlenose dolphins. Therefore, white-beaked dolphins have been assessed as having a Low sensitivity to PTS.

Magnitude

11.7.100 Table 11.21 presents the PTS-onset impact area, impact range and number of white-beaked dolphins within the PTS-onset impact area using the maximum hammer energy. The maximum instantaneous PTS-onset impact range is predicted to be <0.05km at all modelled monopile and pin pile locations which results in no impact to white-beaked dolphins.

11.7.101 Table 11.21 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.10km at all modelled monopile and pin pile locations which also results in no impact to white-beaked dolphins.

11.7.102 Due to the lack of predicted impact, the magnitude of PTS onset to white-beaked dolphins from piling has been assessed as Negligible. The addition of embedded mitigation will ensure the magnitude continues to be assessed as Negligible (adverse).

Significance

11.7.103 The sensitivity of white-beaked dolphins to PTS-onset from piling has been assessed as Low.

11.7.104 The magnitude of PTS-onset to white-beaked dolphins from piling has been assessed as Negligible (adverse).

11.7.105 Therefore, the effect significance of PTS-onset to white-beaked dolphins from piling is **Negligible (not significant)** in EIA terms.

Minke whale

Sensitivity

11.7.106 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. Minke whale communication signals have been demonstrated to be below 2kHz (Edds-Walton, 2000; Mellinger *et al.*, 2000; Gedamke *et al.*, 2001; Risch *et al.*, 2013; Risch *et al.*, 2014). Tubelli (2012) estimated the most sensitive hearing range (the region with thresholds within 40dB of best sensitivity) to extend from 30 to 100Hz up to 7.5 to 25kHz, depending on the specific model used. A 2-10kHz notch of 6dB is likely to affect a small region of minke whale hearing, therefore they have been assumed to have Low sensitivity to PTS-onset from pile driving.

Magnitude

11.7.107 Table 11.21 presents the PTS-onset impact area, impact range and number of minke whale within the PTS-onset impact area using the maximum hammer energy. The maximum instantaneous PTS-onset impact range is predicted to be <0.05km at all modelled monopile and pin pile locations which results in no impact to minke whale.

11.7.108 Table 11.21 also presents the cumulative PTS-onset results. The maximum predicted impact is for a single piling event is at the NE monopile location, with a predicted impact range of 5.5km, impacting 1 minke whale, which equates to <0.01% of the MU (Table 11.21). No impact to minke whales is predicted at any of the other modelling locations. Cumulative PTS was also calculated for concurrent piling at the NE and SW locations with a maximum impact area of 480km^2, within which it is predicted that 5 minke whale could potentially experience PTS, equating to 0.02% of the MU (Table 11.21).

11.7.109 As previously mentioned (paragraph 11.7.86), the modelled results for PTS-onset are highly precautionary and likely an overestimate. Therefore, given this precaution combined with the low number of minke whale and corresponding low proportion of the MU predicted to be impacted, PTS-onset is considered to be of Negligible (adverse) magnitude.

11.7.110 Although the numbers and percentage of minke whale predicted to be at risk from PTS onset are low (maximum of 5 minke whale and 0.02% of the MU), minke whale are EPS and under EPS legislation it is an offence to injure a single individual (this includes PTS auditory injury). Therefore, a piling MMMP will be required to reduce the effect significance of PTS to negligible levels (see Table 11.8). Therefore, the impact of PTS-onset from piling for minke whale continues to be assessed as having a Negligible (adverse) magnitude given pilling MMMP.

Significance

11.7.111 The sensitivity of minke whale to PTS-onset from piling has been assessed as Low.

11.7.112 The magnitude of PTS-onset to minke whale from piling has been assessed as Negligible (adverse).

11.7.113 Therefore, the effect significance of PTS-onset to minke whale from piling is **Negligible (not significant)** in EIA terms.

Seal sensitivity to PTS

11.7.114 The predicted decline in harbour and grey seals vital rates from the impact of a 6dB PTS in the 2-10kHz band for different percentiles of the elicited probability distribution are provided in Table 11.24:. The data provided in Table 11.24: should be interpreted as:

- Experts estimated that the median decline in an individual mature female seal's survival was 0.39% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.14).
- Experts estimated that the median decline in an individual mature female seal's fertility was 0.27% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.15).
- Experts estimated that the median decline in an individual seal pup/juvenile survival was 0.52% (due to a 6dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10kHz) (Figure 11.16).

11.7.115 Whilst PTS is a permanent effect which cannot be recovered from, the evidence does not suggest that PTS from piling will cause a significant impact on either survival or reproductive rates; therefore, both seal species have been assessed as having a Low sensitivity to PTS.

Table 11.24: Predicted decline in harbour and grey seal vital rates for different percentiles of the elicited probability distribution.

	Percentiles of the elicited probability distribution								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Adult survival	0.02	0.1	0.18	0.27	0.39	0.55	0.78	1.14	1.89
Fertility	0.01	0.02	0.05	0.14	0.27	0.48	0.88	1.48	4.34
Calf survival	0	0.04	0.15	0.32	0.52	0.8	1.21	1.88	3

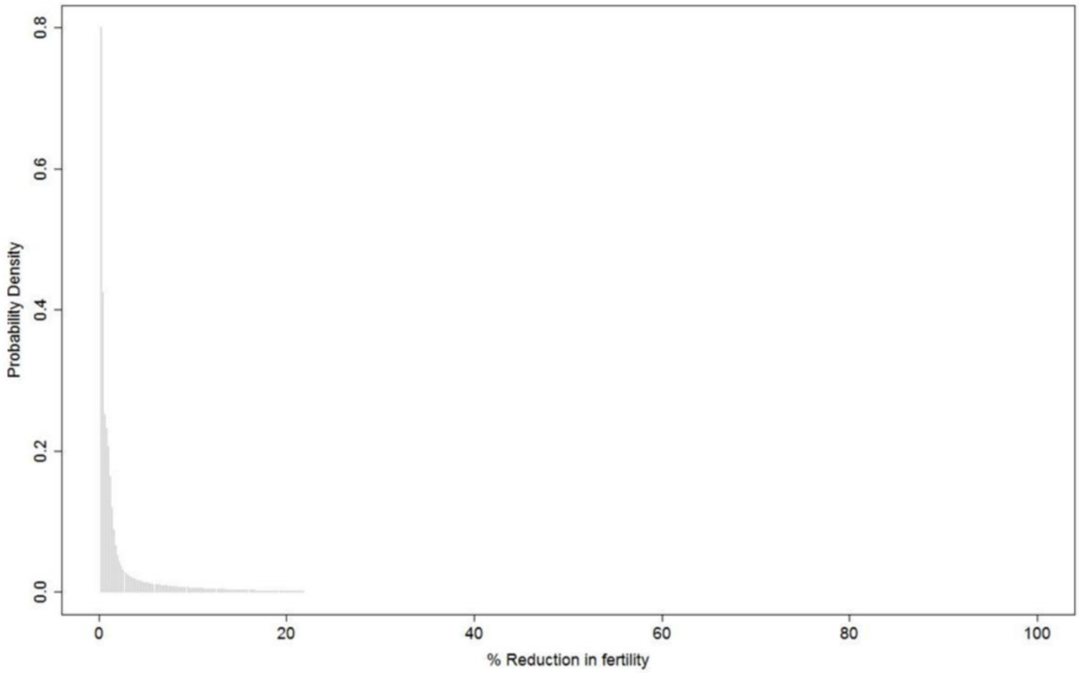


Figure 11.14: Probability distribution showing the consensus distribution for the effects on fertility of a mature female (harbour or grey) seal as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

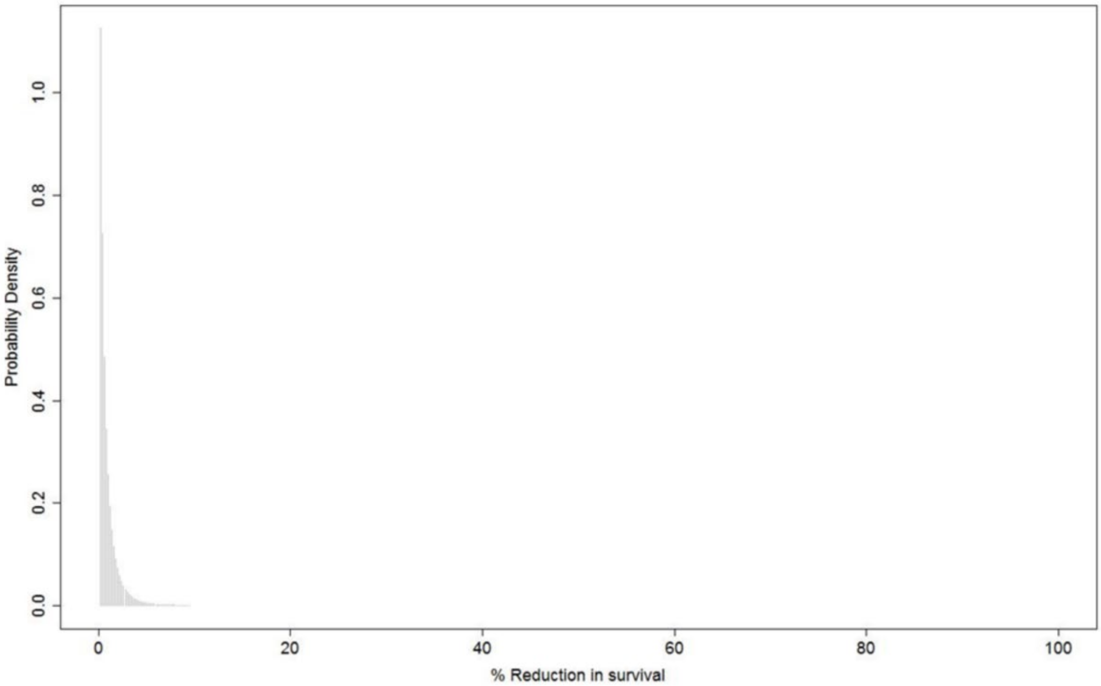


Figure 11.15: Probability distribution showing the consensus distribution for the effects on survival of a mature female (harbour or grey) seal as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

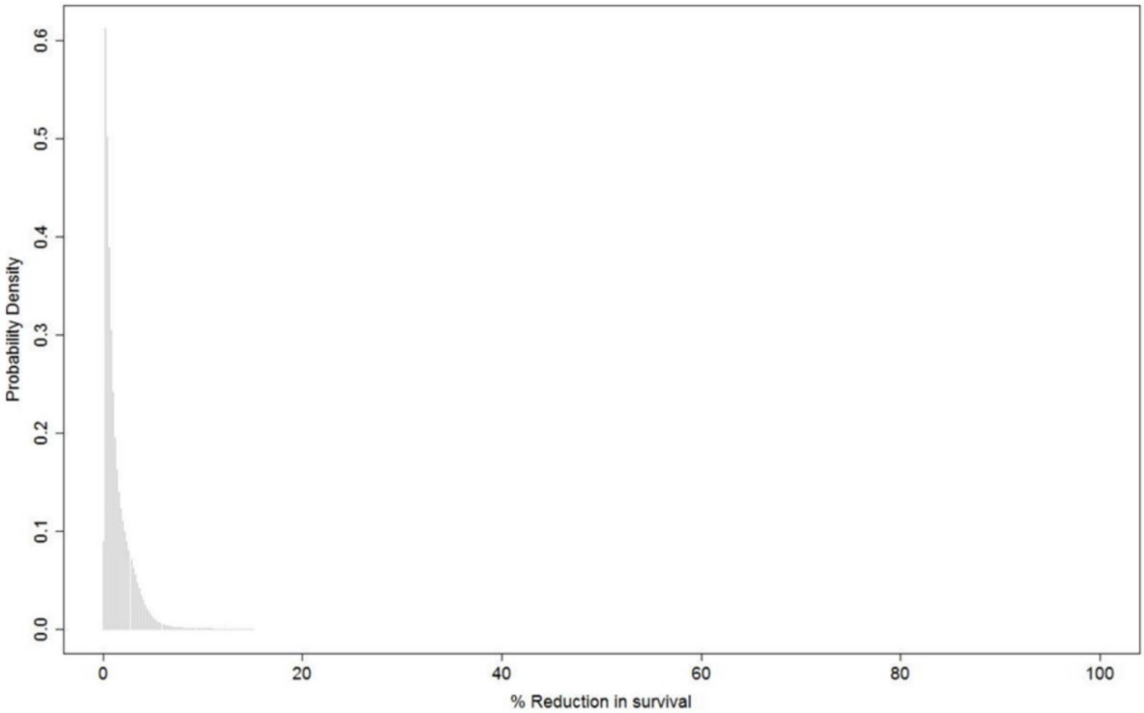


Figure 11.16 Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent pup (harbour or grey) seal as a consequence of a maximum 6dB of PTS within a 2-10kHz band (Booth and Heinis, 2018).

Harbour seal

Magnitude

11.7.116 Table 11.21 presents the PTS-onset impact area, impact range and number of harbour seals within the PTS-onset impact area using the maximum hammer energy. The maximum instantaneous PTS-onset impact range is predicted to be <0.05km at all modelled monopile and pin pile locations which results in no impact to harbour seals.

11.7.117 Table 11.21 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.10km at all modelled monopile and pin pile locations which also results in no impact to harbour seals.

11.7.118 Due to the lack of predicted impact, the magnitude of PTS onset to harbour seals from piling has been assessed as Negligible (adverse).

Significance

11.7.119 The sensitivity of harbour seal to PTS-onset from piling has been assessed as Low.

11.7.120 The magnitude of PTS-onset to harbour seal from piling has been assessed as Negligible (adverse).

11.7.121 Therefore, the effect significance of PTS-onset to harbour seal from piling is **Negligible**, **not significant** in EIA terms.

Grey seal

Magnitude

11.7.122 Table 11.21 presents the PTS-onset impact area, impact range and number of grey seals within the PTS-onset impact area using the maximum hammer energy. The maximum instantaneous PTS-onset impact range is predicted to be <0.05km at all modelled monopile and pin pile locations which results in no impact to grey seals.

11.7.123 Table 11.21 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.10km at all modelled monopile and pin pile locations which also results in no impact to grey seals.

11.7.124 Due to the lack of predicted impact, the magnitude of PTS onset to grey seals from piling has been assessed as Negligible (adverse).

Significance

11.7.125 The sensitivity of grey seals to PTS-onset from piling has been assessed as Low.

11.7.126 The magnitude of PTS-onset to grey seals from piling has been assessed as Negligible (adverse).

11.7.127 Therefore, the effect significance of PTS-onset to grey seals from piling is **Negligible (not significant)** in EIA terms.

Pile driving – PTS summary

11.7.128 Table 11.25 presents a summary of the sensitivity, magnitude and significance of PTS from pile driving for marine mammals. The significance has been assessed as Negligible for all marine mammal species, which is **not significant** in EIA terms.

Table 11.25: Summary of marine mammal sensitivity, magnitude and significance of PTS from pile driving.

Species	Sensitivity	Magnitude	Significance
Harbour porpoise	Low	Negligible	Negligible (**Not significant**)
Bottlenose dolphin	Low	Negligible	Negligible (**Not significant**)
White-beaked dolphin	Low	Negligible	Negligible (**Not significant**)
Minke whale	Low	Negligible	Negligible (**Not significant**)
Harbour seal	Low	Negligible	Negligible (**Not significant**)
Grey seal	Low	Negligible	Negligible (**Not significant**)

ORCP

11.7.1 The following section provides the quantitative assessment of the impact of injury (PTS) from pile driving locations within the ORCP search area on marine mammal species. Results are presented in Table 11.26 at the maximum hammer energy for both monopiles (6,600 kJ) and pin piles (3,500 kJ). For monopiles, modelling assumed only 1 monopile per day was installed at each location and for pin piles scenarios were modelled for the installation of 1 or 4 pin piles per day.

Table 11.26 Impact area, maximum range, number of animal predicted to experience PTS-onset from piling at the ORCP locations.

Species	Location	Monopile		Pin pile			
		CC-NE x1	CC-SW x1	CC-NE x1	CC-NE x4	CC-SW x1	CC-SW x4
Instantaneous PTS (SPL_{peak})							
Harbour porpoise	Area (km^2)	0.46	0.29	0.34	-	0.21	-
	Max range (km)	0.39	0.31	0.34	-	0.26	-
	# animals	1	1	1	-	0	-
	% MU	<0.01%	<0.01%	<0.01%	-	0%	-
Bottlenose dolphin	Area (km^2)	<0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
White-beaked dolphin	Area (km^2)	<0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-
	# animals	0	0	0	-	0	-
	% MU	0.0%	0.0%	0.0%	-	0.0%	-
Minke whale	Area (km^2)	<0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-

Species	Location	Monopile		Pin pile			
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Harbour seal	Area (km^2)	0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Grey seal	Area (km^2)	0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Cumulative PTS (SEL_{cum})							
Harbour porpoise	Area (km^2)	3.4	0.6	0.9	0.9	<0.1	<0.1
	Max range (km)	1.4	0.55	0.75	0.75	0.2	0.2
	# animals	8	1	2	2	0	0
	% MU	<0.01%	<0.01%	<0.01%	<0.01%	0%	0%
Bottlenose dolphin	Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%
White-beaked dolphin	Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%
Minke whale	Area (km^2)	2.2	<0.1	0.2	0.2	<0.1	<0.1
	Max range (km)	1.5	0.2	0.45	0.45	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%
Harbour seal	Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%
Grey seal	Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%

11.7.2 Harbour porpoise: The maximum instantaneous PTS-onset impact range is predicted to occur at the CC-NE monopile location with an impact range of 0.39 km, impacting 1 harbour porpoise and equating to <0.01% of the MU. For the onset of cumulative PTS, the maximum predicted impact is for a single piling event is at the CC-NE monopile location, with a predicted impact range of 1.4 km, impacting 8 harbour porpoise which equates to <0.01% of the MU (Table 11.26). Therefore, given this and the low number and percentage of harbour porpoise predicted to be impacted from piling in the ORCP search area, PTS-onset is considered to be of Negligible (adverse) magnitude. The sensitivity of harbour porpoise to PTS-onset from piling has been assessed as Low. Therefore, the effect significance of PTS-onset to harbour porpoise from piling in the ORCP search area is Negligible (Not significant) which is not significant in EIA terms.

11.7.3 Bottlenose dolphin: The maximum instantaneous PTS-onset impact range is predicted to be <0.05 km at all modelled ORCP search area monopile and pin pile locations which results in no impact to bottlenose dolphins. Table 11.26 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.1 km at all modelled ORCP search area monopile and pin pile locations which also results in no impact to bottlenose dolphins. Due to the lack of predicted impact, the magnitude of PTS onset to bottlenose dolphin from piling in the ORCP search area has been assessed as Negligible (adverse). The sensitivity of bottlenose dolphin to PTS-onset from piling has been assessed as Low. Therefore, the effect significance of PTS-onset to bottlenose dolphin from piling in the ORCP search area is Negligible (Not significant), which is not significant in EIA terms.

11.7.4 White-beaked dolphin: The maximum instantaneous PTS-onset impact range is predicted to be <0.05 km at all modelled ORCP search area monopile and pin pile locations which results in no impact to white-beaked dolphins Table 11.26 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.1 km at all modelled ORCP search area monopile and pin pile locations which also results in no impact to white-beaked dolphins. Due to the lack of predicted impact, the magnitude of PTS onset to white-beaked dolphins from piling has been assessed as Negligible (adverse). The sensitivity of white-beaked dolphins to PTS-onset from piling has been assessed as Low. Therefore, the effect significance of PTS-onset to white-beaked dolphins from piling in the ORCP search area is Negligible (Not significant), which is not significant in EIA terms.

11.7.5 Minke whale: The maximum instantaneous PTS-onset impact range is predicted to be <0.05 km at all modelled ORCP search area monopile and pin pile locations which results in no impact to minke whale. Table 11.26 also presents the cumulative PTS-onset results. The maximum predicted impact is for a single piling event is at the CC-NE monopile location, with a predicted impact range of 2.2 km, but there was no predicted impact to minke whales. Due to the lack of predicted impact, the magnitude of PTS onset to minke whales from piling in the ORCP search area has been assessed as Negligible (adverse). The sensitivity of minke whale to PTS-onset from piling has been assessed as Low. Therefore, the effect significance of PTS-onset to minke whale from piling in the ORCP search area is Negligible (Not significant), which is not significant in EIA terms.

11.7.6 Harbour seal: The maximum instantaneous PTS-onset impact range is predicted to be <0.05 km at all modelled ORCP search area monopile and pin pile locations which results in no impact to harbour seals. Table 11.26 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.1 km at all modelled monopile and pin pile locations which also results in no impact to harbour seals. Due to the lack of predicted impact, the magnitude of PTS onset to harbour seals from piling in the ORCP search area has been assessed as Negligible (adverse). The sensitivity of harbour seal to PTS-onset from piling has been assessed as Low. Therefore, the effect significance of PTS-onset to harbour seal from piling in the ORCP search area is Negligible (Not significant), which is not significant in EIA terms.

11.7.7 Grey seal: The maximum instantaneous PTS-onset impact range is predicted to be <0.05 km at all modelled ORCP search area monopile and pin pile locations which results in no impact to grey seals. Table 11.26 also presents the cumulative PTS-onset results. The maximum range of the impact was <0.1 km at all modelled ORCP search area monopile and pin pile locations which also results in no impact to grey seals. Due to the lack of predicted impact, the magnitude of PTS onset to grey seals from piling in the ORCP search area has been assessed as Negligible (adverse). The sensitivity of grey seals to PTS-onset from piling has been assessed as Low. Therefore, the effect significance of PTS-onset to grey seals from piling in the ORCP search area is Negligible (Not significant), which is not significant in EIA terms.

Impact 4: Pile Driving – TTS

WTGs

11.7.8 Full details of the underwater noise modelling and the resulting TTS-onset impact areas and ranges are detailed in Volume 2, Appendix 3.2: Underwater Noise Assessment. As previously outlined (see Assessment Methodology), there are no thresholds to determine a biologically significant effect from TTS-onset. Therefore, the predicted ranges for the onset of TTS from piling are presented, but no assessment of magnitude, sensitivity or significance of effect is given. This approach was agreed with members of Marine Mammals & Marine Ecology Expert Topic Group (19th January 2022) and aligns with the advice provided in (Natural England, 2022).

11.7.9 The following section provides the quantitative assessment of the impact of TTS from pile driving on marine mammal species (Table 11.27).

Table 11.27 :Impact area, maximum range, number of harbour porpoise, harbour seal and grey seal and percentage of MU predicted to experience TTS-onset from piling.

Species	Location	Monopile				Pin pile			
		SW	NW	NE	NE&SW	SW	NW	NE	NE&SW
Instantaneous TTS (SPL_{peak})									
Harbour porpoise	Area (km^2)	1.8	3.9	5.8	-	1.3	2.9	4.3	-
	Max range (km)	0.81	1.2	1.4		0.69	1	1.2	

Species	Location	Monopile				Pin pile			
	# animals	4	9	14		3	7	10	
	% MU	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	
Bottlenose dolphin	Area (km²)	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
White-beaked dolphin	Area (km²)	<0.01	<0.01	<0.01	-	<0.01	<0.01	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Minke whale	Area (km²)	0.02	0.03	0.04	-	0.01	0.02	0.03	-
	Max range (km)	0.08	0.01	0.11		0.07	0.09	0.1	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Harbour seal	Area (km²)	0.03	0.04	0.05	-	0.02	0.03	0.04	-
	Max range (km)	0.09	0.12	0.13		0.08	0.1	0.11	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Grey seal	Area (km²)	0.03	0.04	0.05	-	0.02	0.03	0.04	-
	Max range (km)	0.09	0.12	0.13		0.08	0.1	0.11	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Cumulative TTS (SEL_{cum})									
Harbour porpoise	Area (km²)	170	360	590	1400	130	280	480	1300
	Max range (km)	9.9	13	16	-	8.7	11	14	-
	# animals	404	855	1401	3325	309	665	1140	3088
	% MU	0.12	0.25	0.40	0.96	0.09	0.19	0.33	0.89

Species	Location	Monopile				Pin pile			
Bottlenose dolphin	Area (km^2)	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	-
	Max range (km)	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
White-beaked dolphin	Area (km^2)	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	-
	Max range (km)	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	
	# animals	0	0	0		0	0	0	
	% MU	0.00	0.00	0.00		0.00	0.00	0.00	
Minke whale	Area (km^2)	160	450	830	1800	100	340	650	1500
	Max range (km)	10	15	20	-	8.5	13	18	-
	# animals	2	5	8	18	1	3	7	15
	% MU	0.01	0.02	0.04	0.09	<0.01	0.02	0.03	0.07
Harbour seal	Area (km^2)	11	43	100	520	6.2	31	79	480
	Max range (km)	2.7	4.3	6.7	-	2.1	3.7	5.9	-
	# animals	2	1	3	6	1	1	3	4
	% MU	0.04	0.02	0.07	0.12	0.03	0.02	0.06	0.09
Grey seal	Area (km^2)	11	43	100	520	6.2	31	79	480
	Max range (km)	2.7	4.3	6.7	-	2.1	3.7	5.9	-
	# animals	12	36	56	69	7	25	44	51
	% MU	0.02	0.07	0.11	0.13	0.01	0.05	0.08	0.10

Harbour porpoise

11.7.10 Using instantaneous TTS-onset thresholds (SPL_{peak}), the maximum impact range for harbour porpoise was calculated at 5.8km at the NE monopile location. This resulted in an impact to 14 harbour porpoise and <0.01% of the MU (Table 11.27).

11.7.11 Using the cumulative TTS-onset thresholds (SEL_{cum}) the maximum impact range for harbour porpoise during a single piling event was calculated at 16km for the NE monopile location. This equated to a maximum of 1,401 harbour porpoise and 0.40% of the MU (Table 11.27). During concurrent piling at the NE and SW locations, the maximum impact area was calculated at 1,400km^2 for monopiles, resulting in impact to 3,325 harbour porpoise and 0.96% of the MU (Table 11.27).

Bottlenose dolphin

11.7.12 Using instantaneous TTS-onset thresholds (SPL_{peak}), the maximum impact range for bottlenose dolphin was calculated at <0.01km at all monopile and pin pile locations. This resulted in no impact from instantaneous TTS from pile driving being predicted for bottlenose dolphin (Table 11.27).

11.7.13 Using the cumulative TTS-onset thresholds (SEL_{cum}) the maximum impact range for bottlenose dolphin during a single piling event was calculated at <0.1km at all monopile and pin pile locations. This resulted in no impact from cumulative TTS from pile driving being predicted for bottlenose dolphin (Table 11.27).

White-beaked dolphin

11.7.14 Using instantaneous TTS-onset thresholds (SPL_{peak}), the maximum impact range for white-beaked dolphin was calculated at <0.01km at all monopile and pin pile locations. This resulted in no impact from instantaneous TTS from pile driving being predicted for white-beaked dolphin (Table 11.27).

11.7.15 Using the cumulative TTS-onset thresholds (SEL_{cum}) the maximum impact range for white-beaked dolphin during a single piling event was calculated at <0.1km at all monopile and pin pile locations. This resulted in no impact from cumulative TTS from pile driving being predicted for white-beaked dolphin (Table 11.27).

Minke whale

11.7.16 Using instantaneous TTS-onset thresholds (SPL_{peak}), the maximum impact range for minke whale was calculated at 0.11km at the NE monopile location. This resulted in no impact from instantaneous TTS from pile driving being predicted for minke whale (Table 11.27).

11.7.17 Using the cumulative TTS-onset thresholds (SEL_{cum}) the maximum impact range for minke whale during a single piling event was calculated at 20km for the NE monopile location. This equated to a maximum of 8 minke whale and 0.04% of the MU (Table 11.27). During concurrent piling at the NE and SW locations, the maximum impact area was calculated at 1,800km^2 for monopiles, resulting in an impact to 18 minke whale and 0.09% of the MU (Table 11.27).

Harbour seal

11.7.18 Using instantaneous TTS-onset thresholds (SPL_{peak}), the maximum impact range for harbour seal was calculated at 0.13km at the NE monopile location. This resulted in no impact from instantaneous TTS from pile driving being predicted for harbour seal (Table 11.27).

11.7.19 Using the cumulative TTS-onset thresholds (SEL_{cum}) the maximum impact range for harbour seal during a single piling event was calculated at 6.7km for the NE monopile location. This equated to a maximum of 3 harbour seal and 0.07% of the MU. The same number of harbour seal was also predicted to be impacted at the NE pin pile location, but the impact area was smaller at 5.9km (Table 11.27). During concurrent piling at the NE and SW locations, the maximum impact area was calculated at 520km^2 for monopiles, resulting in impact to 6 harbour seal and 0.12% of the MU (Table 11.27).

Grey seal

11.7.20 Using instantaneous TTS-onset thresholds (SPL_{peak}), the maximum impact range for grey seal was calculated at 0.13km at the NE monopile location. This resulted in no impact from instantaneous TTS from pile driving being predicted for grey seal (Table 11.27).

11.7.21 Using the cumulative TTS-onset thresholds (SEL_{cum}) the maximum impact range for grey seal during a single piling event was calculated at 6.7km for the NE monopile location. This equated to a maximum of 56 grey seal and 0.11% of the MU (Table 11.27). During concurrent piling at the NE and SW locations, the maximum impact area was calculated at 520km^2 for monopiles, resulting in impact to 69 grey seal and 0.13% of the MU (Table 11.27).

ORCP

11.7.22 Table 11.27 provides the quantitative assessment of the impact of TTS from pile driving within the ORCP search area (Table 11.27). For monopiles, modelling assumed only 1 monopile per day was installed at each location and for pin piles scenarios were modelled for the installation of 1 or 4 pin piles per day. As previously outlined (see Assessment Methodology), there are no thresholds to determine a biologically significant effect from TTS-onset. Therefore, the predicted ranges for the onset of TTS from piling are presented, but no assessment of magnitude, sensitivity or significance of effect is given. This approach was agreed with members of Marine Mammals & Marine Ecology Expert Topic Group (21st September 2020) and aligns with the advice provided in (Natural England, 2022).

Table 11.28 Impact area, maximum range, number of marine mammals and percentage of MU predicted to experience TTS-onset from piling within the ORCP search area.

Species	Location	Monopile		Pin pile			
		CC-NE x1	CC-SW x1	CC-NE x1	CC-NE x4	CC-SW x1	CC-SW x4
Instantaneous PTS (SPL_{peak})							
Harbour porpoise	Area (km^2)	2.1	1.3	1.6	-	0.95	-
	Max range (km)	0.87	0.64	0.75	-	0.56	-
	# animals	5	3	4	-	2	-
	% MU	<0.01%	<0.01%	<0.01%	-	<0.01%	-
Bottlenose dolphin	Area (km^2)	<0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
White-beaked dolphin	Area (km^2)	<0.01	<0.01	<0.01	-	<0.01	-
	Max range (km)	<0.05	<0.05	<0.05	-	<0.05	-

Species	Location	Monopile		Pin pile			
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Minke whale	Area (km^2)	0.02	0.02	0.02	-	0.01	-
	Max range (km)	0.08	0.7	0.7	-	0.06	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Harbour seal	Area (km^2)	0.03	0.02	0.02	-	0.01	-
	Max range (km)	0.1	0.08	0.08	-	0.07	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Grey seal	Area (km^2)	0.03	0.02	0.02	-	0.01	-
	Max range (km)	0.1	0.08	0.08	-	0.07	-
	# animals	0	0	0	-	0	-
	% MU	0%	0%	0%	-	0%	-
Cumulative PTS (SEL_{cum})							
Harbour porpoise	Area (km^2)	180	59	130	130	42	42
	Max range (km)	13	5.6	12	12	4.8	4.8
	# animals	428	140	309	309	100	100
	% MU	0.12%	0.04%	0.09%	0.09%	0.03%	0.03%
Bottlenose dolphin	Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%
White-beaked dolphin	Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Max range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	# animals	0	0	0	0	0	0
	% MU	0%	0%	0%	0%	0%	0%
Minke whale	Area (km^2)	170	38	120	120	22	22
	Max range (km)	15	4.8	12	12	3.7	3.7
	# animals	2	0	1	1	0	0
	% MU	0.01%	0%	0.01%	<0.01%	0%	0%
Harbour seal	Area (km^2)	13	2.2	7.7	7.7	0.9	0.9
	Max range (km)	3	1.1	2.4	2.4	0.7	0.7
	# animals	6	2	4	4	1	1
	% MU	0.13%	0.03%	0.07%	0.07%	0.01%	0.01%
Grey seal	Area (km^2)	13	2.2	7.7	7.7	0.9	0.9
	Max range (km)	3	1.1	2.4	2.4	0.7	0.7
	# animals	18	2	11	11	1	1
	% MU	0.03%	<0.01%	0.02%	0.02%	<0.01%	<0.01%

Impact 5: Pile driving – Disturbance

Array Area (WTGs and OPs)

11.7.23 The following section provides the quantitative assessment of disturbance from pile driving on marine mammal species using the Graham (2017a) dose-response function for harbour porpoise, applied to all cetacean species assessed, and the dose-response function based on the data harbour seal presented in (Whyte *et al.*, 2020), applied to both seal species (Table 11.29).

Table 11.29: Number of marine mammals and percentage of the MU predicted to experience potential behavioural disturbance from piling.

Species	Location	Monopile				Pin pile			
		SW	NW	NE	NE&SW	SW	NW	NE	NE&SW
Harbour porpoise	# animals	1,409	2,720	3,981	5,229	1,226	2,405	3,563	4,629
	% MU	0.41	0.78	1.15	1.51	0.35	0.69	1.03	1.34
Bottlenose dolphin	# animals	1	2	3	4	1	2	3	4
	% MU	0.05	0.10	0.15	0.20	0.05	0.10	0.15	0.20
White-beaked dolphin	# animals	1	2	3	4	1	2	3	4
	% MU	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
Minke whale	# animals	6	11	17	22	5	10	15	19
	% MU	0.03	0.06	0.08	0.11	0.03	0.05	0.07	0.10
Harbour seal	# animals	25 (3-45)	13 (2-24)	11 (2-19)	35 (5-64)	21 (3-39)	11 (1-21)	9 (1-17)	30 (4-55)
	% MU	0.51%	0.27%	0.22%	0.72%	0.43%	0.23%	0.19%	0.62%
Grey seal	# animals	255 (30-474)	377 (44-699)	360 (45-665)	615 (75-1139)	217 (25-407)	327 (38-610)	316 (38-587)	534 (62-994)
	% MU	0.48%	0.71%	0.68%	1.16%	0.41%	0.62%	0.60%	1.01%

Harbour porpoise

Sensitivity

11.7.24 Previous studies have shown that harbour porpoises are displaced from the vicinity of piling events. For example, studies at windfarms in the German North Sea have recorded large declines in porpoise detections close to the piling location (>90% decline at noise levels above 170dB) with decreasing effect with increasing distance from the pile (25% decline at noise levels between 145 and 150dB) (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 (e.g. Rojano-Doñate *et al.*, 2018). This makes them vulnerable to starvation if they are unable to obtain sufficient levels of prey intake.

11.7.25 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.

11.7.26 The results from Wisniewska (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.

11.7.27 Monitoring of harbour porpoise activity at the Beatrice Offshore Windfarm 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 7km (Graham *et al.*, 2019). 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 1.3km. In addition, the study indicated that porpoise activity recovered between pile driving events.

11.7.28 A study of tagged harbour porpoises has shown large variability between individual responses to an airgun stimulus (van Beest *et al.*, 2018). Of the five porpoises tagged and exposed to airgun pulses at ranges of 420 – 690m (SEL 135–147dB re 1µPa^{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 individual variability in responses among harbour porpoises exposed to low frequency broadband pulsed noise (including both airguns and pile-driving).

11.7.29 At the most recent expert elicitation workshop in 2018 (Booth *et al.*, 2019), experts assessed the most likely potential consequences of a six hour period of zero energy intake, assuming that disturbance (from exposure to low frequency broadband pulsed noise, e.g., impact piling, airgun pulses) resulted in missed foraging opportunities (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. A Dynamic Energy Budget model for harbour porpoise (based on the DEB model in Hin *et al.* (2019)) was used to aid discussions regarding the potential effects of missed foraging opportunities on survival and reproduction. The model described the way in which the life history processes (growth, reproduction and survival) of a female and her calf depend on the way in which assimilated energy is allocated between different processes and was used during the elicitation to model the effects of energy intake and reserves following simulated disturbance.

11.7.30 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 porpoises 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 high levels of repeated disturbance to an individual before there was any effect on that individual's fertility (Figure 11.17, left), 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 (Figure 11.17 right); 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.

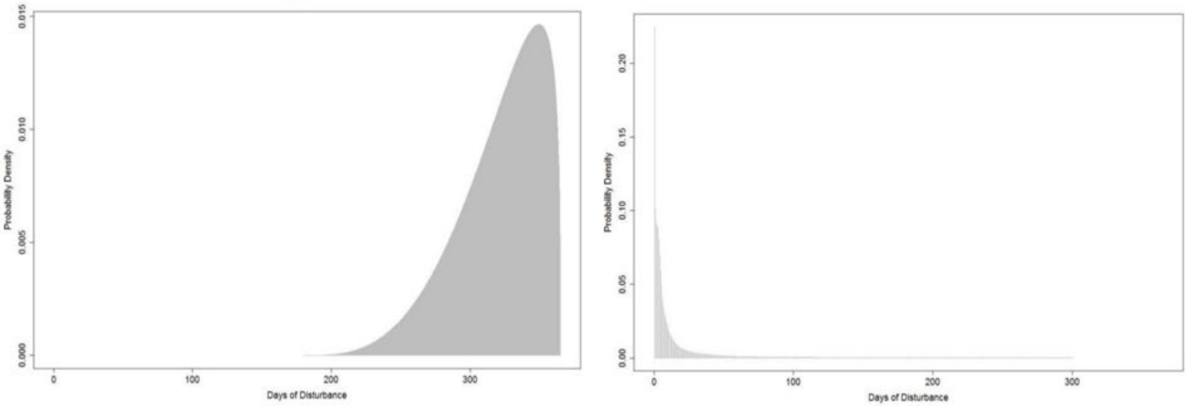


Figure 11.17: Probability distributions showing the consensus of the expert elicitation for harbour porpoise disturbance from piling (Booth *et al.*, 2019). Left: the number of days of disturbance (i.e. days on which an animal does not feed for six hours) a pregnant female could 'tolerate' before it has any effect on fertility. Right: the number of days of disturbance (of six hours zero energy intake) a mother/calf pair could 'tolerate' before it has any effect on survival.

11.7.31 A recent study by Benhemma-Le Gall (2021) provided two key findings in relation to harbour porpoise response to pile driving. Porpoise were not completely displaced from the piling site: detections of clicks (echolocation) and buzzing (associated with prey capture) in the short-range (2km) did not cease in response to pile driving, and porpoise appeared to compensate: detections of both clicks (echolocation) and buzzing (associated with prey capture) increased above baseline levels with increasing distance from the pile, which suggests that those porpoise that are displaced from the near-field, compensate by increasing foraging activities beyond the impact range (Figure 11.18). Therefore, porpoise that experience displacement are expected to be able to compensate for the lost foraging opportunities and increased energy expenditure of fleeing.

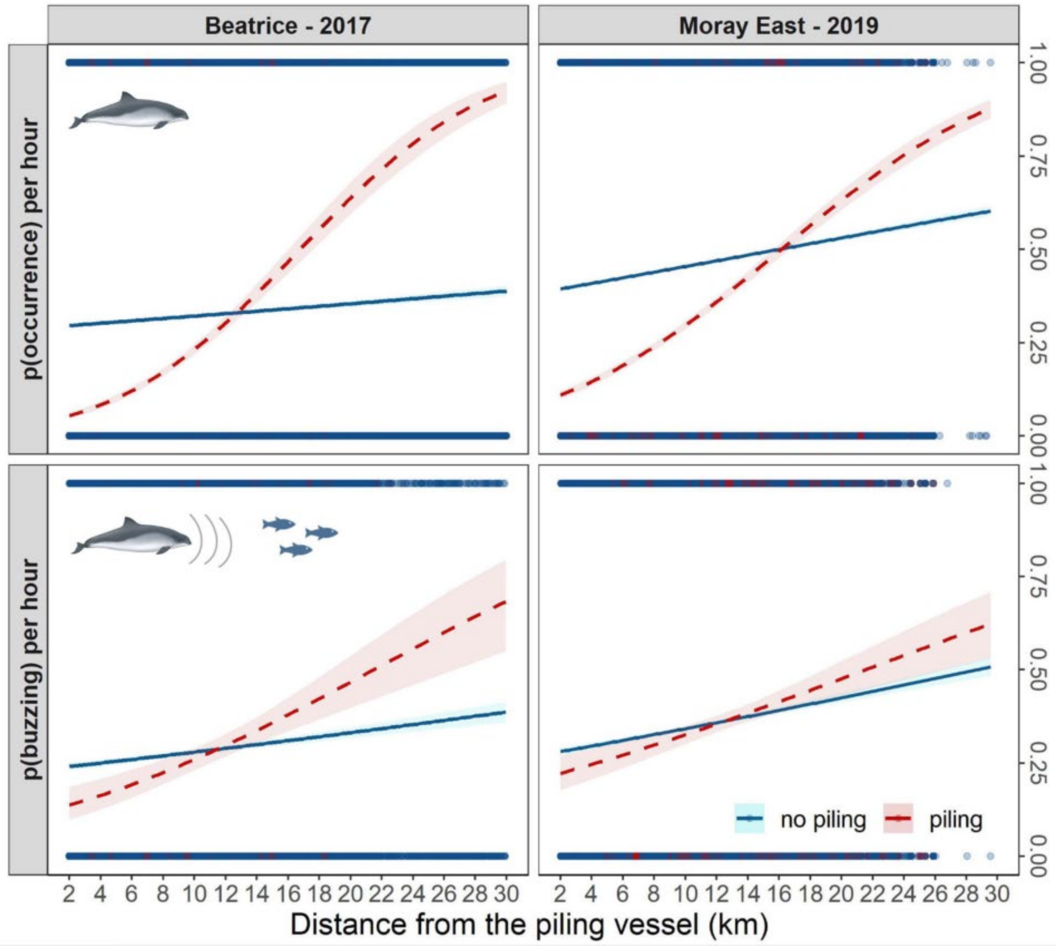


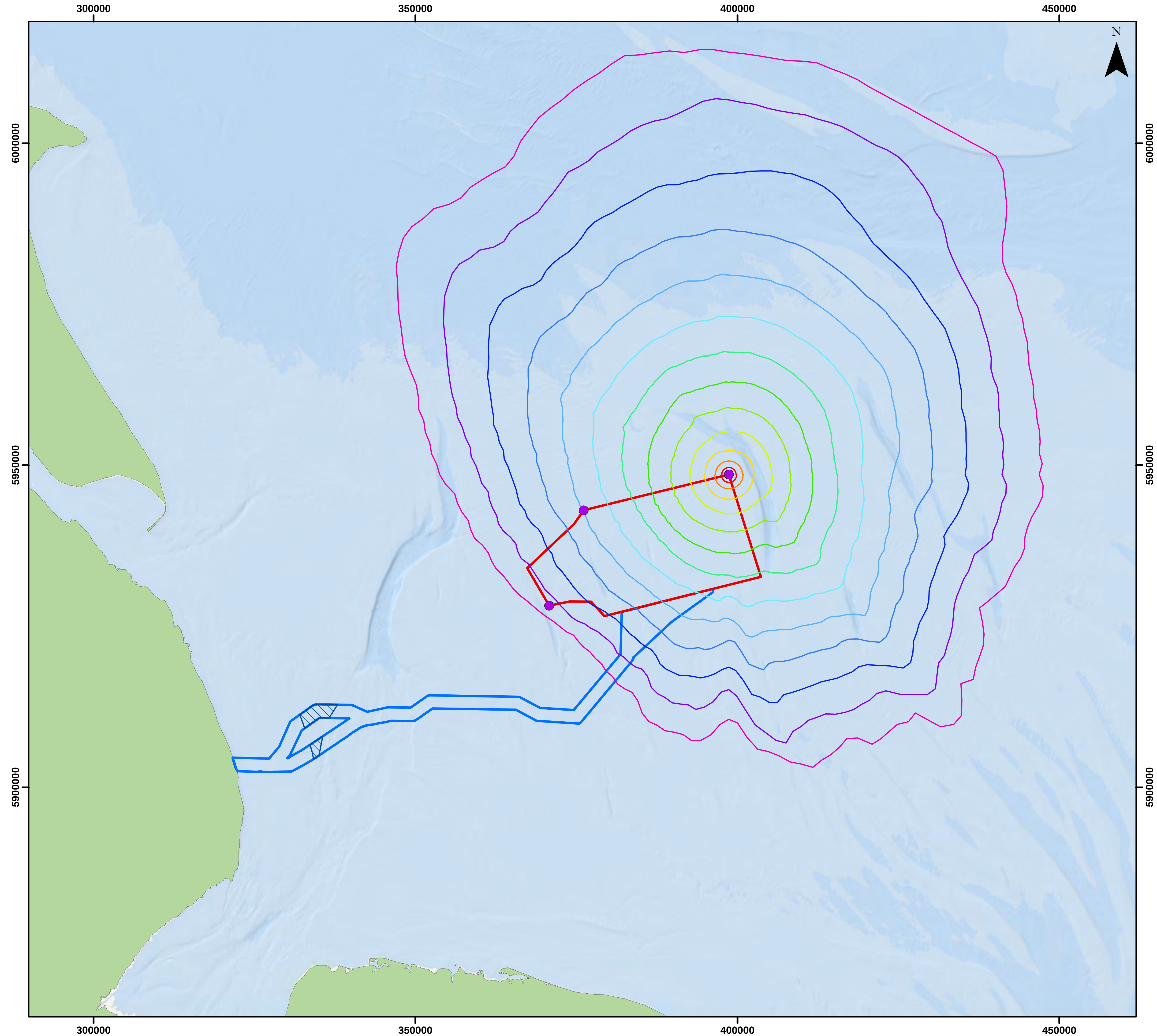
Figure 11.18: The probability of harbour porpoise occurrence and buzzing activity per hour during (dashed red line) and out with (blue line) pile-driving hours, in relation to distance from the pile-driving vessel at Beatrice (left) and Moray East (right).

11.7.33 Whilst it is expected that only a low number of days would be required to affect calf survival due to the observed responsiveness to piling and the income breeder life history, harbour porpoises have been assessed as having a low sensitivity to disturbance and resulting displacement from foraging grounds.

Magnitude

11.7.34 The results of disturbance to harbour porpoise from pile driving are presented in Table 11.29. From a single pile driving event, the maximum disturbance is predicted to occur at the NE monopile location, disturbing 3,981 harbour porpoise which is equivalent to 1.15% of the MU.

11.7.35 During concurrent pile driving at the NE and SW locations, the maximum disturbance is predicted to occur during monopile installation. This is predicted to disturb 5,229 harbour porpoise, equivalent to 1.51% of the MU (Table 11.29).

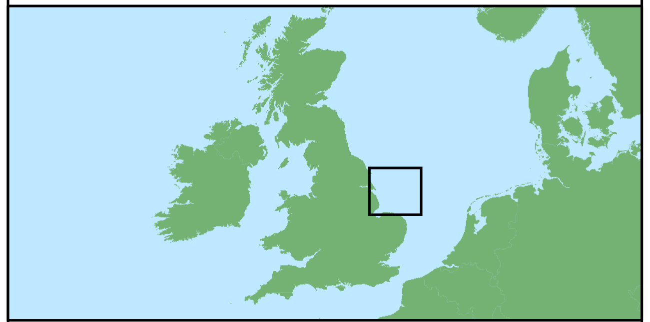


Legend

- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Piling Locations

Monopile 5dB SELss Disturbance Contours (dB)

- 120
- 125
- 130
- 135
- 140
- 145
- 150
- 155
- 160
- 165
- 170
- 175
- 180



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:550,000

Preliminary Environmental Information Report

Behavioural disturbance noise contours for harbour seal overlain on at-sea density estimates (Carter et al., 2022)

Figure 11.19

OUTER DOWSING OFFSHORE WIND

Date: 17/04/2023
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11.7.36 Given the results of the expert elicitation on the likely effects of behavioural disturbance on harbour porpoise vital rates (Booth *et al.*, 2019), a maximum of 194 days of piling is considered to be 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. The impact is predicted to be of short-term duration, intermittent and is reversible. Given the number of porpoise predicted to be impacted and the proportion of the population this represents, this is considered to be a Low (negligible) magnitude.

Significance

11.7.37 The sensitivity of harbour porpoise to disturbance from piling has been assessed as Low.

11.7.38 The magnitude of impact of disturbance from piling to harbour porpoise has been assessed as Low (negligible).

11.7.39 Therefore, the effect significance of disturbance from piling to harbour porpoise is **Minor (not significant)** in EIA terms.

Bottlenose dolphin

Sensitivity

11.7.40 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 were 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 240dB re 1µPa (range ±8dB) with a single pulse source level of 198dB re μPa^2s. 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.

11.7.41 According to the opinions of the experts involved in the expert elicitation for iPCoD, which represents the current best available knowledge on the topic, disturbance would be most likely to affect bottlenose dolphin calf survival, where: “Experts felt that disturbance could affect calf survival if it exceeded 30-50 days, because it could result in mothers becoming separated from their calves and this could affect the amount of milk transferred from the mother to her calf” (Harwood *et al.*, 2014).

11.7.42 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. Therefore, since bottlenose dolphins are expected to be able to adapt their behaviour, with the impact most likely to result in potential changes in calf survival (but not expected to affect adult survival or future reproductive rates) bottlenose dolphins are considered to have a Low sensitivity to behavioural disturbance from piling.

Magnitude

11.7.43 The results of disturbance to bottlenose dolphin from pile driving are presented in Table 11.29. From a single pile driving event, the maximum disturbance is predicted to occur at the NE monopile and pin pile locations, both disturbing 3 bottlenose dolphins which is equivalent to 0.15% of the MU.

11.7.44 During concurrent pile driving at the NE and SW monopile and pin pile locations, it is predicted that 4 bottlenose dolphins will be disturbed, equivalent to 0.20% of the MU (Table 11.29).

11.7.45 The harbour porpoise dose-response function has been used as a proxy for bottlenose dolphin response in the absence of similar empirical data. However, this makes the assumption that the same disturbance relationship is observed in bottlenose dolphins. It is anticipated that this approach will be overly precautionary as evidence suggests that bottlenose dolphins are less sensitive to disturbance compared to harbour porpoise. A literature review of recent (post Southall (2007)) behavioural responses by harbour porpoises and bottlenose dolphins to noise was conducted by Moray Offshore Renewables Limited (2012). Several studies have reported a moderate to high level of behavioural response at a wide range of received SPLs (100 and 180dB re 1µPa) (Lucke *et al.*, 2009; Tougaard *et al.*, 2009; Brandt *et al.*, 2011). Conversely, a study by Niu (2012) reported moderate level responses to non-pulsed noise by bottlenose dolphins at received SPLs of 140dB re 1µPa. Another high frequency cetacean, Risso's dolphin, reported no behavioural response at received SPLs of 135dB re 1µPa (Southall *et al.*, 2010). Whilst both species showed a high degree of variability in responses and a general positive trend with higher responses at higher received levels, moderate level responses were observed above 80dB re 1µPa in harbour porpoise and above 140dB re 1µPa in bottlenose dolphins (Moray Offshore Renewables Limited, 2012), indicating that moderate level responses by bottlenose dolphins will be exhibited at a higher received SPL and, therefore, they are likely to show a lesser response to disturbance. Furthermore, the relatively dynamic social structure of bottlenose dolphins (Connor *et al.*, 2001) and the fact that they have no significant predation threats and do not appear to face excessive competition for food with other marine mammal species, have potentially resulted in a higher tolerance to perceived threats or disturbances in their environment, which may make them less sensitive to disturbance.

11.7.46 Due to the low number and percentage of the MU predicted to experience disturbance, and the fact that bottlenose dolphins are considered to be less sensitive to disturbance than harbour porpoise (upon which their disturbance has been modelled), the magnitude of disturbance from pile driving is assessed as Negligible (adverse).

Significance

11.7.47 The sensitivity of bottlenose dolphin to disturbance from piling has been assessed as Low.

11.7.48 The magnitude of impact of disturbance from piling to bottlenose dolphin has been assessed as Negligible (adverse).

11.7.49 Therefore, the effect significance of disturbance from piling to bottlenose dolphin is **Negligible (not significant)** in EIA terms.

White-beaked dolphin

Sensitivity

11.7.50 In the absence of any species-specific data for white-beaked dolphin, given that they are also grouped as high-frequency cetaceans, and are, therefore, likely to have similar hearing abilities as bottlenose dolphin. As a result, white-beaked dolphins are also considered to have a Low sensitivity to behavioural disturbance from piling.

Magnitude

11.7.51 The results of disturbance to white-beaked dolphin from pile driving are presented in Table 11.29. From a single pile driving event, the maximum disturbance is predicted to occur at the NE monopile and pin pile locations, both disturbing three white-beaked dolphins which is equivalent to 0.01% of the MU.

11.7.52 During concurrent pile driving at the NE and SW monopile and pin-pile locations, it is predicted that four white-beaked dolphins will be disturbed, equivalent to 0.01% of the MU (Table 11.29).

11.7.53 Given the low number of white-beaked dolphin predicted to be impacted and the proportion of the population this represents, this is considered to be a Negligible (adverse) magnitude.

Significance

11.7.54 The sensitivity of white-beaked dolphin to disturbance from piling has been assessed as Low.

11.7.55 The magnitude of impact of disturbance from piling to white-beaked dolphin has been assessed as Negligible (adverse).

11.7.56 Therefore, the effect significance of disturbance from piling to white-beaked dolphin is **Negligible (not significant)** in EIA terms.

Minke whale

Sensitivity

11.7.57 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 behavioural response severity scores above 4 (the stage at which avoidance to a sound source first occurs) for a received SPL of 146dB re 1µPa (score 7[25]) and a received SPL of 158dB re 1µPa (score 8[26]). There is a study detailing minke whale responses to a Lofitech ADD which has a source level of 204dB re 1µPa @ 1m, which showed minke whales within 500m and 1,000m of the source exhibiting a sustained behavioural response. The estimated received level at 1,000m was 136.1dB re 1µPa (McGarry *et al.*, 2017). There are no equivalent such studies of responses to pile driving noise.

11.7.58 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. However, 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 and individuals are expected to be able to recover from any impact on vital rates. Therefore, minke whales have been assessed as having a Low sensitivity to disturbance from pile driving.

Magnitude

11.7.59 The results of disturbance to minke whales from pile driving are presented in Table 11.29. From a single pile driving event, the maximum disturbance is predicted to occur at the NE monopile location, disturbing 17 minke whales which is equivalent to 0.08% of the MU.

11.7.60 During concurrent pile driving, the maximum disturbance is predicted to occur during monopile installation. This is predicted to disturb 22 minke whales, equivalent to 0.11% of the MU (Table 11.29).

11.7.61 Given the low number of minke whales predicted to be impacted and the proportion of the population this represents, this is considered to be of Negligible (adverse) magnitude.

Significance

11.7.62 The sensitivity of minke whales to disturbance from piling has been assessed as Low.

[25] Defined in Sivle *et al* (2015) as: *Prolonged avoidance – The animal increased speed and swam directly away from the sound source throughout the rest of the exposure. Opportunistic visual observations of skim feeding at the surface before the start of the sonar exposure indicated that this response might also have involved a cessation of feeding.*

[26] Defined in Sivle *et al* (2015) as: *Obvious progressive aversion (and sensitization) – The animal continued to increase its speed as the exposure progressed, swimming at such a high speed that the distance to the source ship remained constant. About halfway through the exposure, the dive pattern changed to shallower diving, which may be a way to move more effectively away from the source.*

11.7.63 The magnitude of impact of disturbance from piling to minke whales has been assessed as Negligible (adverse).

11.7.64 Therefore, the effect significance of disturbance from piling to minke whales is **Negligible (not significant)** in EIA terms.

Harbour seal

Sensitivity

11.7.65 A study of tagged harbour seals in the Wash has shown that they are displaced from the vicinity of piles during impact piling activities. Russell (2016a) showed that seal abundance was significantly reduced within an area with a radius of 25km from a pile during piling activities, with a 19 to 83% decline in abundance during impact piling 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 piling 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.

11.7.66 At the most recent expert elicitation workshop in 2018 (Booth *et al.*, 2019), experts assessed the most likely potential consequences of a six-hour period of zero energy intake, assuming that disturbance (from exposure to low frequency broadband pulsed noise, e.g., impact piling, airgun pulses) 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. Unlike for harbour porpoise, there was no DEB model available to simulate the effects of disturbance on seal energy intake and reserves; therefore, the opinions of the experts were less certain. 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 (Figure 11.20 left); however, there was a large amount of uncertainty in this estimate. 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 (Figure 11.20 right); however, again, there was a lot of uncertainty surrounding this estimate. It is considered unlikely that individual harbour seals would repeatedly return to a site where they had been previously displaced from in order to experience this number of days of repeated disturbance.

11.7.67 Due to observed responsiveness to piling, harbour seals have been assessed as having Low sensitivity to disturbance and resulting displacement from foraging grounds during impact piling events.

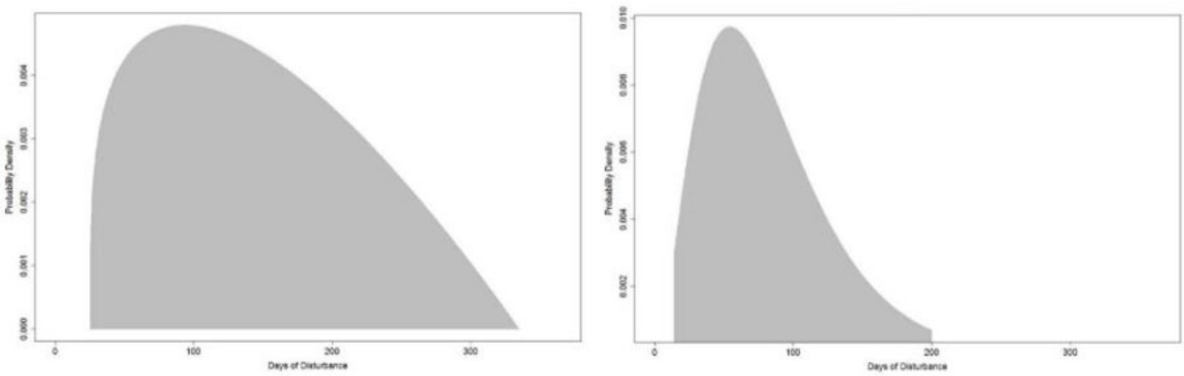


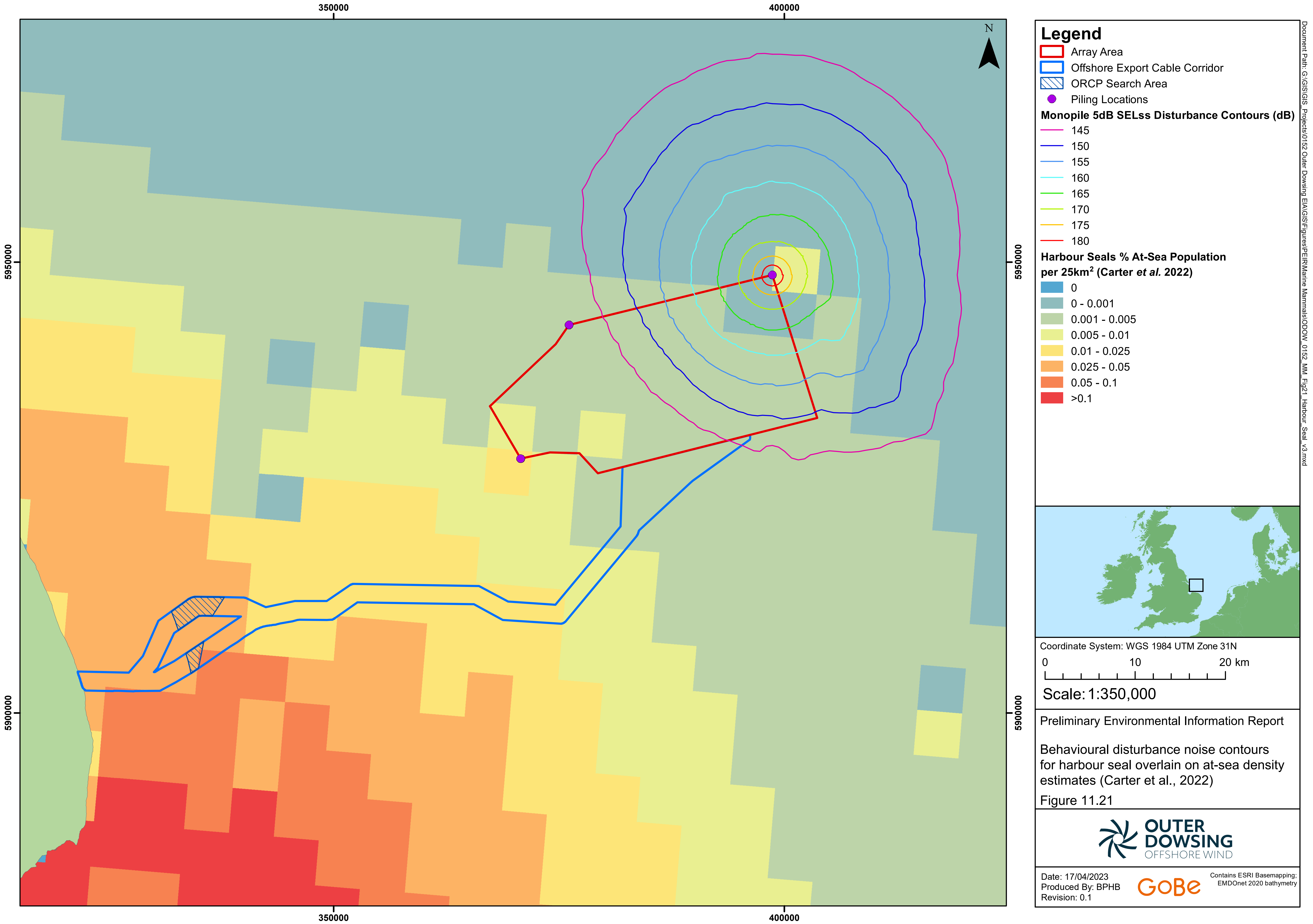
Figure 11.20: Probability distributions showing the consensus of the expert elicitation for harbour seal disturbance from piling. X-axis = days of disturbance; y-axis = probability density. Left: the number of days of disturbance (i.e. days on which an animal does not feed for six hours) a pregnant female could 'tolerate' before it has any effect on fertility. Right: the number of days of disturbance (of six hours zero energy intake) a 'weaned of the year' harbour seal could 'tolerate' before it has any effect on survival. Figures obtained from Booth (2019).

<u>Magnitude</u>

11.7.68 The results of disturbance to harbour seals from pile driving are presented in Table 11.29. From a single pile driving event, the maximum disturbance is predicted to occur at the SW monopile location, both disturbing 25 harbour seals which is equivalent to 0.51% of the MU.

11.7.69 During concurrent pile driving, the maximum disturbance is predicted to occur during monopile installation. This is predicted to disturb 35 harbour seals, equivalent to 0.72% of the MU (Table 11.29).

11.7.70 Given the low number of harbour seals predicted to be impacted and the proportion of the population this represents, this is considered to be a Negligible (adverse) magnitude.



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Behavioural disturbance noise contours for harbour seal overlain on at-sea density estimates (Carter et al., 2022)

Figure 11.21

Significance

11.7.71 The sensitivity of harbour seals to disturbance from piling has been assessed as Low.

11.7.72 The magnitude of impact of disturbance from piling to harbour seals has been assessed as Negligible (adverse).

11.7.73 Therefore, the effect significance of disturbance from piling to harbour seals is **Negligible (not significant)** in EIA terms.

Grey seal

Sensitivity

11.7.74 There are still limited data on grey seal behavioural responses to pile driving. The key dataset on this topic is presented in Aarts (2018) where 20 grey seals were tagged in the Wadden Sea to record their responses to pile driving at two offshore windfarms: 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.

11.7.75 The distances at which seals responded varied significantly; in one instance a grey seal showed responses at 45km from the pile location, while other grey seals showed no response when within 12km. Potential reasons for these differences in responses include 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. While this evidence base is from studies of grey seals tagged in the Wadden Sea, it is expected that grey seals in the North Sea would respond in a similar way, and therefore the data are considered to be applicable.

11.7.76 The expert elicitation workshop 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 the 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 moderate-high levels of repeated disturbance before there was any effect on fertility rates to reduce fertility (Figure 11.22 left). 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 (Figure 11.22 right); however, there was a lot of uncertainty surrounding this estimate.

11.7.77 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.

11.7.78 In an experimental study on captive seals, Hastie (2021) found that grey seal avoidance rates in response to pile driving sounds were dependent on the quality of the prey patch, with grey seals continuing to forage at high density prey patches when exposed to pile driving sounds but showing reduced foraging success at low density prey patches when exposed to pile driving sounds. Additionally, the seals showed an initial aversive response to the pile driving playbacks (lower proportion of dives spent foraging) but this diminished during each trial. Therefore, the likelihood of grey seal response is expected to be linked to the quality of the prey patch.

11.7.79 Due to observed responsiveness to piling, and their life-history characteristics, grey seals have been assessed as having Negligible sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

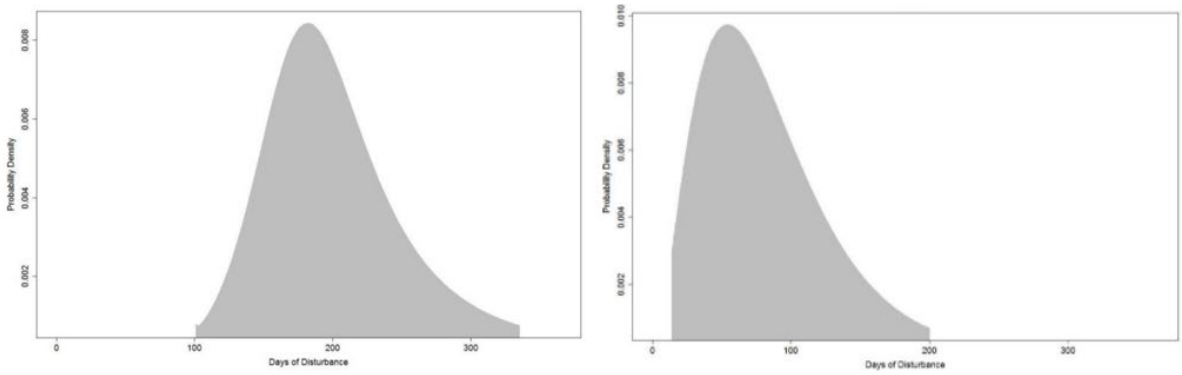


Figure 11.22: Probability distributions showing the consensus of the expert elicitation for grey seal disturbance from piling (Booth *et al.*, 2019). Left: the number of days of disturbance (i.e. days on which an animal does not feed for six hours) a pregnant female could 'tolerate' before it has any effect on fertility. Right: the number of days of disturbance (of six hours zero energy intake) a 'weaned of the year' grey seal could 'tolerate' before it has any effect on survival.

<u>Magnitude</u>

11.7.80 The results of disturbance to grey seals from pile driving are presented in Table 11.29. From a single pile driving event, the maximum disturbance is predicted to occur at the NW monopile location, both disturbing 377 grey seals which is equivalent to 0.71% of the MU.

11.7.81 During concurrent pile driving, the maximum disturbance is predicted to occur during monopile installation. This is predicted to disturb 615 grey seals, equivalent to 1.16% of the MU (Table 11.29).

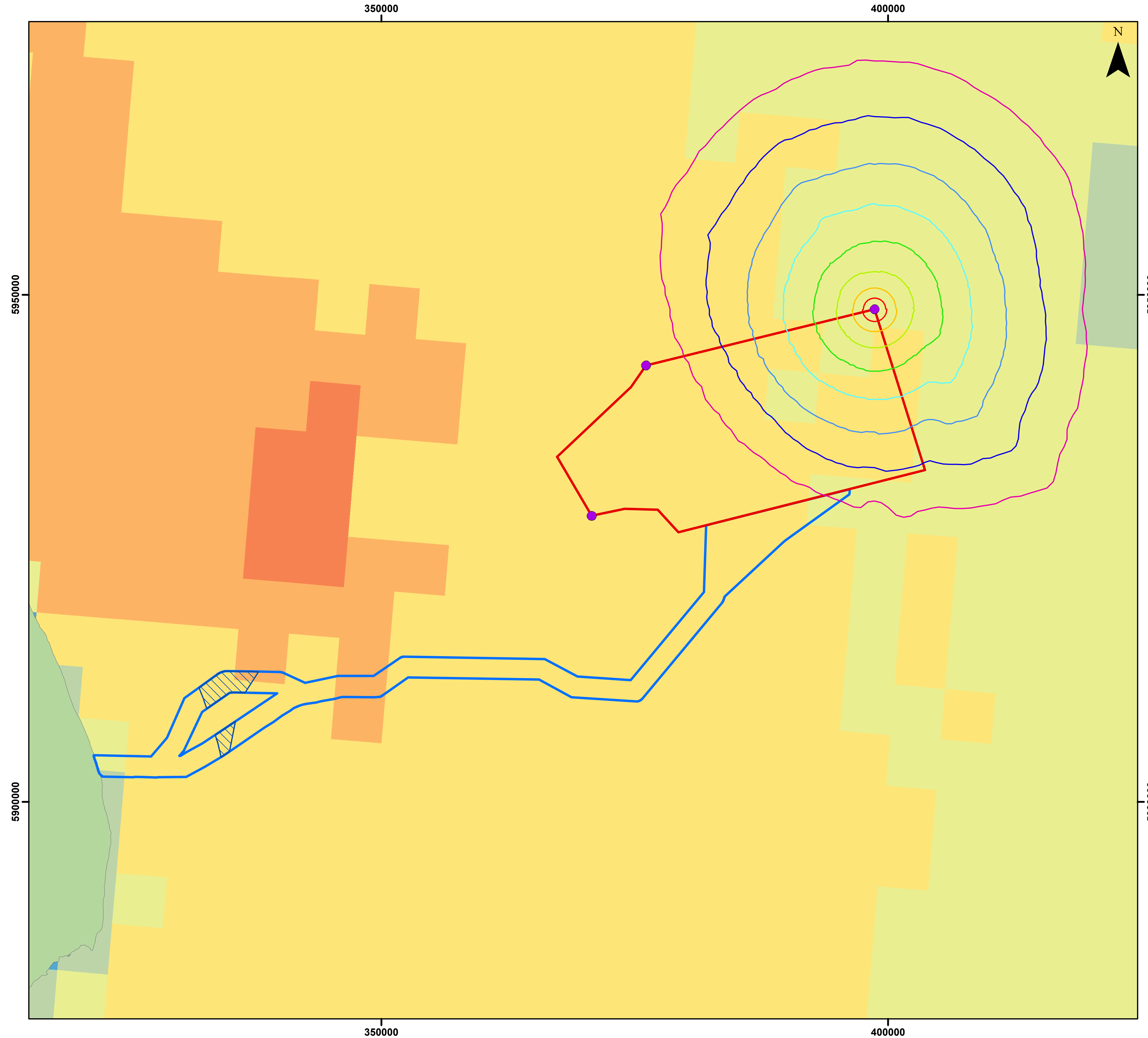
11.7.82 Given the number of grey seals predicted to be impacted and the proportion of the population this represents, this is considered to be a Low (adverse) magnitude.

Significance

11.7.83 The sensitivity of grey seals to disturbance from piling has been assessed as Negligible.

11.7.84 The magnitude of impact of disturbance from piling to grey seals has been assessed as Low (adverse).

11.7.85 Therefore, the effect significance of disturbance from piling to grey seals is **Negligible (not significant)** in EIA terms.



Legend

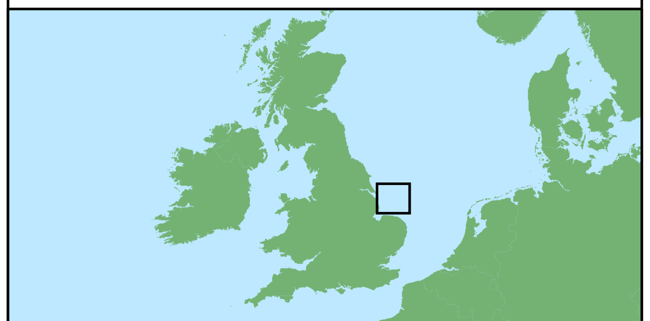
- Array Area
- Offshore Export Cable Corridor
- ORCP Search Area
- Piling Locations

Monopile 5dB SELss Disturbance Contours (dB)

- 145
- 150
- 155
- 160
- 165
- 170
- 175
- 180

Grey Seals % At-Sea Population per 25km^2 (Carter *et al.* 2022)

- 0
- 0.001 - 0.005
- 0.005 - 0.01
- 0.01 - 0.025
- 0.025 - 0.05
- 0.05 - 0.1



Coordinate System: WGS 1984 UTM Zone 31N

0 10 20 km

Scale: 1:350,000

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Behavioural disturbance noise contours for grey seal overlain on at-sea density estimates (Carter *et al.*, 2022)

Figure 11.23

OUTER DOWSING OFFSHORE WIND

Date: 17/04/2023
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Pile driving – disturbance summary

11.7.86 Table 11.30 present a summary of the sensitivity, magnitude and significance of disturbance from pile driving for marine mammals. The significance has been assessed as Negligible for all marine mammal species except harbour porpoise, which has been assessed as Minor, which is **not significant** in EIA terms.

Table 11.30: Summary of marine mammal sensitivity, magnitude and significance of disturbance from pile driving.

Species	Sensitivity	Magnitude	Significance
Harbour porpoise	Low	Low	**Minor (Not significant)**
Bottlenose dolphin	Low	Negligible	**Negligible (Not significant)**
White-beaked dolphin	Low	Negligible	**Negligible (Not significant)**
Minke whale	Low	Negligible	**Negligible (Not significant)**
Harbour seal	Low	Negligible	**Negligible (Not significant)**
Grey seal	Negligible	Low	**Negligible (Not significant)**

ORCP

11.7.87 The following section provides the quantitative assessment of disturbance from pile driving within the ORCP search area on marine mammal species (Table 11.29).

11.7.88 Harbour porpoise: From a single pile driving event, the maximum disturbance is predicted to occur at the CC-NE monopile location, disturbing 1,288 harbour porpoise which is equivalent to 0.37% of the MU. Given the number of porpoise predicted to be impacted and the proportion of the population this represents, this is considered to be a Negligible (adverse) magnitude. The sensitivity of harbour porpoise to disturbance from piling has been assessed as Low. Therefore, the effect significance of disturbance from piling in the ORCP search area to harbour porpoise is Negligible (Not significant), which is not significant in EIA terms.

11.7.89 Bottlenose dolphin: From a single pile driving event, the maximum disturbance is predicted to occur at the CC-NE monopile and pin pile location, both disturbing 1 bottlenose dolphin which is equivalent to 0.05% of the MU. Due to the low number and percentage of the MU predicted to experience disturbance, and the fact that bottlenose dolphins are considered to be less sensitive to disturbance than harbour porpoise (upon which their disturbance has been modelled), the magnitude of disturbance from pile driving is assessed as Negligible (adverse). The sensitivity of bottlenose dolphin to disturbance from piling has been assessed as Low. Therefore, the effect significance of disturbance from piling in the ORCP search area to bottlenose dolphin is Negligible (Not significant), which is not significant in EIA terms.

11.7.90 White-beaked dolphin: From a single pile driving event, the maximum disturbance is predicted to occur at the CC-NE monopile and pin pile locations, both disturbing 1 white-beaked dolphin which is equivalent to <0.01% of the MU. Given the low number of white-beaked dolphin predicted to be impacted and the proportion of the population this represents, this is considered to be a Negligible (adverse) magnitude. The sensitivity of white-beaked dolphin to disturbance from piling has been assessed as Low. Therefore, the effect significance of disturbance from piling in the ORCP search area to white-beaked dolphin is Negligible (Not significant), which is not significant in EIA terms.

11.7.91 Minke whale: From a single pile driving event, the maximum disturbance is predicted to occur at the CC-NE monopile and pin pile locations, disturbing 5 minke whales which is equivalent to 0.02% of the MU. Given the low number of minke whales predicted to be impacted and the proportion of the population this represents, this is considered to be of Negligible (adverse) magnitude. The sensitivity of minke whales to disturbance from piling has been assessed as Low. Therefore, the effect significance of disturbance from piling in the ORCP search area to minke whales is Negligible (Not significant), which is not significant in EIA terms.

11.7.92 Harbour seal: From a single pile driving event, the maximum disturbance is predicted to occur at the CC-NE monopile location, disturbing 110 harbour seals (95% CIs: 14 - 204) which is equivalent to 2.28% (95% CIs: 0.28 - 4.22%) of the MU. Given the moderate number of harbour seals predicted to be impacted and the proportion of the population this represents, this is considered to be a Low (adverse) magnitude. The sensitivity of harbour seals to disturbance from piling has been assessed as Low. Therefore, the effect significance of disturbance from piling in the ORCP search area to harbour seals is Minor (Not significant), which is not significant in EIA terms.

11.7.93 Grey seal: From a single pile driving event, the maximum disturbance is predicted to occur at the CC-NE monopile location, both disturbing 388 grey seals (95% CIs: 47 - 722) which is equivalent to 0.73% (95% CIs: 0.09 - 1.36%) of the MU. Given the number of harbour seals predicted to be impacted and the low proportion of the population this represents, this is considered to be a Negligible (adverse) magnitude. The sensitivity of grey seals to disturbance from piling has been assessed as Negligible. Therefore, the effect significance of disturbance from piling in the ORCP search area to grey seals is Negligible (Not significant), which is not significant in EIA terms.

Table 11.31 Number of marine mammals and percentage of the MU predicted to experience potential behavioural disturbance from piling within the ORCP search area.

Species	Location	Monopile		Pin pile	
		CC-NE	CC-SW	CC-NE	CC-SW
Harbour porpoise	# animals	1,288	570	1,150	502
	% MU	0.37%	0.16%	0.33%	0.14%
Bottlenose dolphin	# animals	1	<1	1	<1
	% MU	0.05%	0.02%	0.05%	0.02%
	# animals	1	0	1	0

Species	Location	Monopile		Pin pile	
White-beaked dolphin	% MU	<0.01%	0%	<0.01%	0%
Minke whale	# animals	5	2	5	2
	% MU	0.02%	0.01%	0.02%	0.01%
Harbour seal	# animals	110 (14-204)	84 (11-156)	96 (11-178)	72 (9-133)
	% MU	2.28% (0.28-4.22%)	1.74% (0.22-3.22%)	1.98% (0.24-3.68%)	1.49% (0.19-2.75%)
Grey seal	# animals	388 (47-722)	101 (13-185)	336 (39-630)	87 (11-160)
	% MU	0.73% (0.09-1.36%)	0.19% (0.02-0.35%)	0.63% (0.07-1.19%)	0.16% (0.02-0.30%)

Impact 6: PTS from other construction activities

11.7.94 The following section provides the quantitative assessment of the impact of injury (PTS) from other construction activities on marine mammal species detailed in Volume 2, Appendix 3.2: Underwater Noise Assessment (Table 11.32).

Table 11.32: PTS impact ranges for the different construction noise sources using the non-impulsive criteria from Southall *et al.* (2019).

Southall (2019) weighted SEL_{cum}	Cable laying	Backhoe dredging	Suction dredging	Drilling	Trenching	Rock placement
173dB (VHF)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m
198dB (HF)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m
199dB (LF)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m
201dB (PCW)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m

Sensitivity

Dredging

11.7.95 Dredging is described as a continuous broadband sound source, with the main energy below 1kHz; however, the frequency and sound pressure level can vary considerably depending on the equipment, activity, and environmental characteristics (Todd *et al.*, 2015). For the Project, dredging will potentially be required for seabed preparation work for foundations as well as for export cable, array cable and interconnector cable installations. The source level of dredging has been described to vary between SPL 172-190dB re 1µPa @ 1m with a frequency range of 45Hz to 7kHz (Evans, 1990; Thompson *et al.*, 2009; Verboom, 2014). It is expected that the underwater noise generated by dredging will be below the PTS-onset threshold (Todd *et al.*, 2015) and thus the risk of injury is unlikely, though disturbance may occur. For porpoise, dolphins and seals, the hearing sensitivity below 1kHz is relatively poor and thus it is expected that a PTS at this frequency would result in little impact to vital rates. Therefore, the sensitivity of porpoise, dolphins and seals to PTS from dredging is assessed as Low.

11.7.96 The low frequency noise produced during dredging may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Minke whale communication signals have been demonstrated to be below 2kHz (Edds-Walton, 2000; Mellinger *et al.*, 2000; Gedamke *et al.*, 2001; Risch *et al.*, 2013; Risch *et al.*, 2014). Tubelli (2012) estimated the most sensitive hearing range (the region with thresholds within 40dB of best sensitivity) to extend from 30 to 100Hz up to 7.5 to 25kHz, depending on the specific model used. Therefore, the sensitivity of minke whale to PTS from dredging is precautionarily assessed as Medium.

Trenching

11.7.97 Underwater noise generation during cable trenching is highly variable and dependent on the physical properties of the seabed that is being cut. At the North Hoyle OWF, trenching activities had a peak energy between 100Hz – 1kHz and in general the sound levels were generally only 10-15dB above background levels (Nedwell *et al.*, 2003). For porpoise, dolphins and seals, the hearing sensitivity below 1kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates. Therefore, the sensitivity of porpoise, dolphins and seals to PTS from trenching is assessed as Low. The low frequency noise produced during trenching may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, the sensitivity of minke whale to PTS from trenching is precautionarily assessed as Medium.

Cable laying

11.7.98 Underwater noise generated during cable installation is generally considered to have a low potential for impacts to marine mammals due to the non-impulsive nature of the noise generated and the fact that any generated noise is likely to be dominated by the vessel from which installation is taking place (Genesis, 2011). OSPAR (2009) summarise general characteristics of commercial vessel noise. Vessel noise is continuous, and is dominated by sounds from propellers, thrusters and various rotating machinery (e.g., power generation, pumps). In general, support and supply vessels (50-100 m) are expected to have broadband source levels in the range 165-180dB re 1µPa, with the majority of energy below 1kHz (OSPAR, 2009). Large commercial vessels (>100 m) produce relatively loud and predominately low frequency sounds, with the strongest energy concentrated below several hundred Hz. For porpoise, dolphins and seals, the hearing sensitivity below 1kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates. Therefore, the sensitivity of porpoise, dolphins and seals to PTS from cable laying is assessed as Low. The low frequency noise produced during cable laying may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, the sensitivity of minke whales to PTS from cable laying is assessed as Medium.

Drilling

11.7.99 The continuous sound produced by drilling has been likened to that produced by dredging activity; low frequency noise caused by rotating machinery (Greene, 1987). Recordings of drilling at the North Hoyle offshore windfarm suggest that the sound produced has a fundamental frequency at 125Hz (Nedwell *et al*., 2003). For porpoise, dolphins and seals, the hearing sensitivity below 1kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates. Therefore, the sensitivity of porpoise, dolphins and seals to PTS from drilling noise is assessed as Low. The low frequency noise produced during cable laying may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, the sensitivity of minke whales to PTS from cable laying is precautionarily assessed as Medium.

Summary

11.7.100 MMO (2015) provide information on the acoustic properties of anthropogenic continuous noise sources; this includes noise sources such as dredging, drilling and shipping. For all three activities, the main energy is listed as being <1kHz. For porpoise, dolphins and seals species considered here, the hearing sensitivity below 1kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates and, therefore, their sensitivity is assessed as Low. As minke whales have a greater hearing sensitivity below 1kHz, meaning their hearing range is more likely to overlap with other construction, activities their sensitivity has precautionarily been assessed as Medium.

Magnitude

11.7.101 For all non-piling construction activities assessed (Table 11.32), the PTS-onset impact ranges are <100 m. Therefore, non-piling construction noise sources will have a local spatial extent and are transient and intermittent. This means that, with the most precautionary estimates, a marine mammal would have to remain within proximity (<100 m) for a 24-hour period for PTS-onset to occur, which is extremely unlikely to occur. Therefore, the magnitude of impact of PTS from non-piling construction noise is considered Negligible (adverse).

Significance

11.7.102 The sensitivity of porpoise, dolphins and seals to PTS from other construction activities has been assessed as Low and minke whales have precautionarily been assessed as having a Medium sensitivity.

11.7.103 The magnitude of impact of PTS to all marine mammals from other construction activities has been assessed as Negligible (adverse).

11.7.104 Therefore, the effect significance of PTS from other construction activities is **Negligible** for porpoise, dolphins and seals and **Minor** for minke whales, which is **not significant** in EIA terms.

Table 11.33: Summary of marine mammal sensitivity, magnitude and significance of PTS from other construction activities.

Species	Sensitivity	Magnitude	Significance
Harbour porpoise	Low	Negligible	**Negligible (Not significant)**
Bottlenose dolphin	Low	Negligible	**Negligible (Not significant)**
White-beaked dolphin	Low	Negligible	**Negligible (Not significant)**
Minke whale	Medium	Negligible	**Minor (Not significant)**
Harbour seal	Low	Negligible	**Negligible (Not significant)**
Grey seal	Low	Negligible	**Negligible (Not significant)**

Impact 7: TTS from other construction activities

11.7.105 The TTS-onset impact areas and ranges for other construction activities are detailed in Volume 2, Appendix 3.2: Underwater Noise Assessment. As previously outlined, there are no thresholds to determine a biologically significant effect from TTS-onset. As with the results for piling, the predicted ranges for the onset of TTS from other construction activities are presented, but no assessment of magnitude, sensitivity or significance of effect is given.

11.7.106 For harbour porpoise, the TTS-onset impact ranges are predicted to be greatest for rock placement at 990 m, followed by suction dredging at 230 m, and <100m for the other construction activities (Table 11.34). For all other species, all impact ranges are predicted to be <100m (Table 11.34).

11.7.107 Overall, non-piling construction noise sources will have a local spatial extent, short-term duration, and be intermittent, meaning that, with the most precautionary estimates, a marine mammal would have to remain within close proximity for a 24-hour period for TTS-onset to occur, which is extremely unlikely to happen.

Table 11.34: TTS impact ranges for the different construction noise sources using the non-impulsive criteria from Southall *et al.* (2019).

Southall (2019) weighted SEL_{cum}	Cable laying	Backhoe dredging	Suction dredging	Drilling	Trenching	Rock placement
153dB (VHF)	100 m	<100 m	230 m	<100 m	<100 m	990 m
178dB (HF)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m
179dB (LF)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m
181dB (PCW)	<100 m	<100 m	<100 m	<100 m	<100 m	<100 m

Impact 8: Disturbance from other construction activities

Sensitivity

11.7.108 Information regarding the sensitivity of marine mammals to other construction activities is currently limited. Available studies focus primarily on disturbance from dredging and confirmed behavioural responses have been observed in cetaceans. Pirotta *et al.*, (2013) noted that bottlenose dolphin presence in foraging areas of Aberdeen harbour decreased as dredging intensity increased. Due to the consistently high presence of shipping activity all year round, the dolphins were considered to be habituated to high levels of vessel disturbance and, therefore, in this particular instance, Pirotta *et al.*, (2013) concluded that the avoidance behaviour was a direct result of dredging activity. However, this distinction in the source of the disturbance reaction cannot always be determined. For example, Anderwald (2013) observed minke whales off the coast of Ireland in an area of high vessel traffic during the installation of a gas pipeline where dredging activity occurred. The data suggested that the avoidance response observed was likely attributed to the vessel presence rather than the dredging and construction activities themselves. As the disturbance impact from other construction activities is closely associated with the disturbance from vessel presence required for the activity, it is difficult to determine the sensitivity specifically to disturbance from other construction activities in isolation (Todd *et al.*, 2015).

11.7.109 Harbour porpoise occurrence decreased at the Beatrice and Moray East offshore windfarms during non-piling construction periods. The probability of detecting porpoise in the absence of piling decreased by 17% as the sound pressure levels from vessels during the construction period increased by 57dB (note: vessel activity included not only windfarm construction related vessels, but also other third party traffic such as fishermen, bulk carrier and cargo vessels). Despite this, harbour porpoise continued to regularly use both the Beatrice and Moray East sites throughout the three-year construction period. While a reduction in occurrence and buzzing was associated with increased vessel activity, this was of local scale and buzzing activity increased beyond a certain distance from the exposed areas, suggesting displaced animals resumed foraging once a certain distance from the noise source, or potential compensation behaviour for lost foraging or the increased energy expenditure of fleeing. While porpoise may be sensitive to disturbance from other construction-related activities, it is expected that they are able to compensate for any short-term local displacement, and thus it is not expected that individual vital rates would be impacted. Therefore, the sensitivity of porpoise to disturbance from other construction activities is considered to be Low.

11.7.110 For dolphin species, disturbance responses to non-piling construction activity appears to vary. Increased dredging activity at Aberdeen harbour was associated with a reduction in bottlenose dolphin presence and, during the initial dredge operations, bottlenose dolphins were absent for five weeks (Pirotta *et al.*, 2013). In an urbanised estuary in Western Australia, bottlenose dolphin responses to dredging varied between sites. At one site no bottlenose dolphins were sighted on days when backhoe dredging was present, while dolphins remained using the other site (Marley *et al.*, 2017). A study conducted in northwest Ireland, construction related activity (including dredging) did not result in any evidence of a negative impact to common dolphins (Culloch *et al.*, 2016). Therefore, their sensitivity to disturbance from other construction activities is assessed as Low.

11.7.111 The same study conducted by Culloch (2016) found evidence that the fine-scale temporal occurrence of minke whales in northwest Ireland was influenced by the presence of construction activity, with lower occurrence rates on these days (Culloch *et al.*, 2016). 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 and individuals are expected to be able to recover from any impact on vital rates. Therefore, their sensitivity to disturbance from other construction activities is assessed as Low.

11.7.112 While seals are sensitive to disturbance from pile driving activities, there is evidence that the displacement is limited to the piling activity period only. At the Lincs windfarm, seal usage in the vicinity of construction activity was not significantly decreased during breaks in the piling activities and displacement was limited to within 2 hours of the piling activity (Russell *et al.*, 2016a). There was no evidence of displacement during the overall construction period, and the authors recommended that environmental assessments should focus on short-term displacement to seals during piling rather than displacement during construction as a whole. Even during periods of piling at the Lincs offshore windfarm, individual seals travelled in and out of the Wash which suggests that the motivation to forage offshore and come ashore to haul out could outweigh the deterrence effect of piling. The Project array area is located in a low density area for both species of seal, and thus it is not expected that any short term-local displacement caused by construction related activities would result in any changes to individual vital rates. Therefore, the sensitivity of both seal species to disturbance from other construction activities is considered to be Negligible.

Magnitude

Dredging

11.7.113 Harbour porpoise: Dredging at a source level of 184dB re 1µPa at 1m resulted in avoidance up to 5km from the dredging site (Verboom, 2014). Conversely, Diederichs (2010) found much more localised impacts; using Passive Acoustic Monitoring there was short term avoidance (~3 hours) at distances of up to 600m from the dredging vessel, but no significant long-term effects. Modelling potential impacts of dredging using a case study of the Maasvlatke port expansion (assuming maximum source levels of 192dB re 1µPa) predicted a disturbance range of 400m, while a more conservative approach predicted avoidance of harbour porpoise up to 5km (McQueen *et al.*, 2020).

11.7.114 Bottlenose dolphin: Increased dredging activity at Aberdeen Harbour was associated with a reduction in bottlenose dolphin presence and, during the initial dredge operations, bottlenose dolphins were absent for five weeks (Pirotta *et al.*, 2013). Based on the results of Pirotta *et al.*, (2013), subsequent studies have assumed that dredging activities exclude dolphins from a 1km radius of the dredging site (Pirotta *et al.*, 2015). Dredging operations had no impact on sightings of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in South Australia (Bossley *et al.*, 2022).

11.7.115 White-beaked dolphin: There is currently no information available on the impacts of dredging for white beaked dolphins. Currently their hearing range has only been investigated at frequencies above 16kHz (Nachtigall *et al.*, 2008) which is above the typical range for dredging. Localised, temporary avoidance of dredging activities is assumed.

11.7.116 Minke whale: In northwest Ireland, construction-related activity (including dredging) has been linked to reduced minke whale presence (Culloch *et al.*, 2016). Minke whale distance to construction site increased and relative abundance decreased during dredging and blasting activities in Newfoundland (Borggaard *et al.*, 1999).

11.7.117 Grey and harbour seal: Based on the generic threshold of behavioural avoidance of pinnipeds (140dB re 1µPa SPL) (Southall *et al.*, 2007), acoustic modelling of dredging demonstrated that disturbance could be caused to individuals between 400m to 5km from site (McQueen *et al.*, 2020).

Drilling

11.7.118 Information on the disturbance effects of drilling is limited and the majority of the research available was conducted more than 20 years ago and is focussed on baleen whales (Sinclair *et al.*, 2021). For example, drilling and dredging playback experiments observed that 50% of bowhead whales exposed to noise levels of 115dB re 1µPa exhibited some form of response, including changes to calling, foraging and dive patterns (Richardson and Wursig, 1990). More recent studies of bowhead whales also observed changes in behaviour from increased drilling noise levels, specifically an increase in call rate. However, the call rate plateaued and then declined as noise level continued to increase, which could be interpreted as the whales aborting their attempt to overcome the masking effects of the drilling noise (Blackwell *et al.*, 2017). Playback experiments of drilling and industrial noise have also been undertaken with grey whales at a noise level of 122dB re 1µPa. This resulted in a 90% response from the individuals in the form of diverting their migration track (Malme *et al.*, 1984). Overall, the literature indicates that the impacts of drilling disturbance on marine mammals may occur at distances of between 10-20km and will vary depending on the species (Greene Jr, 1986; LGL and Greeneridge, 1986; Richardson *et al.*, 1990).

11.7.119 Whilst information is not available for the species of concern for the Project, it is still considered useful as it suggests that at least some species of cetacean may experience disturbance as a result of drilling. Furthermore, drilling is considered under the umbrella of industrial and construction noise, and has similar properties to dredging, for which more information is available for species relevant to the Project. Therefore, it is considered that drilling could potentially cause disturbance over distances of up to 5-10km from the noise source based on results for dredging, or potentially up to 20km based on results from the drilling literature, although this literature is considered slightly outdated.

Other

11.7.120 There is a lack of information in the literature on disturbance ranges for other non-piling construction activities such as cable laying, trenching or rock placement. While construction-related activities (acoustic surveys, dredging, rock trenching, pipe laying and rock placement) for an underwater pipeline in northwest Ireland resulted in a decline in harbour porpoise detections, there was a considerable increase in detections after construction-activities ended which suggests that any impact is localised and temporary (Todd *et al.*, 2020).

11.7.121 It is expected that any disturbance impact will be primarily driven by the underwater noise generated by the vessel during these non-piling construction related activities, and, as such, it is expected that any impact of disturbance is highly localised (within 5km). The indicative offshore construction period is expected to start in 2027 with:

- offshore export cable installation lasting up to 24 months,
- foundation installation lasting up to 18 months,
- array cable installation lasting up to 24 months,
- WTG installation lasting up to 18 months; and
- OSS installation lasting up to 12 months.

11.7.122 Given that there will be overlap in these activities, it is expected that offshore construction related work within the array area or within the Offshore ECC will occur within a 36-month period. Therefore, the duration of disturbance will be limited to three breeding cycles. This aligns with the definition of Low (adverse) magnitude.

Significance

11.7.123 The sensitivity of cetaceans to disturbance from other construction activities has been assessed as Low. The sensitivity of seals to disturbance from other construction activities has been assessed as Negligible.

11.7.124 The magnitude of the impact to all marine mammals for disturbance from other construction activities has been assessed as Low (adverse).

11.7.125 Therefore, the effect significance of disturbance to cetaceans from other construction activities is Minor and the effect significance of disturbance to seals from other construction activities is **Negligible (not significant)** in EIA terms.

Impact 9: Vessel collisions

11.7.126 The area surrounding the Project already experiences high levels of vessel traffic (see Volume 1, Chapter 15: Shipping and Navigation). Volume 1, Chapter 3: Project Description shows there will be 131 total construction vessels and that during the busiest period for vessel traffic there would be up to 10 vessels (major installation and commissioning vessels) in a given 5km^2 active construction area. The introduction of additional vessels during construction of the Project is not a novel impact for marine mammals present in the area.

11.7.127 During construction of the windfarm, 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.

11.7.128 There is currently a lack of information on the frequency of occurrence of vessel collisions as a source of marine mammal mortality, and 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. The CSIP data shows that very few strandings have been attributed to vessel collisions[27], 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. However, it is important to note that the strandings data are biased to those carcases that wash ashore for collection and therefore may not be representative.

11.7.129 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. Minke whales have previously shown displacement in areas with high vessel density in response to noise (Anderwald *et al*., 2013), which can reduce the chance of impact collision. Predictability of vessel movement by marine mammals is known to be a key aspect in minimising the potential collision risks imposed by vessel traffic (Nowacek *et al*., 2001; Lusseau, 2003; Lusseau, 2006). The adoption of a VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme[28], Scottish Marine Wildlife Watching Code[29] or Guide to Best Practice for Watching Marine Wildlife[30]) during construction will minimise the potential for any potential collision risk. 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 moving around the site and to/from port to the site will occur over short periods of the offshore construction activity, thus minimising the risk of collisions.

11.7.130 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 VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife) during construction will minimise the potential for any impact. Therefore, the risk of vessel collisions occurring is of negligible (adverse) magnitude.

11.7.131 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 has the potential to kill the animal. As a result of the low vulnerability to a strike but the serious consequences of a strike, marine mammal receptors are considered to have a high sensitivity to vessel collisions.

[27] CSIP (2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018)

[28] https://www.wisescheme.org/

[29] https://www.nature.scot/scottish-marine-wildlife-watching-code-smwwc-part-1

[30] https://www.nature.scot/guide-best-practice-watching-marine-wildlife-smwwc-part-2

11.7.132 The magnitude of the impact has been assessed as negligible and the sensitivity of receptors as high. Therefore, the significance of the effect of collisions from vessels is concluded to be of **minor (not significant)** in terms of the EIA regulations.

Impact 10: Vessel disturbance

11.7.133 As stated above, the area surrounding the Project already experiences high levels of vessel traffic (see Volume 2, Chapter 15: Shipping and Navigation for full details). Volume 1, Chapter 3: Project Description shows there will be 131 total construction vessels per year. Therefore, the introduction of additional vessels during construction the Project is not a novel impact for marine mammals present in the area.

11.7.134 Vessel noise levels from construction vessels will result in an increase in non-impulsive, continuous sound in the vicinity of the Project array, typically in the range of 10 – 100Hz (although higher frequencies may also be produced) (Sinclair *et al*., 2021) with an estimated source level of 161 – 168 SEL_{cum} dB re 1µPa@1m (RMS). It is anticipated there will be maximum of 131 construction vessels in total. 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 Project area, even considering the addition of the Project construction traffic will still be well below this figure. The adoption of a VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife) during construction will minimise the potential for any disturbance impact. Therefore, the impact is expected to be of low (adverse) magnitude.

11.7.135 Harbour porpoise have a high frequency generalised hearing range (275Hz – 160kHz) and, therefore, the majority of additional vessel traffic noise will fall below their range of hearing. However, they are known to exhibit an avoidance response to vessels that contain low levels of high frequency components (Dyndo *et al*., 2015). Studies have shown that, whilst there may be short-term effects on foraging, harbour porpoise show a quick recovery time to responses to vessel traffic, remaining in heavily trafficked areas (Wisniewska *et al.,* 2018). There appears to be little fitness cost to exposure to vessel noise and any local scale responses taken to avoid vessels. It is also likely that porpoise may become habituated where vessel movements are regular and predictable.

11.7.136 Previous modelling of bottlenose dolphin in the Moray Firth in response to increase vessel traffic from offshore wind development found it to have no negative impact on the local population (Lusseau *et al*., 2011). There is also evidence of bottlenose dolphins becoming habituated to increased boat traffic, particularly larger commercial vessels which have predictable patterns of movement and do not actively disrupt feeding behaviour as a recreational or tourist vessel may (Sini *et al*., 2005). As both HF cetaceans with similar hearing abilities, it is anticipated that bottlenose and white beaked dolphin will react similarly to construction vessel traffic. The generalised hearing range of high frequency cetaceans 150Hz – 160kHz (Southall *et al*., 2019) is also above the anticipated frequency range of much of the construction vessel noise.

11.7.137 Minke whales have a low frequency generalised hearing range of 7Hz – 35kHz which falls within the expected frequency range of construction vessel traffic. They have been shown to exhibit a decrease in foraging activity in response to whale watching vessels (Christiansen *et al*., 2013). However, these vessels were specifically following minke whales and, therefore, it is not known how they would respond to construction vessels that would be following a pre-determined route and not directly interacting with the animals. As generalist feeders with a varied diet, it is not expected that any temporary displacement resulting from vessel activity in relation to the Project will lead to any significant effect on individual energy budgets and subsequently fitness.

11.7.138 Evidence suggests that any behavioural changes and displacement are likely to be temporary and that some species (harbour porpoise particularly) may even become habituated to the construction vessel presence due to their more predictable movements and therefore exhibit less of a response over time. Based on modelling conducted by Southall *et al*., (2019), harbour porpoise would have to be <100m from a large vessel for a 24-hour period to experience either TTS or PTS (Table 54 in Volume 2, Appendix 3.2: Underwater Noise Assessment). These impacts are unlikely 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. The sensitivity of cetacean species under consideration to vessel disturbance has, therefore, been assessed as low.

11.7.139 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 50km 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 (~2kHz) and large (~0.25kHz) vessels at approximately 400 m. The sensitivity of grey and harbour seals for vessel disturbance has, therefore, been assessed as negligible.

11.7.140 The magnitude of the impact has been assessed as low and the sensitivity of receptors as low (cetaceans) or negligible (grey seals and harbour seals). Therefore, the significance of the effect of disturbance from vessels is concluded to be of **minor** significance for cetaceans and **negligible** significance for grey and harbour seals, which is **not significant** in terms of the EIA regulations.

Impact 11: Indirect impacts on prey

11.7.141 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 11.35.

11.7.142 Regarding fish prey species, the worst-case impacts from the construction of the Project have been assessed in Volume 1, Chapter 10: Fish and Shellfish Ecology. Potential impacts from underwater noise will arise from the piling of foundations and UXO clearance during the construction phase. There is the potential for fish mortality and potential mortal injury, recoverable injury, TTS, behavioural impacts and auditory masking arising from underwater noise from these activities. Taking into consideration the implementation of embedded mitigation, no significant effects on fish prey species were concluded. In addition, there is the potential for direct impacts to occur on fish prey species inclusive of direct damage and crushing, temporary habitat loss, and increase in SSC and deposition leading to smothering. All such impacts were assessed, and no significant effects were concluded on fish prey species.

11.7.143 Fishing pressure may be reduced during construction at the Project due to the required safety distances of 500m around infrastructure around construction and fishing effort may be displaced into the surrounding area. However, it would not be expected that any changes in fishing activities in this area would lead to changes in populations of these species as any increase would be very localised and any population level effects would be minimised by fisheries management measures.

Table 11.35: Key prey species of the marine mammal receptors

Species	Prey species	Reference
Harbour porpoise	Whiting, sandeel, herring, haddock, saith, pollock, bobtail squid	Pierce *et al.*, (2007)
Bottlenose dolphin	Cod, saith, whiting, salmon, mackerel, haddock, pout, squid	Santos *et al.*, (2001) De Pierrepont *et al.*, (2005)
White beaked dolphin	Haddock, whiting, cod, herring, mackerel	Canning *et al.*, (2008)
Minke whale	Sandeel, herring, sprat, mackerel, goby, Norway pout/poor cod	Pierce *et al.*, (2004)
Harbour seal	Sandeel, whiting, dragonet, cod, herring, sprat, dover sole, plaice, lemon sole, dab, flounder, goby, bullrout, sea scorpion, octopus, squid	Wilson and Hammond (2016) SCOS (2021)
Grey seal	Sandeel, cod, whiting, haddock, ling, plaice, sole, flounder, dab	SCOS (2021)

11.7.144 Due to the lack of significant effect on prey species and the generalist/opportunist nature of the receptors in question, together with the low numbers of marine mammals in vicinity of the Project, the magnitude of changes to prey availability to during construction activities is considered to be negligible (adverse), indicating that the potential is for very short-term and recoverable effects, with no potential for survival and reproductive rates to be impacted to the extent that the population trajectory will be altered.

11.7.145 Changes to prey availability could increase the energy expenditure required for feeding through increased effort. However, as marine mammals are generalists they can switch prey species removing the requirement for additional energy expenditure. No impact on survival and reproduction is predicted and therefore the sensitivity of the receptor is considered to be low.

11.7.146 The magnitude of the impact has been assessed as negligible (adverse) and the sensitivity of receptors as low. Therefore, the significance of the effect of changes in fish abundance/distribution is concluded to be of **negligible (not significant)** in terms of the EIA regulations.

Impact 12: Water quality impacts

11.7.147 Disturbance to water quality as a result of construction activities can have both direct and indirect impacts on marine mammals. Indirect impacts include effects on prey species (see paragraphs 11.7.141 to 11.7.146). Direct impacts include the impairment of visibility and therefore foraging ability which might be expected to reduce foraging success.

11.7.148 During construction of the Project, sediment will be disturbed and released into the water column. This will give rise to suspended sediment plumes and localised changes in bed levels as material settles out of suspension. The main activities resulting in disturbance of seabed sediments are:

- Pre-lay cable trenching;
- Sandwave clearance;
- Cable installation;
- Dredge spoil disposal; and
- Drill arisings release.

11.7.149 The maximum distance (and therefore the overall spatial extent) that any local plume effects might be (temporarily) experienced can be reasonably estimated as the spring tidal excursion distance. The assessment provided in Volume 1, Chapter 7: Marine Processes found that:

- Within 5m of the activity, Suspended Sediment Concentration (SSC) might be millions of mg/l or more locally, i.e. more sediment than water in parts of the local plume. The effect is very localised and of very short duration.
- During the first half tidal cycle (~six hours), the width of the plume increases through dispersion to between 500 and 2000m, all non-silt sediments have settled to the seabed, and SSC consequentially reduces rapidly to 50mg/l.
- After 20 hours SSC will have reduced to below 5mg/l, with no measurable SSC during peak high current speed conditions.

11.7.150 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 (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.

11.7.151 Volume 1, Chapter 7: Marine Processes concluded that the magnitude of the maximum potential increase in SSC resulting from construction activities is negligible and the impact will be short-term, intermittent and of localised extent and reversible. Therefore, there is expected to be no significant increase in the level of SSC from the construction of the Project. The magnitude of this impact is therefore considered to be negligible (adverse).

11.7.152 Short-term increased turbidity is not anticipated to impact marine mammals which rely primarily on hearing, resulting in negligible sensitivity to changes in water quality.

11.7.153 The magnitude of the impact has been assessed as negligible (adverse) and the sensitivity of receptors as negligible. Therefore, the significance of the effect of changes in water quality is concluded to be of **negligible (not significant)** in terms of the EIA regulations.

Impact 13: Disturbance at seal haul-outs

11.7.154 Both grey and harbour seals are known to haul out at Donna Nook, the Wash, Blakeney Point, Horsey and Scroby Sands. There is the potential for disturbance to seals at haul out sites from the construction of the proposed development as a result of the transit of vessels. Previous studies have demonstrated the disturbance effects of vessels on harbour seals at haul-out sites. For example, controlled disturbance vessel trials have shown that harbour seals would reduce the amount of time hauled out around the point of disturbance and they would embark on a foraging trip before hauling out again at the next low-tide cycle (Paterson *et al*., 2015). This was also shown in Andersen *et al*., (2011) where extended inter-haul-out trips occurred directly after a disturbance event. This is particularly important in terms of energetic consequences if this disturbance occurs at a time that is critical for seals to be hauled out, such as during the annual moult or the breeding season.

11.7.155 The other primary concern with respect to hauled out seals is the potential proximity of construction vessels, as vessel traffic is known to disturb seals at haul out sites and often result in the animals flushing into the water (Jansen *et al*., 2015). Andersen *et al*., (2011) showed that flushing out at Danish haul out sites occurred at distances of 510-830m from approaching vessels. However, in the proposed study area, the local haul out sites are already exposed to relatively high levels of vessel activities and it is therefore considered that there will be a de minimis disturbance effect to seals at haul out caused by the additional vessels for the Project (see the vessel disturbance assessment above, and Table 11.14). Additionally, the vessel transit routes for the Project are based on the assumption of the Humber being the main port for construction and operation and maintenance activities. The main commercial routes for cargo vessels, tankers, operation and maintenance vessels in the area are from Humber Ports to Rotterdam (Netherlands), Cuxhaven (Germany), Bremenhaven/Hamburg (Germany) and Hornsea Offshore Windfarms which are the likely routes that could be followed.

11.7.156 Heart rate responses to incidental and experimental vessel disturbance have previously been used assess harbour seal disturbance (Karpovich *et al*., 2015). Hauled out seals exhibited a vigilance behaviour (head-lift) and experienced a 4 bpm vessel^{-1} increase as a result of incidental vessel traffic, and a 5 bpm vessel^{-1} increase from experimental vessel disturbance. This increase in heart rate could be a result of the seal switching from a sleeping to awake status as the vessel approached or could indicate that the seal is experiencing a stress response. If seals remained hauled out, their heart rate continued to increase with each additional vessel that approached; if seals entered the water following the disturbance, the heart rate decreased, suggesting they are shifting to an energetically conservative state in response to the disturbance event. However, the effect of the heart rate increase was still noticeable in the following haul out, indicating that the disturbance has a prolonged energetic cost for harbour seals (Karpovich *et al*., 2015). The sensitivity of harbour seals to disturbance at haul-outs is therefore classified as Medium.

11.7.157 Bishop *et al*. (2015) reported that breeding male grey seals exhibit similar activity (behavioural) budgets across varying exposures to human activity. Male grey seals exhibited similar time budgets for non-active behaviours (i.e., resting or alert) versus active behaviours (i.e., aggressions or attempted copulation) suggesting strong selection pressures for overarching conservation of energy, in the presence or absence of human activities and/or disturbance. Bishop *et al*. (2015) reported that selection for this lack of a behavioural response is likely driven by the increased mating success of males who maintain their position amongst groups of females for the longest time because of reduced energy expenditure, irrespective of human activity. Although Bishop *et al*. (2015) classified alert behaviours under the non-active category, as Karpovich *et al*. (2015) indicated, increased alertness/vigilance and in turn, increased stress levels, can increase the heart rate of seals (irrespective of sex) and thus, energy expenditure. Should vessel disturbance to grey seals, male or female, be repetitive, this could lead to increased heart rates over time and a prolonged energetic cost. The sensitivity of grey seals to disturbance at haul-out sites is therefore classified as Medium.

11.7.158 The impact is predicted to be of local spatial extent, short term duration, intermittent and is reversible. In line with best-practise vessel management measures, where possible vessel traffic associated with the Project will follow existing shipping routes, and are therefore unlikely to transit close to the key haul out sites (at Donna Nook and within the Wash). The magnitude is therefore considered to be negligible (adverse), indicating that the potential is for very short-term and recoverable effects, with no potential for survival and reproductive rates to be impacted to the extent that the population trajectory will be altered.

11.7.159 Overall, the sensitivity of seals to disturbance has been assessed as medium and the magnitude is predicted to be negligible (adverse). Therefore, the resulting impact significance for disturbance to seal haul outs is of **minor (not significant)** in EIA terms.

Operation and Maintenance

11.7.160 This section presents the assessment of impacts arising from the operational and maintenance phases of the Project.

Impact 14: Operational noise

PTS & TTS

Sensitivity

11.7.161 Operational noise derived from operational wind turbines is primarily low frequency (well below 1kHz) (Thomsen *et al.*, 2006). For the majority of marine mammal species, the hearing sensitivity below 1kHz is relatively poor and thus it is expected that a PTS at this frequency would result in little impact to vital rates. Therefore, the sensitivity of all marine mammals except minke whale to PTS from operational noise is assessed as Negligible.

11.7.162 The low frequency noise produced during operations may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Minke whale communication signals have been demonstrated to be below 2kHz (Edds-Walton, 2000; Mellinger *et al.*, 2000; Gedamke *et al.*, 2001; Risch *et al.*, 2013; Risch *et al.*, 2014). Tubelli *et al.*, (2012) estimated the most sensitive hearing range (the region with thresholds within 40dB of best sensitivity) to extend from 30 to 100Hz up to 7.5 to 25kHz, depending on the specific model used. Therefore, the sensitivity of minke whale to PTS from operational noise is assessed as Low.

Magnitude

11.7.163 The PTS and TTS-onset impact areas and ranges for operational noise are detailed in Volume 2, Appendix 3.2: Underwater Noise Assessment. Table 11.36 shows that a marine mammal would have to remain within close proximity (<100 m) to an operational turbine for a 24-hour period for PTS-onset to occur, which is extremely unlikely. Therefore, the magnitude of impact of PTS from operational noise is considered Negligible (adverse).

Table 11.36: Operational WTG noise impact ranges using the non-impulsive noise criteria from Southall *et al.* (2019).

Southall (2019) weighted SEL_{cum}		12 MW	18 MW
PTS (non-impulsive)	173dB (VHF)	<100 m	<100 m
	198dB (HF)	<100 m	<100 m
	199dB (LF)	<100 m	<100 m
	201dB (PCW)	<100 m	<100 m
TTS (non-impulsive)	153dB (VHF)	<100 m	<100 m
	178dB (HF)	<100 m	<100 m
	179dB (LF)	<100 m	<100 m
	181dB (PCW)	<100 m	<100 m

Significance

11.7.164 The sensitivity of marine mammals to PTS from operational noise has been assessed as Negligible, with exception of minke whales which have been assessed as having a Low sensitivity.

11.7.165 The magnitude of the impact of PTS to marine mammals from operational noise has been assessed as Negligible (adverse).

11.7.166 Therefore, the effect significance of PTS from operational noise is assessed as **Negligible** for porpoise, dolphins and seals to **Minor** for minke whale, which is **not significant** in EIA terms.

Disturbance

Sensitivity

11.7.167 Operational noise is primarily low frequency (well below 1kHz) (Thomsen *et al.*, 2006). For the majority of marine mammal species, the hearing sensitivity below 1kHz is relatively poor and, thus, it is expected that a disturbance at this frequency would result in little impact to vital rates. Therefore, the sensitivity of porpoise, dolphins and seals to disturbance from operational noise is assessed as Negligible.

11.7.168 The low frequency noise produced during operations may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Minke whale communication signals have been demonstrated to be below 2kHz (Edds-Walton, 2000; Mellinger *et al.*, 2000; Gedamke *et al.*, 2001; Risch *et al.*, 2013; Risch *et al.*, 2014). Tubelli *et al.*, (2012) estimated the most sensitive hearing range (the region with thresholds within 40dB of best sensitivity) to extend from 30 to 100Hz up to 7.5 to 25kHz, depending on the specific model used. Furthermore, 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. 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. Therefore, it has been precautionarily assumed that minke whales have a Low sensitivity to disturbance from operational noise.

OUTER DOWSING OFFSHORE WIND

Magnitude

11.7.169 A number of studies have reported the presence of marine mammals within windfarm footprints. For example, at the Horns Rev and Nysted offshore windfarms in Denmark, long-term monitoring showed that both harbour porpoise and harbour seals were sighted regularly within the operational OWFs, 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 OWF in the Netherlands reported that significantly more porpoise activity was recorded within the OWF compared to the reference area during the operational phase (Scheidat *et al.*, 2011) indicating the presence of the windfarm was not adversely affecting harbour porpoise presence. Other studies at Dutch and Danish OWFs (2011) and in the Moray Firth in Scotland (Fernandez-Betelu *et al.*, 2022) also suggest that harbour porpoise may be attracted to increased foraging opportunities within operating offshore windfarms. The study conducted by Fernandez-Betelu *et al.* (2022) found the increased foraging activity and the occurrence of harbour porpoise happened at night, with the change in diel patten being specifically linked to the presence of an offshore structure. There was also a significant increase in porpoise presence and foraging activity near isolate offshore structures (Fernandez-Betelu *et al.*, 2022). In addition, 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 being used for foraging. Previous reviews have also concluded that operational windfarm noise will have negligible barrier effects (Madsen *et al.*, 2006; Teilmann *et al.*, 2006a; Teilmann *et al.*, 2006b; Cefas, 2010; Brasseur *et al.*, 2012).

11.7.170 These studies were all conducted at windfarms with relatively small sized turbines, and thus there is uncertainty as to how applicable the results are to future larger turbine sizes. Tougaard (2020) and Stöber and Thomsen (2021) showed that as WTG size increases, the underwater sound pressure level also increases. Both studies highlighted that as the size of turbines continues to increase it is expected that the operational noise they produce will also increase. One important factor to consider is that all data used in the studies to date have been measured at geared turbines, and it is the gearbox that is one of the main contributing factors to the generated underwater noise levels. However, recent advances in technology mean that newer WTGs use direct drive technology rather than gears, which are expected to generate lower operational underwater noise levels (sound reduction of around 10dB compared to the same size geared turbine) (Stöber and Thomsen, 2021).

11.7.171 Therefore, while underwater sound is expected to increase with increasing turbine size, new direct drive technology means that new turbines will produce considerably less underwater noise compared to the older geared turbines. Additionally, as turbines increase in size fewer are required to be installed to meet a projects capacity. The Applicant acknowledges that there is still a lack of data on operational noise generated by larger size turbines; however, given the presence of marine mammals (both porpoise and seals) within operational windfarms, it is unlikely that operational noise is expected to be of a level that would result in any disturbance effect. As such, the magnitude of disturbance from operational noise is assessed as Negligible (adverse).

Significance

11.7.172 The sensitivity of marine mammals to disturbance from operational noise has been assessed as Negligible, with exception of minke whales which have been precautionarily assessed as having a Low sensitivity.

11.7.173 The magnitude of the impact to marine mammals for disturbance from operational noise has been assessed as Negligible (adverse).

11.7.174 Therefore, the effect significance of disturbance from operational noise is assessed as **Negligible** for porpoise, dolphins and seals to **Minor** for minke whales, neither of which **are significant** in EIA terms.

Impact 15: Vessel Collisions

11.7.175 As stated in section 11.7.126, the area surrounding the Project already experiences a high amount of vessel traffic (see Volume 1, Chapter 15: Shipping and Navigation for full details). Volume 1, Chapter 3: Project Description states there will be an indicative peak number of 10 vessels within a 5km^2 area on site simultaneously during operation. The introduction of additional vessels during O&M of the Project is not a novel impact for marine mammals present in the area.

11.7.176 Predictability of vessel movement by marine mammals is known to be a key aspect in minimising the potential risks imposed by vessel traffic (Nowacek *et al*., 2001, Lusseau 2003, 2006). The adoption of a VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife) will minimise the potential for any impact. Additional traffic during operations includes an increased frequency and greater variety of vessel types than in the construction phase e.g. jack-up vessels, small O&M vessels, lift vessels, cable maintenance vessels and auxiliary vehicles, and will take place over a longer period of time e.g. lifetime of the Project. Therefore, vessel traffic increase will be greater during this phase. However, it is still highly likely that a proportion of vessels will be stationary or slow moving throughout operations at the Project for significant periods of time.

11.7.177 It is not expected that the level of vessel activity during operations would cause an increase in the risk of mortality from collisions. The adoption of a VMP during O&M will minimise the potential for any impact. Therefore, the risk of vessel collisions occurring is of negligible (adverse) magnitude.

11.7.178 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 has the potential to kill the animal, from which they have no ability to recover from. As a result of the low vulnerability to a strike but the serious consequences of a strike, marine mammal receptors are considered to have a high sensitivity to vessel collisions.

11.7.179 The magnitude of the impact has been assessed as negligible (adverse) and the sensitivity of receptors as high. Therefore, the significance of the effect of collisions from O&M vessels is concluded to be of **minor (not significant)** in terms of the EIA regulations.

Impact 16: Vessel disturbance

11.7.180 As stated in paragraph 11.7.126, the area surrounding the Project already experiences a high amount of vessel traffic (see Volume 1, Chapter 15: Shipping and Navigation for full details). Volume 1, Chapter 3: Project Description states the MDS is 36 vessels. Therefore, the introduction of additional vessels during O&M of the Project is not a novel impact for marine mammals present in the area.

11.7.181 Vessel noise levels from vessels during operations will result in an increase in non-impulsive, continuous sound in the vicinity of the Project array, typically in the range of 10 – 100Hz (although higher frequencies may also be produced) (Sinclair *et al*., 2021) with an estimated source level of 161 – 168 SEL_{cum} dB re 1 µPa@1m (RMS). It is anticipated that numerous different vessel types would be conducting round trips to and from port and the Project array area, but peak numbers for jack-up vessels would be two and service offshore vessels would be four.

11.7.182 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 5km^2 area). Vessel traffic in the Project area, even considering the addition of the Project O&M traffic will still be well below this figure. The adoption of a VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife) during O&M will minimise the potential for any impact. Therefore, the impact is expected to be of low (adverse) magnitude.

11.7.183 All marine mammal receptors are deemed to be of low vulnerability given the existing evidence of behavioural responses to vessels (paragraph 11.7.140). Therefore, the sensitivity of marine mammal receptors to vessel disturbance is considered to be negligible.

11.7.184 The magnitude of the impact has been assessed as low and the sensitivity of receptors as negligible. Therefore, the significance of the effect of disturbance from O&M vessels is concluded to be of **negligible (not significant)** in terms of the EIA regulations.

Impact 17: Indirect impacts on prey

11.7.185 Any change in fish abundance and/or distribution as a result of the Project operations is important to assess as, given marine mammals are dependent on fish as prey species, there is the potential for indirect effect on marine mammals. The key prey species for each marine mammal receptor are listed in Table 11.35.

11.7.186 The presence of turbine infrastructure has the potential to impact on fish species by removing essential habitats (e.g. spawning, nursery and feeding habitats) (see Volume 1, Chapter 10: Fish and Shellfish Ecology). The Project array area overlaps with sandeel spawning grounds, but comparable habitats are present and widespread within the wider area.

11.7.187 Fishing pressure in the Project array area will be able to resume around and between infrastructure within the Project where possible, with a 50m operating distance advised for infrastructure, areas of cable protection and safety zones around infrastructure undergoing maintenance. However, individual decisions made by skippers of fishing vessels with their own perception of risk will determine the likelihood of whether fishing will resume in the array area. Additionally, the type and dimension of fishing gear will also influence whether fishing returns as some gear, such as twin-rigged trawls, require greater distances for safe operation. It would not be expected that any changes in fishing activities in this area would lead to changes in populations of prey species.

11.7.188 Any effects on fish species during the operational phase will be highly localised and therefore will have a negligible (adverse) magnitude on the prey availability for marine mammals.

11.7.189 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. Therefore, they are assessed as having a low sensitivity to changes in prey abundance and distribution.

11.7.190 The magnitude of the impact has been assessed as negligible (adverse) and the sensitivity of receptors as low. Therefore, the significance of the effect of changes in fish abundance/distribution during O&M the significance is concluded to be of **negligible (not significant)** in terms of the EIA regulations.

Decommissioning

11.7.191 The impacts of the offshore decommissioning of the Project have been assessed on marine mammals. The environmental impacts arising from the decommissioning of the Project are listed in paragraph 11.5.1 along with the MDS (Table 11.7) 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.

Impact 18: Underwater noise from decommissioning

11.7.192 It is envisaged that piled foundations would be cut below seabed level, and the protruding section removed. Typical current methods for cutting piles are abrasive water jet cutters or diamond wire cutting. The final method chosen shall be dependent on the technologies available at the time of decommissioning.

11.7.193 As the exact methods to be used for decommissioning are to be decided, the impact from PTS and disturbance levels of decommissioning activities cannot be accurately determined at this time. However, it is anticipated that with the implementation of embedded mitigation in the form of a Decommissioning Plan/Program and a MMMP specific to decommissioning activities (Table 11.8) the significance of these impacts will be reduced. The impacts of decommissioning activities will likely be similar or of a lesser extent than during piling in the construction phase and therefore will be of negligible significance to minor significance, which is **not significant** in terms of the EIA regulations.

Impact 19: Vessel collisions

11.7.194 As stated in section 11.7.126, the area surrounding the Project already experiences a high amount of vessel traffic (see Volume 1, Chapter 15: Shipping and Navigation). Volume 1, Chapter 3: Project Description states Project Description states that vessel numbers during decommissioning will be involve similar types and numbers of vessels as during construction. Therefore, the introduction of additional vessels during decommissioning of the Project is not a novel impact for marine mammals present in the area.

11.7.195 The adoption of a VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife) during decommissioning will minimise the potential for any impact. It is assumed that similar vessel types and number will be present in the Project array area as during the construction phase. Therefore, it is highly likely that a proportion of vessels will be stationary or slow moving throughout decommissioning activities for significant periods of time. Therefore, the actual increase in vessel traffic moving around the site and to/from port to the site will occur over short periods of the offshore decommissioning activity.

11.7.196 It is not expected that the level of vessel activity during decommissioning operations would cause an increase in the risk of mortality from collisions. The adoption of a VMP will minimise the potential for any impact. Therefore, the risk of vessel collisions occurring is of negligible (adverse) magnitude.

11.7.197 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 has the potential to kill the animal, from which they have no ability to recover from. As a result of the low vulnerability to a strike but the serious consequences of a strike, marine mammal receptors are considered to have a high sensitivity to vessel collisions.

11.7.198 The magnitude of the impact has been assessed as negligible (adverse) and the sensitivity of receptors as high. Therefore, the significance of the effect of collision risk from decommissioning vessels is concluded to be of **minor (not significant)** in terms of the EIA regulations.

Impact 20: Vessel disturbance

11.7.199 Vessel noise levels from decommissioning vessels will result in an increase in non-impulsive, continuous sound in the vicinity of the Project array, typically in the range of 10 – 100Hz (although higher frequencies may also be produced) (Sinclair *et al*., 2021) with an estimated source level of 161 – 168dB re 1µPa@1m (RMS). It is anticipated that levels and types of vessel traffic during decommissioning would be similar to that during construction.

11.7.200 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 5km^2 area). Vessel traffic in the Project area, even considering the addition of the Project decommissioning traffic will still be well below this figure. The adoption of a VMP based on best practice vessel handing protocols (e.g. following the Codes of Conduct provided by the WiSe Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife) during decommissioning will minimise the potential for any impact. Therefore, the impact is expected to be of low (adverse) magnitude.

11.7.201 All marine mammal receptors are deemed to be of low vulnerability given the existing evidence of behavioural responses to vessels (see paragraph 11.7.140). Therefore, the sensitivity of marine mammal receptors to vessel disturbance is considered to be negligible.

11.7.202 The magnitude of the impact has been assessed as low (adverse) and the sensitivity of receptors as negligible. Therefore, the significance of the effect of disturbance from decommissioning vessels is concluded to be of negligible significance for all cetaceans and seal species, which is **not significant** in terms of the EIA regulations.

Impact 21: Indirect impact on prey

11.7.203 Any change in fish abundance and/or distribution as a result of the Project decommissioning is important to assess as, given marine mammals are dependent on fish as prey species, there is the potential for indirect effect on marine mammals. The key prey species for each marine mammal receptor are listed in Table 11.35. 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. Therefore, they are assessed as having a low sensitivity to changes in prey abundance and distribution.

11.7.204 Decommissioning of offshore infrastructure for the Project may result in temporarily elevated underwater noise levels and disturbance which may have effects on fish. However, the maximum noise levels and disturbance are anticipated to be far below that than during pile driving in the construction phase, therefore the impacts would also be less. The assessment provided in Volume 1, Chapter 10: Fish and Shellfish Ecology indicates that the overall adverse impacts to fish species from the decommissioning of the Project will be of negligible magnitude and thus the predicted impact on marine mammals is of negligible magnitude.

11.7.205 The magnitude of the impact has been assessed as negligible and the sensitivity of receptors as low. Therefore, the significance of the effect of changes in fish abundance/distribution is concluded to be of negligible significance, which **is not significant** in terms of the EIA regulations.

Impact 22: Water quality impacts

11.7.206 During decommissioning, SSC could potentially be increased and associated deposition of material within the Project array and the offshore ECC from the following activities:

- Removal of foundation structures;
- Cutting off of monopiles and jacket foundation legs; and
- (Possible) removal of cables from the intertidal zone.

11.7.207 Any disturbance to the seabed will be localised and any resultant increase in SSC will be temporary. The changes in SSC and resultant water quality during decommissioning are anticipated to be lesser than those associated with construction. Short-term increased turbidity is not anticipated to impact marine mammals which rely primarily on hearing, resulting in negligible sensitivity to changes in water quality.

11.7.208 The increase in SSC will be temporary and therefore the magnitude has been assessed as negligible (adverse).

11.7.209 The magnitude of the impact has been assessed as negligible (adverse) and the sensitivity of receptors as negligible. Therefore, the significance of the effect of changes in water quality is concluded to be of **negligible (not significan**t) in terms of the EIA regulations.

11.8 Cumulative Impact Assessment

11.8.1 Cumulative effects can be defined as effects upon a single receptor when those from the Project are 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. A screening process has identified a number of reasonably foreseeable projects and developments which may act cumulatively with the Project. The full list of such projects that have been identified in relation to the offshore environment are set out in. Volume 2, Appendix 5.1: Cumulative Impact Assessment Methodology.

11.8.2 In assessing the potential cumulative impacts for the Project, it is important to consider 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.

11.8.3 With this in mind, all projects and plans considered alongside the Project 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 is intended to ensure that there is a clear understanding of the level of confidence in the cumulative effects assessment (CEA). An explanation of each tier is included in Table 11.37. This tier structure is in line with that recommended by Natural England (2022).

Table 11.37: Description of tiers of other developments considered within the marine mammal cumulative effect assessment (Natural England, 2022).

Tier	Consenting or construction stage
1	Built and operational projects should be included within the cumulative assessment where they have not been included within the environmental characterisation survey, i.e. they were not operational when baseline surveys were undertaken, and/or any residual impact may not have yet fed through to and been captured in estimates of “baseline” conditions.
2	Projects under construction.
3	Projects that have been consented (but construction has not yet commenced).
4	Projects that have an application submitted to the appropriate regulatory body that have not yet been determined.
5	Projects that have produced a PEIR and have characterisation data within the public domain.
6	Projects that the regulatory body are expecting an application to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects).
7	Projects that have been identified in relevant strategic plans or programmes.

Screening Projects

11.8.4 The projects and plans selected as relevant to the assessment of impacts to marine mammals are based upon an initial screening exercise undertaken on a long list. Each project, plan or activity has been considered and screened in or out on the basis of effect–receptor pathway, data confidence and the temporal and spatial scales involved. In order to create the CEA long list, a Zone of Influence (ZoI) has been applied to screen in relevant offshore projects. The ZoI for marine mammals is the species-specific MU (North Sea MU for porpoise, Greater North Sea MU for bottlenose dolphins, Celtic and Greater North Seas MU for white-beaked dolphins and minke whales, Southeast England MU for harbour seals, combined Southeast and Northeast MUs for grey seals).

11.8.5 The time period considered in the CEA for marine mammals is 2022-2032 inclusive. This allows for the quantification of impacts to the MUs both prior to the construction of the Project (since the baseline was collated) and during the potential construction window for the Project (the potential construction window for the Project is expected to be: UXO clearance in 2026 and piling in 2027-2029 inclusive).

11.8.6 The CEA methodology and long-list are described in Volume 2, Appendix 5.1: Cumulative Effects Assessment Methodology. The long-list of projects, plans and activities was used to generate a list of projects initially screened into the marine mammal CEA. The long-list of projects was screened to remove all projects that have:

- no data available;
- no timeline available;
- no conceptual effect-receptor pathway;
- no physical effect-receptor overlap; and
- no temporal overlap.

11.8.7 Subsequently, the following offshore project types were screened out of the marine mammal CEA short list:

- Wave developments (none constructing between 2026-29);
- Cables and pipelines (all operational: ongoing impact and part of the baseline);
- Commercial fisheries (all operational: ongoing impact and part of the baseline);
- Shipping (all active: ongoing impact and part of the baseline);
- Aggregates (all operational: ongoing impact and part of the baseline);
- Oil and Gas (all active: ongoing impact and part of the baseline);
- Military, Aviation & Radar (all active: ongoing impact and part of the baseline); and
- Coastal (all active: ongoing impact and part of the baseline).

11.8.8 The marine mammal CEA short list therefore consists of the following offshore project types:

- Offshore windfarms;
- Tidal developments; and
- Oil and Gas seismic surveys (including for Carbon Capture and Storage).

Table 11.38: Marine mammal CEA short list. HP = harbour porpoise, BND = bottlenose dolphin, WD = white-beaked dolphin, MW = minke whale, HS = harbour seal and GS = grey seal. 'Y' indicates that the project is within the species-specific MU, 'N' indicates that the project is not within the species-specific MU (and is thus screened out for that specific species)

Project	Type	Status	IA?[31]	Tier	HP	BD	WD	MW	HS	GS
The Project	OWF	-	-	-	y	y	y	y	y	y
Awel y Môr	OWF	Application submitted	ES	4	n	n	y	y	n	n
Blyth Demonstration Phases 2&3	OWF	Consented	ES	3	y	y	y	y	n	y
Borkum Riffgrund 3	OWF	Approved	No	3	y	y	y	y	n	n
CampionWind Shell Wind Energy SPR E2	OWF	Pre-planning Application	No	6	y	y	y	y	n	n
Clogherhead	OWF	Concept/ Early Plan	No	6	n	n	y	y	n	n
Cluaran Deas Ear DEME E3	OWF	Pre-planning Application	No	6	y	y	y	y	n	n
Courseulles-sur-mer	OWF	Consented	No	3	y	y	y	y	n	n
Dogger Bank C	OWF	Under construction	ES	2	y	y	y	y	y	y
Dieppe - Le Treport	OWF	Consented	ES	3	y	y	y	y	n	n
Dudgeon Extension	OWF	Application submitted	ES	4	y	y	y	y	y	y
East Anglia 1N	OWF	Consented	ES	3	y	y	y	y	y	y
East Anglia 2	OWF	Consented	ES	3	y	y	y	y	y	y
East Anglia 3	OWF	Consented	ES	3	y	y	y	y	y	y
EnBW He Dreiht	OWF	Consented	No	3	y	y	y	y	n	n
Endurance	OWF	Concept/ Early Plan	No	6	y	y	y	y	y	y
Fecamp	OWF	Consented	No	3	y	y	y	y	n	n
Five Estuaries	OWF	Pre-planning Application	PEIR	5	y	y	y	y	y	y
Forthwind Ltd	OWF	Planned	No	6	y	y	y	y	n	n
Gode Wind 3	OWF	Consented	No	3	y	y	y	y	n	n
Hollandse Kust Nord	OWF	Under construction	No	2	y	y	y	y	n	n
Hollandse Kust (West)	OWF	Planned	No	6	y	y	y	y	n	y
Hornsea 3	OWF	Consented	ES	3	y	y	y	y	y	y
Hornsea 4	OWF	Application submitted	ES	4	y	y	y	y	y	y
Inch cape	OWF	Under construction	ES	2	y	y	y	y	n	n
Kilmichael Point	OWF	Concept/ Early Plan	6	6	n	n	y	y	n	n
Llyr 1 Cierco Ltd.,SBM Offshore N.V.	OWF	Pre-planning Application	No	5	n	n	y	y	n	n
Llyr 2 Cierco Ltd.,SBM Offshore N.V.	OWF	Pre-planning Application	No	5	n	n	y	y	n	n
Moray West	OWF	Consented	ES	3	y	y	y	y	n	n

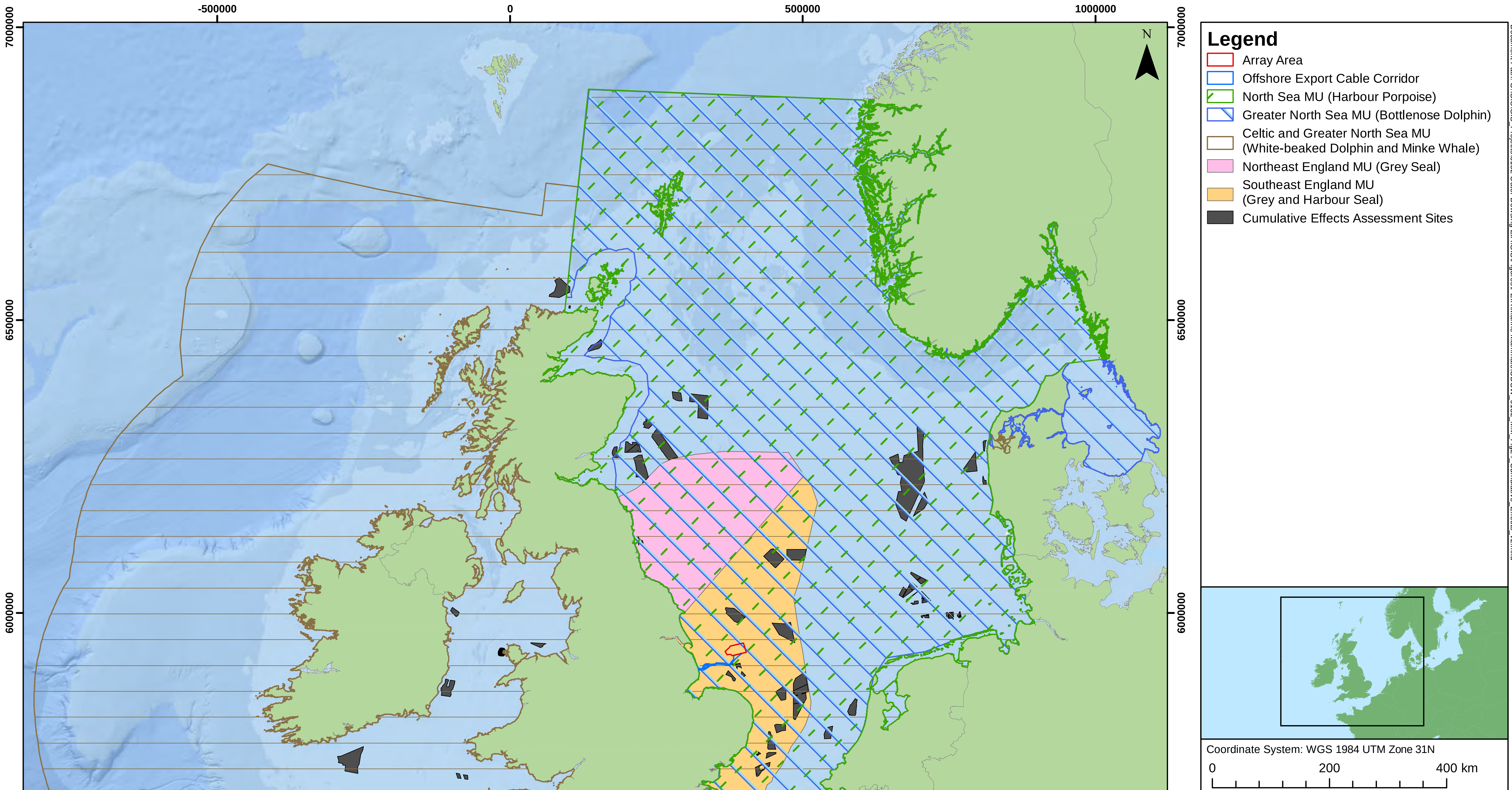
[31] Denotes whether or not the results of a quantitative impact assessment (ES or PEIR) were available to use in this CEA

Project	Type	Status	IA?[31]	Tier	HP	BD	WD	MW	HS	GS
Morven BP E1	OWF	Pre- planning Application	No	6	y	y	y	y	n	n
Muir Mhor	OWF	Pre-planning application	No	6	y	y	y	y	n	n
N-10.1	OWF	Planned	No	6	y	y	y	y	n	n
N-10.2	OWF	Planned	No	6	y	y	y	y	n	n
N-3.5 North Sea Cluster – Nordsee Three	OWF	Planned	No	6	y	y	y	y	n	n
N-3.6 North Sea Cluster – Delta Nordsee 1&2	OWF	Planned	No	6	y	y	y	y	n	n
N-3.7 North Sea Cluster – Gode Wind	OWF	Planned	No	6	y	y	y	y	n	n
N-3.8 North Sea Cluster – Nordsee Two	OWF	Planned	No	6	y	y	y	y	n	n
N-6.6 Atlantis 1	OWF	Planned	No	6	y	y	y	y	n	n
N-6.7	OWF	Planned	No	6	y	y	y	y	n	n
N-7.2 Global Tech II	OWF	Planned	No	6	y	y	y	y	n	n
N-9.1	OWF	Planned	No	6	y	y	y	y	n	n
N-9.2	OWF	Planned	No	6	y	y	y	y	n	n
N-9.3	OWF	Planned	No	6	y	y	y	y	n	n
Nordsoen II vest	OWF	Planned	No	6	y	y	y	y	n	n
Nordsoen III vest	OWF	Planned	No	6	y	y	y	y	n	n
Norfolk Boreas	OWF	Consented	ES	3	y	y	y	y	y	y
Norfolk Vanguard East	OWF	Consented	ES	3	y	y	y	y	y	y
Norfolk Vanguard West	OWF	Consented	ES	3	y	y	y	y	y	y
North Falls	OWF	Pre-planning Application	No	6	y	y	y	y	y	y
Parc eolien pose au large de la Normadie (AO4)	OWF	Planned	No	6	y	n	y	y	n	n
Pentland floating demonstrator	OWF	Application submitted	ES	4	y	y	y	y	n	n
Perpetuus Tidal Energy	OWF	Approved	No	3	y	n	y	y	n	n
Rampion 2	OWF	Pre-planning Application	PEIR	5	y	n	y	y	y	y
SeaGreen Alpha	OWF	Under Construction	ES	2	y	y	y	y	n	n
SeaGreen Bravo	OWF	Under construction	ES	2	y	y	y	y	n	n
Seagreen Charlie (Berwick Bank)	OWF	Application submitted	ES	4	y	y	y	y	n	n
Shelmalere	OWF	Pre-planning Application	No	6	n	n	y	y	n	n
Sheringham Shoal Extension	OWF	Application submitted	ES	4	y	y	y	y	y	y
Sofia	OWF	Under Construction	ES	2	y	y	y	y	y	y
Thor	OWF	Concept/ Early plan	No	6	y	y	y	y	n	n
Vesterhav Nord/Syd	OWF	Consented	No	3	y	y	y	y	n	n
West Anglesey Demonstration Zone (Morlais)	Tidal	Consented	ES	3	n	n	y	y	n	n
West of Orkney	OWF	Pre-planning Application	No	6	y	y	y	y	n	n

Table 11.39: Offshore construction programme for each project in the marine mammal CEA short list. P = years in which piling activities are expected, C = years in which tidal projects are expected to be constructing, U = years in which UXO clearance is expected

Project	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
The Project					U	P	P	P		
Awel y Môr							U	P	P	
Blyth Demo Phases 2&3	U	P	P	P						
Borkum Riffgrund 3		U	P	P						
Campion			U	P	P	P	P			
Clogherhead						U	P	P	P	P
Cluaran Deas Ear DEME E3			U	P	P	P	P			
Courseulles-sur-mer	U	P								
Dogger Bank C			U	P	P	P				
Dieppe - Le Treport	U	P								
Dudgeon Extension				U	P					
East Anglia 1N				U	P	P	P			
East Anglia 2			U	P	P	P				
East Anglia 3			U	P	P	P				
EnBW He Dreiht		U	P							
Endurance		U	P	P						
Fecamp	U	P								
Five Estuaries					U	P	P	P	P	
Forthwind Ltd			U	P	P	P	P			
Gode Wind 3		U	P	P						
Hollandse Kust Nord	U	P								
Hollandse Kust (West)			U	P						
Hornsea 3			U	U		P				
Hornsea 4					U	P	P			
Inch cape	U	P								
Kilmichael Point						U	P	P	P	P
Llyr 1 Cierco Ltd.,SBM	P	P	P	P	P	P				
Llyr 2 Cierco Ltd.,SBM	P	P	P	P	P	P				
Moray west		U	P							
Morven BP E1			U	P	P	P	P			
Muir Mhor									U	P
N-10.1							U	P		
N-10.2							U	P		
N-3.5						U	P			
N-3.6					U	P				
N-3.7			U	P						
N-3.8			U	P						
N-6.6					U	P				
N-6.7					U	P				
N-7.2				U	P					
N-9.1						U	P			
N-9.2						U	P			
N-9.3					U	P				
Nordsoen II vest		U	P							
Nordsoen III vest		U	P							
Norfolk Boreas				U	P	P	P			

Project	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Norfolk Vanguard East		U	P	P						
Norfolk Vanguard West		U	P	P						
North Falls				U	P	P	P			
Parc eolien			U	P	P					
Pentland		U	P	P	P					
Perpetuus Tidal Energy		U	C							
Rampion 2		U	P	P	P	P	P			
SeaGreen Alpha	U	P								
SeaGreen Bravo	U	P								
Seagreen Charlie (Berwick Bank)		U	P	P						
Shelmalere	P	P	P	P	P	P				
Sheringham Shoal Extension				U	P					
Sofia			U	P						
Thor			U	P	P	P				
Vesterhav Nord/syd	U	P								
Morlais							U	C	C	
West of Orkney					U	P	P	P		



Preliminary Environmental Information Report

Projects screened into marine mammal CEA

Figure 11.24

OUTER DOWSING OFFSHORE WIND

Date: 17/04/2023
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Revision: 0.1

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Screening Impacts

11.8.9 Certain impacts assessed for the Project alone are not considered in the marine mammal CEA due to:

- the highly localised nature of the impacts;
- management and mitigation measures in place at the Project and on other projects will reduce the risk occurring; and
- where the potential significance of the impact from the Project alone has been assessed as negligible.

11.8.10 The impacts excluded from the marine mammal CEA for these 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);
- Collision with vessels: it is expected that all offshore energy projects will employ a VMP or follow best practice guidance to reduce the already low risk of collisions with marine mammals;
- Changes in water quality: highly localised and negligible significance;
- Changes in prey availability: highly localised and negligible significance; and
- Barrier effects/operational noise: highly localised and negligible significance.

11.8.11 Therefore, the impacts that are considered in the marine mammal CEA are as follows:

- The potential for disturbance from underwater noise during construction and decommissioning of offshore energy developments; and
- The potential for disturbance from vessel activity during construction, operation and decommissioning of offshore energy developments.

Disturbance from underwater noise

Method

UXO clearance

11.8.12 For all offshore projects that had a quantitative impact assessment available for UXO clearance (PEIR or ES chapter), the maximum number of animals predicted to be disturbed was obtained from the project-specific assessment and used in this CEA for that specific project.

11.8.13 For all projects that have no quantitative impact assessment available (PEIR or ES chapter), a 26km EDR was assumed for high order UXO clearance, based on the guidance in JNCC (2020). The density of cetaceans used to calculate the number of animals impacted was the relevant SCANS III block-wide density estimate for each project. The density of harbour and grey seals used to calculate the number of animals impacted was the average habitat preference at-sea usage estimate throughout the array area for each project.

Piling for OWF

11.8.14 For all offshore projects that had a quantitative impact assessment for pile driving available (PEIR or ES chapter), the maximum number of animals predicted to be disturbed was obtained from the project-specific assessment and used in this CEA for that specific project.

11.8.15 For all projects that have no quantitative impact assessment available (PEIR or ES chapter), a 26km EDR was assumed for disturbance for monopiles, 15km EDR for pin-piles and 15km for mitigated piling (in EU waters), based on the guidance in JNCC (2020). The density of cetaceans used to calculate the number of animals impacted was the relevant SCANS III block wide density estimate for each project. The density of harbour and grey seals used to calculate the number of animals impacted was the average habitat preference at sea usage estimate throughout the array area for each project.

Tidal Projects

11.8.16 For tidal projects it is assumed there will be no pile driving. Therefore, construction-related impacts are limited to a 5km EDR, as per the project alone assessment for other construction related noise.

Seismic surveys

11.8.17 The potential number of seismic surveys that could be undertaken is unknown[32]. Therefore, it has been assumed that four seismic surveys could be conducted within the North Sea at any one time (to account for concurrent surveys in the northern and southern North Sea in both UK waters and those of neighbouring North Sea nations). It has been assumed that the EDR for seismic surveys is 12km as per the advice provided in JNCC (2020). It is considered that this approach is sufficiently precautionary (i.e. it is unlikely that this number of seismic surveys will be occurring concurrently, less so concurrently with the Project construction).

11.8.18 It is acknowledged that seismic surveys are a moving sound source and not a point source. Therefore, data on shooting statics provided by Sarah Canning (JNCC, pers. Comm, Nov. 2022) was used to provide an indicative distance travelled while shooting. The mean distance travelled while shooting for 3D seismic surveys between 2011 and 2020 was 116 km. Therefore, it has been assumed that a seismic survey vessel travelling 116km of survey line while shooting in a single 24 hr period and therefore impact an area of 3,236km^2 per day.

11.8.19 To estimate the number of cetaceans predicted to be disturbed from seismic surveys in the North Sea, the average density across each species-specific MU was calculated:

- For porpoise: abundance in North Sea MU (346,601)/area of MU (680,487km^2) = 0.51 porpoise/km^2.
- For bottlenose dolphins: abundance in Greater North Sea MU (2,022)/area of MU (642,520km^2) = 0.003 dolphins/km^2
- For white-beaked dolphins: abundance in Celtic & Greater North Sea MU (43,951)/area of MU (1,568,078km^2) = 0.028 dolphins/km^2

[32] Maps from the Marine Noise Registry were examined but it was not possible to extract information on the number of seismic surveys occurring concurrently in the North Sea on any one day.

- For minke whales: abundance in Celtic & Greater North Sea MU (20,118)/area of MU (1,568,078km^2) = 0.013 whales/km^2

11.8.20 To estimate the number of harbour and grey seals predicted to be disturbed by seismic surveys in the North Sea, the average habitat preference at-sea usage estimate throughout the MU was used (this is highly conservative since seals are generally in higher densities closer to shore, whereas seismic surveys tend not to occur close to shore). Given that the MUs for seals are smaller than that for harbour porpoise, it was assumed that the CEA for both harbour and grey seals would incorporate only two seismic survey operations within their respective MUs at any one time.

Precaution in the CEA

11.8.21 A combination of uncertainties in project timelines and the need to apply precautionary assumptions leads to significant levels of precaution within this CEA which results in highly precautionary and unrealistic estimates of effects. The main areas of precaution in the assessment include:

- The number of developments active at the same time (clearing UXOs, piling or surveying). For example, the maximum level of disturbance to porpoise across Tier 1-7 projects would require that 29 offshore windfarm developments and four seismic surveys are all active at the same time. This is considered to be extremely unrealistic.
- The inclusion of lower tier developments. In reality, the best information in terms of construction timeline is available for Tier 1-3 projects which have consent. By including projects that have no consent, no ES chapter or no submitted information at all (Tiers 4-7) then worst-case scenarios have to be assumed in the absence of other information.
- The assumption that UXO clearance or pile driving can occur at any point throughout the construction window for each development. This results in most projects having UXO and piling activities occurring over multiple consecutive years. For example, the piling window for the Project is listed as 2027-2029 (which results in three years of potential impact in the CEA); however, piling would only occur within a one-year period within this window. Since the exact timing of the UXO and piling activities within the respective development construction windows is unknown, it had to be assumed that it could occur at any point, thus resulting in piling schedules and subsequent disturbance levels that are far greater than would ever occur in reality.
- The assumption that all OWF developments will install pile-driven monopile foundations. The project envelope for most of these developments includes options for pin-piles or monopiles. As a worst case, monopiles have been assumed; however, it is likely that a portion of these projects will use jacket foundations with pin-piles, which have a much lower recommended effective deterrence range (15km instead of 26km) (JNCC, 2020), and are therefore considered to disturb far fewer animals.

Harbour porpoise – Disturbance from underwater noise

11.8.22 The potential number of harbour porpoise disturbed per day by project is provided in Table 11.40.

11.8.23 A summary of the total disturbance impact to harbour porpoise per day by Tier, is provided in Table 11.41.

11.8.24 A summary of the total disturbance impact to harbour porpoise per day across all projects in Tier 1-3 is provided in Figure 11.25 Figure 11.25.

11.8.25 Across all years considered in the CEA (2022-2031 inclusive) and all Tiers (1-7), the period with highest level of predicted disturbance to harbour porpoise is in 2027, during the first year of piling at the Project.

11.8.26 When considering the potential impact from the Project in addition to all Tier 1-3 projects (those consented and thus with higher levels of data confidence), the highest level of predicted disturbance to harbour porpoise across the North Sea MU is in 2027, when the Project alongside several other projects are constructing. At this time, a maximum of 20,078 porpoise (5.8% MU) may be disturbed per day, of which, only 20% is disturbance from the Project (assuming all Tier 1-3 projects are constructing at the same time, and that disturbance is additive across projects i.e. no overlapping disturbance footprints).

Table 11.40: Number of harbour porpoise potentially disturbed by underwater noise by project (UXO and piling)

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	The Project						5044	3981	3981	3981		
OWF	Blyth Demo	3	1272	47	47	47						
OWF	Borkum Rifgrund 3	3		592	592	592						
OWF	Campion	6			423	423	423	423	423			
OWF	Cluaran Deas Ear	6			1272	1272	1272	1272	1272			
OWF	Courseulles-sur-mer	3	151	151								
OWF	Dogger Bank C	2			0	1920	1920	1920				
OWF	Dieppe - Le Treport	3	151	151								
OWF	Dudgeon Ext	4				5161	5161					
OWF	East Anglia 1N	3				1551	1551	1551	1551			
OWF	East Anglia 2	3			1551	1551	1551	1551				
OWF	East Anglia 3	3			NA	3825	3825	3825				
OWF	EnBW He Dreidt	3		196	196							
OWF	Endurance	6		70	70	70						
OWF	Fecamp	3	151	151								
OWF	Five Estuaries	5					3865	7031	7031	7031	7031	
OWF	Forthwind	6			1272	1272	1272	1272	1272			
OWF	Gode Wind3	3		196	196	196						
OWF	Hollandse Kust Nord	2	592	592								
OWF	Hollandse Kust West	6			592	592						
OWF	Hornsea 3	3			1896	1896		4999				
OWF	Hornsea 4	4					3394	6417	6417			
OWF	Inch Cape	2	NA	261								
OWF	Moray West	3		NA	1377							
OWF	Morven BP E1	6			1272	1472	1472	1472	1472			
OWF	Muir Mhor	6									423	423
OWF	N-10.1	6							196	196		
OWF	N-10.2	6							196	196		
OWF	N-3.5	6						196	196			
OWF	N-3.6	6					196	196				
OWF	N-3.7	6			196	196						

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	N-3.8	6			196	196						
OWF	N-6.6	6					592	592				
OWF	N-6.7	6					592	592				
OWF	N-7.2	6				196	196					
OWF	N-9.1	6						592	592			
OWF	N-9.2	6						592	592			
OWF	N-9.3	6					196	196				
OWF	Nordsren II Vest	6		582	582							
OWF	Nordsren III Vest	6		582	582							
OWF	Norfolk Boreas	3				2251	2251	2251	2251			
OWF	Norfolk Vanguard E	3		2676	2676	2676						
OWF	Norfolk Vanguard W	3		2676	1886	1886						
OWF	North Falls	6				1289	1289	1289	1289			
OWF	Parc Eolien	6			151	151	151					
OWF	Pentland	4		151	641	641	641					
Tidal	PTEC	3		17	17							
OWF	Rampion 2	5		452	633	633	633	633	633			
OWF	SeaGreen Alpha	2	NA	2113								
OWF	SeaGreen Bravo	2	NA	2391								
OWF	Seagreen Charlie (Berwick Bank)	4		995	1754	1754						
OWF	Sheringham Ext	4				3101	1338					
OWF	Sofia	2			NA	2035						
OWF	Thor	6			196	196	196	196				
OWF	Vesterhav Nord/syd	3	196	196								
OWF	West of Orkney	6							654	654	654	
SS	Seismic Survey 1	7	1648	1648	1648	1648	1648	1648	1648	1648	1648	1648
SS	Seismic Survey 2	7	1648	1648	1648	1648	1648	1648	1648	1648	1648	1648
SS	Seismic Survey 3	7	1648	1648	1648	1648	1648	1648	1648	1648	1648	1648
SS	Seismic Survey 4	7	1648	1648	1648	1648	1648	1648	1648	1648	1648	1648

Table 11.41: Total number of harbour porpoise disturbed by underwater noise across the Tiers. Results including lower Tier projects with lower data confidence are denoted by grey text.

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2022	0	0.0%	2513	0.7%	2513	0.7%	9105	2.6%
2023	0	0.0%	12406	3.6%	13552	3.9%	21830	6.3%
2024	0	0.0%	10434	3.0%	12829	3.7%	26858	7.7%
2025	0	0.0%	20426	5.9%	31083	9.0%	45633	13.2%
2026	5044	1.5%	16142	4.7%	26676	7.7%	45613	13.2%
2027	3981	1.1%	20078	5.8%	26495	7.6%	49631	14.3%
2028	3981	1.1%	7783	2.2%	14200	4.1%	36610	10.6%
2029	3981	1.1%	3981	1.1%	3981	1.1%	18650	5.4%
2030	0	0.0%	0	0.0%	0	0.0%	14700	4.2%
2031	0	0.0%	0	0.0%	0	0.0%	7015	2.0%
Min 2026-29	3981	1.1%	3981	1.1%	3981	1.1%	18650	5.4%
Max 2026-29	5044	1.5%	20078	5.8%	26676	7.7%	49631	14.3%
Max 2022-31	5044	1.5%	20426	5.9%	31083	9.0%	49631	14.3%

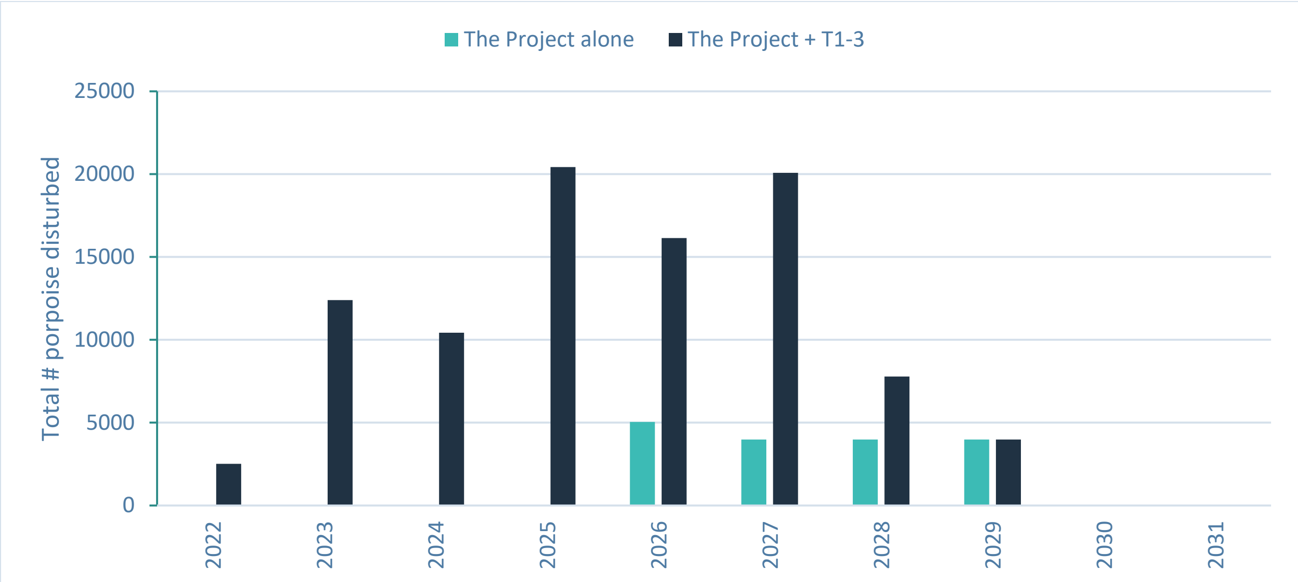

Figure 11.25: Cumulative underwater noise disturbance estimates to harbour porpoise for the Project alone and the Project in addition to Tier 1-3 projects.

11.8.27 There are significant levels of precaution built into this CEA which makes the resulting estimates highly precautionary and unrealistic. The main areas of precaution in the assessment include those listed previously (Paragraph 11.8.21), plus those specific to harbour porpoise:

- The assumption that all porpoise within a 26km range are disturbed. Pile driving activities at other offshore windfarms have shown that this assumption of total displacement within 26km of pile driving is a significant over-estimate. At Beatrice, there was only a 50% probability of response at 7.4km and a 28% response within 26km for the first location piled, with decreasing response levels over the construction period to 50% probability of response at only 1.3km by the final location (Figure 11.26Figure 11.26Figure 11.26) (Graham *et al*., 2019). Likewise, pile driving at the first seven large-scale offshore windfarms in the German Bight (including unmitigated piling) found declines in porpoise activity out to only 17km, with unmitigated piling in isolation also illustrating only weak declines beyond approximately 17km (Brandt *et al*., 2018).

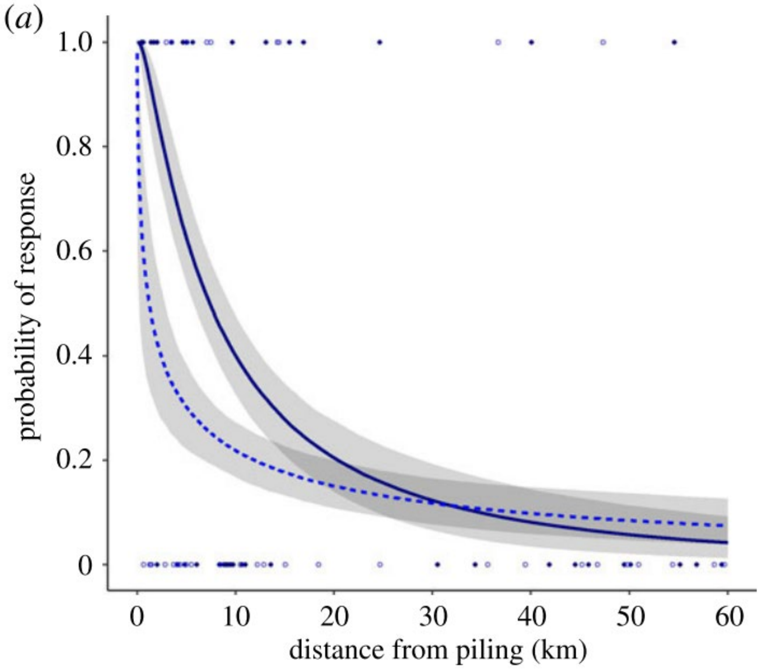

Figure 11.26: The probability of harbour porpoise response (in the 24 h following the end of piling) in relation to the partial contribution of distance from piling for the first location piled (solid navy line) and the final location piled (dashed blue line) (Graham *et al*., 2019)

11.8.28 Although the estimate of cumulative impact of disturbance from underwater noise is considered to be highly precautionary (for the reasons listed above), there remains the potential for the cumulative increase in disturbance from construction activities across these developments to result in individuals experiencing multiple successive days of disturbance. Assuming that disturbance results in a period of zero energy intake, there is the potential for high levels of repeated disturbance to lead to a reduction in calf survival and potentially an effect on adult fertility (see Booth *et al*., 2019 for further details).

11.8.29 The number of animals predicted to be impacted in this CEA (though acknowledging that this is a vast over-estimate) could potentially result in 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 likely not enough to affect the population trajectory over a generational scale. For example, previous population modelling (using iPCoD) of offshore windfarms in eastern English waters has demonstrated low probabilities of population-level impacts, even when 16 piling operations were modelled over a 12-year period (disturbing up to a total of 34,396 porpoise per day) (Booth *et al*., 2017).

11.8.30 Similarly, the DEPONS model found that the North Sea porpoise population was unlikely to be significantly impacted by construction of 65 windfarms over a 10-year period, unless impact ranges were assumed to be much larger (exceeding 50km) than that indicated by existing studies (Nabe-Nielsen *et al*., 2018). Therefore, given that impacts are likely not enough to affect the population trajectory over a generational scale, the magnitude of the cumulative disturbance from underwater noise is Medium (adverse).

11.8.31 The sensitivity of harbour porpoise to disturbance from both piling and UXO clearance has been assessed as Low. The same has been assumed here for disturbance from seismic surveys.

11.8.32 Therefore, the effect significance of disturbance to harbour porpoise from the cumulative impact of underwater noise is **Minor (not significant)** in EIA terms.

Bottlenose dolphin – Disturbance from underwater noise

11.8.33 Of the 53 projects screened into the CEA for bottlenose dolphins, 25 projects were in a location where the SCANS III block-wide density estimate is 0.00 dolphins/km2 (blocks C, L, M, N, O); therefore, these projects were not included further in this CEA. In addition, nine projects within the bottlenose dolphin MU scoped bottlenose dolphins out of their project-specific EIAs (Dogger Bank C, Sofia, East Anglia projects, Norfolk Vanguard, Norfolk Boreas and Hornsea 3) and therefore these projects were not included further in this CEA. This left a total of 19 OWF projects plus four seismic surveys included in the bottlenose dolphin CEA (Table 11.42).

11.8.34 The potential number of bottlenose dolphins disturbed per day by project is provided in Table 11.42.

11.8.35 A summary of the total disturbance impact to bottlenose dolphins per day by Tier, is provided in Table 11.43.

11.8.36 A summary of the total disturbance impact to bottlenose dolphins per day across all projects in Tier 1-3 is provided in Figure 11.27Figure 11.27.

11.8.37 Across all years considered in the CEA (2022-2031 inclusive), and all Tiers (1-7), the period with highest level of predicted disturbance to bottlenose dolphins is in 2024, which is two years before offshore UXO clearance is anticipated to commence at the Project.

11.8.38 When considering the potential impact from the Project in addition to all Tier 1-3 projects (those consented and thus with higher levels of data confidence), the highest level of predicted disturbance to bottlenose dolphins across the MU is in 2026 when pre-construction UXO clearance is occurring at the Project. At this time, a maximum of 67 dolphins (3.3% MU) may be disturbed per day of which, only 6% is disturbance from the Project (assuming all Tier 1-3 projects are constructing at the same time, and that disturbance is additive across projects i.e. no overlapping disturbance footprints).

11.8.39 There are significant levels of precaution built into this CEA which makes the resulting estimates highly precautionary and unrealistic. The main areas of precaution in the assessment include those listed previously (Paragraph 11.8.21), plus those specific to bottlenose dolphins. A key source of precaution in this assessment is that the harbour porpoise dose-response function and harbour porpoise EDRs have been used for bottlenose dolphins, as there is no bottlenose dolphin-specific equivalent. Harbour porpoise have a lower auditory injury threshold (i.e. higher hearing sensitivity) than bottlenose dolphins (Southall *et al*., 2019) and are considered to be particularly responsive to anthropogenic disturbance, with playback experiments showing avoidance reactions to very low levels of sound (Tyack, 2009) and multiple studies showing that porpoise respond (avoidance and reduced vocalisation) to a variety of anthropogenic noise sources to distances of multiple kilometres (e.g., Brandt *et al*., 2013, Thompson *et al*., 2013, Tougaard *et al*., 2013, Brandt *et al*., 2018, Sarnocinska *et al*., 2019, Thompson *et al*., 2020, Benhemma-Le Gall *et al*., 2021).

11.8.40 Studies have shown that dolphin species show comparatively less of a disturbance response from underwater noise compared to harbour porpoise. For example, through an analysis of 16 years of marine mammal observer data from seismic survey vessels, Stone *et al*., (2017) found a significant reduction in porpoise detection rates when large seismic airgun arrays were actively firing, but not for bottlenose dolphins. While the strength and significance of responses varied between porpoise and other dolphin species for different measures of effect, the study emphasised the sensitivity of the harbour porpoise (Stone *et al*., 2017). In the Moray Firth, bottlenose dolphins have been shown to remain in the impacted area during both seismic activities and pile installation activities (Fernandez-Betelu *et al*., 2021) which highlights a lack of complete displacement response.

11.8.41 Likewise, other high-frequency cetacean species such as striped and common dolphins have been shown to display less of a response to underwater noise signals and construction-related activities compared to harbour porpoise (e.g. Kastelein *et al*., 2006, Culloch *et al*., 2016). Noise modelling in support of UXO clearance impact assessments consistently estimate that, based on differences in hearing sensitivity alone, the anticipated range to the onset of temporary hearing loss (TTS, sometimes used as a proxy for behavioural responses to a single impulse) for harbour porpoise is c. 10-20 times greater than that for dolphins (e.g. Mason and Barnham, 2018, Neart na Gaoithe Offshore Windfarm, 2019). Considering the above, it can be concluded that using porpoise response data as a proxy for bottlenose dolphins is likely to result in an over-estimate of the response for bottlenose dolphins.

11.8.42 The number of animals predicted to be impacted in this CEA (though acknowledging that this is a vast over-estimate) could potentially result in 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 likely not enough to affect the population trajectory over a generational scale. Given that impacts are likely not enough to affect the population trajectory over a generational scale, the magnitude of the cumulative disturbance from underwater noise is Medium (adverse).

11.8.43 The sensitivity of bottlenose dolphins to disturbance from both piling and UXO clearance has been assessed as Low. The same has been assumed here for disturbance from seismic surveys.

11.8.44 Therefore, the effect significance of disturbance to bottlenose dolphins from the cumulative impact of underwater noise is **Minor (not significant)** in EIA terms.

Table 11.42: Number of bottlenose dolphins potentially disturbed by underwater noise by project (UXO and piling)

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	the Project						4	3	3	3		
OWF	Blyth Demo	3	63	2	2	2						
OWF	Campion	6			21	21	21	21	21			
OWF	Cluaran Deas Ear	3			63	63	63	63	63			
OWF	Dudgeon Ext	4				2	0					
OWF	Forthwind	6			63	63	63	63	63			
OWF	Hornsea 4	4					6	14	14			
OWF	Inch Cape	2	NA	7								
OWF	Moray West	3		NA	14							
OWF	Morven BP E1	6			63	63	63	63	63			
OWF	Muir Mhor	6									21	21
OWF	Nordsren II vest	6		2	2							
OWF	Nordsren III vest	6		2	2							
OWF	Pentland	4		5	6	6	6					
OWF	SeaGreen Alpha	2	NA	7								
OWF	SeaGreen Bravo	2	NA	5								
OWF	Seagreen Charlie (Berwick Bank)	4		0	64	64						
OWF	Sheringham Ext	4				2	0					
OWF	West of Orkney	6							8	8	8	
SS	Seismic Survey 1	7	10	10	10	10	10	10	10	10	10	10
SS	Seismic Survey 2	7	10	10	10	10	10	10	10	10	10	10
SS	Seismic Survey 3	7	10	10	10	10	10	10	10	10	10	10
SS	Seismic Survey 4	7	10	10	10	10	10	10	10	10	10	10

Table 11.43: Total number of bottlenose dolphins disturbed by underwater noise across the Tiers. Results including lower Tier projects with lower data confidence are denoted by grey text.

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2022	0	0.0%	63	3.1%	63	3.1%	103	5.1%
2023	0	0.0%	21	1.0%	26	1.3%	70	3.5%
2024	0	0.0%	79	3.9%	149	7.4%	340	16.8%
2025	0	0.0%	65	3.2%	139	6.9%	326	16.1%
2026	4	0.2%	67	3.3%	79	3.9%	266	13.2%
2027	3	0.1%	66	3.3%	80	4.0%	267	13.2%
2028	3	0.1%	66	3.3%	80	4.0%	275	13.6%
2029	3	0.1%	3	0.1%	3	0.1%	51	2.5%
2030	0	0.0%	0	0.0%	0	0.0%	69	3.4%
2031	0	0.0%	0	0.0%	0	0.0%	61	3.0%
Min 2026-29	3	0.1%	3	0.1%	3	0.1%	51	2.5%
Max 2026-29	4	0.2%	67	3.3%	80	4.0%	275	13.6%
Max 2022-31	4	0.2%	79	3.9%	149	7.4%	340	16.8%

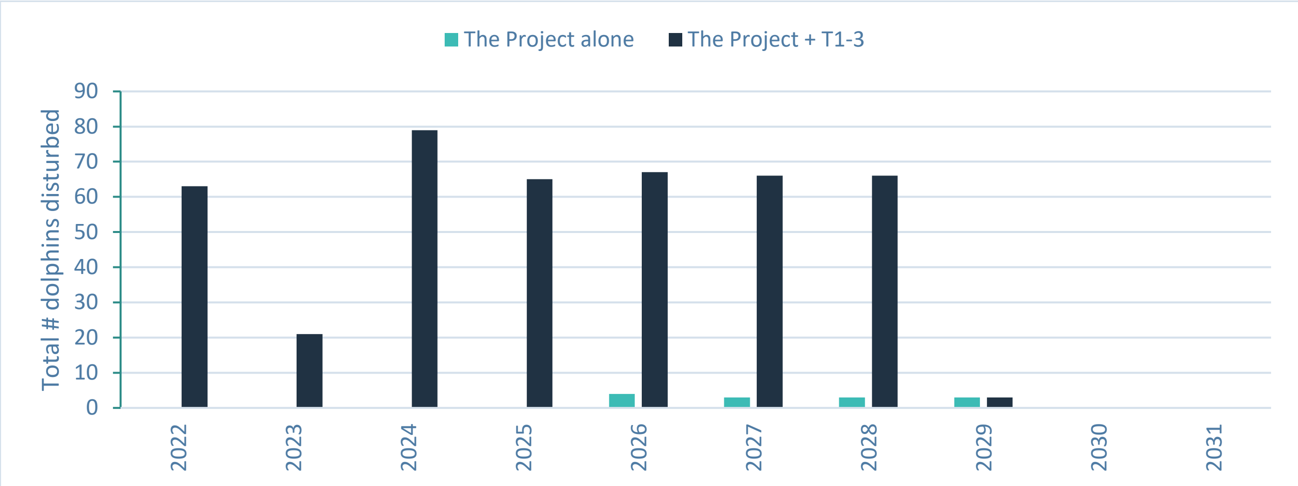

Figure 11.27: Cumulative underwater noise disturbance estimates to bottlenose dolphins for the Project alone and the Project in addition to Tier 1-3 projects.

White-beaked dolphin – Disturbance from underwater noise

11.8.45 Of the 63 projects screened into the CEA for white-beaked dolphins, 31 projects were in a location where the SCANS III block-wide density estimate is 0.00 dolphins/km2 (blocks C, D, E, L, M, N, O); therefore, these projects were not included further in this CEA. In addition, 10 projects within the white-beaked dolphin MU scoped white-beaked dolphins out of their project-specific EIAs (Awel y Mor, Moray West, East Anglia projects, Norfolk Vanguard, Norfolk Boreas, Rampion 2 and Morlais) and therefore these projects were not included further in this CEA. This left a total of 22 OWF projects plus four seismic surveys included in the white-beaked dolphin CEA.

11.8.46 The potential number of white-beaked dolphins disturbed per day by project is provided in Table 11.44.

11.8.47 A summary of the total disturbance impact to white-beaked dolphins per day by Tier, is provided in Table 11.45.

11.8.48 A summary of the total disturbance impact to white-beaked dolphins per day across all projects in Tier 1-3 is provided in Figure 11.28Figure 11.28.

11.8.49 Across all years considered in the CEA (2022-2031 inclusive), and all Tiers (1-7), the period with highest level of predicted disturbance to white-beaked dolphins is in 2024, which is two years before offshore UXO clearance is anticipated to commence at the Project.

11.8.50 When considering the potential impact from the Project in addition to all Tier 1-3 projects (those consented and thus with higher levels of data confidence), the highest level of predicted disturbance to white-beaked dolphins across the MU is in 2027, during the first year of piling at the Project. At this time, a maximum of 13 dolphins (0.0% MU) may be disturbed per day, of which 31% is disturbance from the Project (assuming all Tier 1-3 projects are constructing at the same time, and that disturbance is additive across projects i.e. no overlapping disturbance footprints).

11.8.51 There are significant levels of precaution built into this CEA which makes the resulting estimates highly precautionary and unrealistic. For precaution specific to dolphin species, please see section 11.8.39 et seq. The same over precautions inherent in the bottlenose dolphin assessment are also relevant here for white-beaked dolphins.

11.8.52 The number of animals predicted to be impacted in this CEA (though acknowledging that this is a vast over-estimate) could potentially result in 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 likely not enough to affect the population trajectory over a generational scale. Given that impacts are likely not enough to affect the population trajectory over a generational scale, the magnitude of the cumulative disturbance from underwater noise is Medium (adverse).

11.8.53 The sensitivity of white-beaked dolphins to disturbance from both piling and UXO clearance has been assessed as Low. The same has been assumed here for disturbance from seismic surveys.

11.8.54 Therefore, the effect significance of disturbance to white-beaked from the cumulative impact of underwater noise is **Minor (not significant)** in EIA terms.

Table 11.44: Number of white-beaked dolphins potentially disturbed by underwater noise by project (UXO and piling)

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	the Project						3	4	4	4		
OWF	Blyth Demo	3	19	63	63	63						
OWF	Campion	6			172	172	172	172	172			
OWF	Cluaran Deas Ear	6			516	516	516	516	516			
OWF	Dogger Bank C	2			0	3	3	3				
OWF	Dudgeon Ext	4				0	0					
OWF	Endurance	6		0	0	0						
OWF	Forthwind	6			516	516	516	516	516			
OWF	Hornsea 3	3			43	43		6				
OWF	Hornsea 4	4					37	85	85			
OWF	Inch Cape	2	NA	0								
OWF	Morven BP E1	6			516	516	516	516	516			
OWF	Muir Mhor	6									172	172
OWF	Nordsren II Vest	6		21	21							
OWF	Nordsren III Vest	6		21	21							
OWF	Pentland	4		118	337	337	337					
OWF	SeaGreen Alpha	2	NA	858								
OWF	SeaGreen Bravo	2	NA	971								
OWF	Seagreen Charlie (Berwick Bank)	4		1	516	516						
OWF	Sheringham Ext	4				0	0					
OWF	Sofia	2			NA	3						
OWF	West of Orkney	6							461	461	461	
SS	Seismic Survey 1	7	91	91	91	91	91	91	91	91	91	91
SS	Seismic Survey 2	7	91	91	91	91	91	91	91	91	91	91
SS	Seismic Survey 3	7	91	91	91	91	91	91	91	91	91	91
SS	Seismic Survey 4	7	91	91	91	91	91	91	91	91	91	91

Table 11.45: Total number of white-beaked dolphins disturbed by underwater noise across the Tiers. Results including lower Tier projects with lower data confidence are denoted by grey text.

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2022	0	0.0%	19	0.0%	19	0.0%	383	0.9%
2023	0	0.0%	1892	4.3%	2011	4.6%	2417	5.5%
2024	0	0.0%	106	0.2%	959	2.2%	3085	7.0%
2025	0	0.0%	112	0.3%	965	2.2%	3049	6.9%
2026	3	0.0%	6	0.0%	380	0.9%	2464	5.6%
2027	4	0.0%	13	0.0%	98	0.2%	2182	5.0%
2028	4	0.0%	4	0.0%	89	0.2%	2634	6.0%
2029	4	0.0%	4	0.0%	4	0.0%	829	1.9%
2030	0	0.0%	0	0.0%	0	0.0%	997	2.3%
2031	0	0.0%	0	0.0%	0	0.0%	536	1.2%
Min 2026-29	3	0.0%	4	0.0%	4	0.0%	829	1.9%

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
Max 2026-29	4	0.0%	13	0.0%	380	0.9%	2634	6.0%
Max 2022-31	4	0.0%	1892	4.3%	2011	4.6%	3085	7.0%

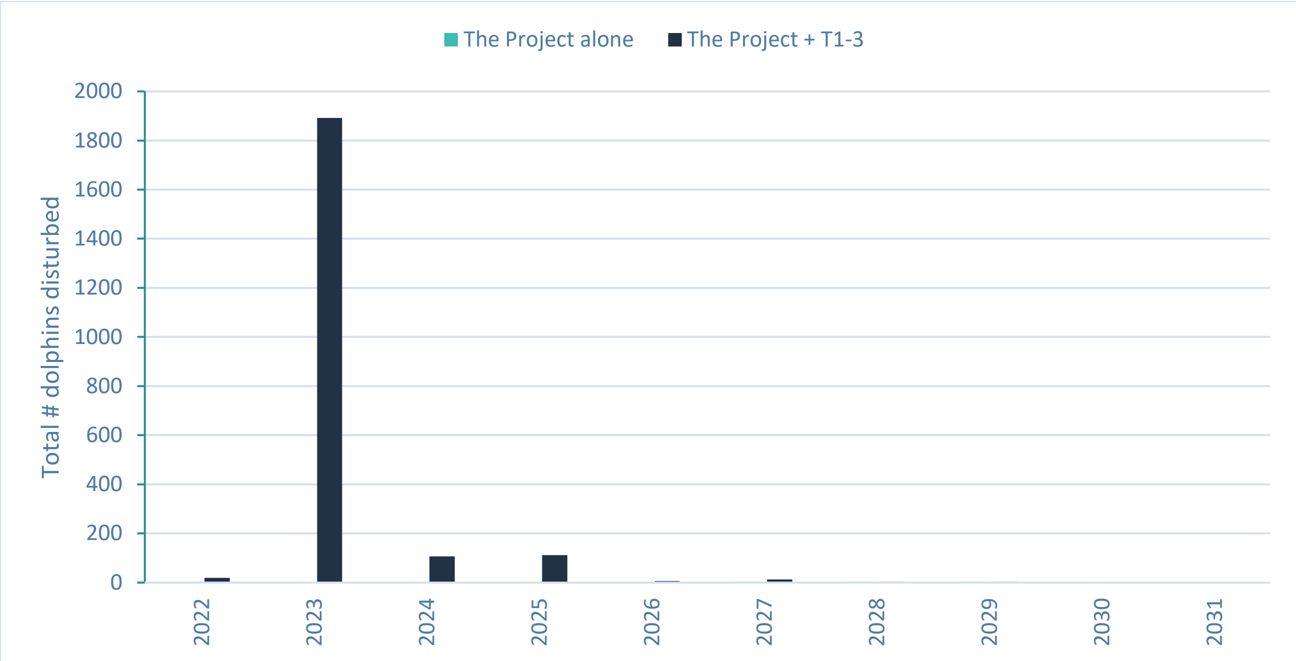

Figure 11.28: Cumulative underwater noise disturbance estimates to white-beaked dolphins for the Project alone and the Project in addition to Tier 1-3 projects.

Minke whale – Disturbance from underwater noise

11.8.55 Of the 63 projects screened into the CEA for minke whales, 14 projects were in a location where the SCANS III block-wide density estimate is 0.00 whales/km2 (blocks L, M); therefore, these projects were not included further in this CEA. In addition, six projects within the MU scoped minke whales out of their project specific EIAs (East Anglia projects, Norfolk Vanguard, Norfolk Boreas) and therefore these projects were not included further in this CEA. This left a total of 43 OWF projects plus four seismic surveys included in the minke whale CEA.

11.8.56 The potential number of minke whales disturbed per day by project is provided in Table 11.46.

11.8.57 A summary of the total disturbance impact to minke whales per day by Tier is provided in Table 11.47.

11.8.58 A summary of the total disturbance impact to minke whales per day across all projects in Tier 1-3 is provided in Figure 11.29Figure 11.29.

11.8.59 Across all years considered in the CEA (2022-2031 inclusive), and all Tiers (1-7), the period with highest level of predicted disturbance to minke whales is in 2025, which is a year before offshore UXO clearance is anticipated to commence at the Project.

11.8.60 When considering the potential impact from the Project in addition to all Tier 1-3 projects (those consented and thus with higher levels of data confidence), the highest level of predicted disturbance to minke whales across the MU is in 2027, during the first year of piling at the Project. At this time, a maximum of 89 whales (0.4% MU) may be disturbed per day, of which 19% is disturbance from the Project (assuming all Tier 1-3 projects are constructing at the same time, and that disturbance is additive across projects i.e. no overlapping disturbance footprints).

11.8.61 There are significant levels of precaution built into this CEA which makes the resulting estimates highly precautionary and unrealistic. In addition to this, this assessment assumes that all activities occur in the summer months when minke whales are present and their density estimates are highest. Given that impacts are likely not enough to affect the population trajectory over a generational scale, the magnitude of the cumulative disturbance from underwater noise is Medium (adverse).

11.8.62 The sensitivity of minke whales to disturbance from both piling and UXO clearance has been assessed as Low. The same has been assumed here for disturbance from seismic surveys.

11.8.63 Therefore, the effect significance of disturbance to minke whales from the cumulative impact of underwater noise is **Minor (not significant)** in EIA terms.

Table 11.46: Number of minke whales potentially disturbed by underwater noise by project (UXO and piling)

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	the Project						21	17	17	17		
OWF	Awel y Mor	4							36	36	36	
OWF	Blyth Demo	3	3	3	3	3						
OWF	Borkum Rifgrund 3	3		14	14	14						
OWF	Campion	6			27	27	27	27	27			
OWF	Clogherhead	6						37	37	37	37	37
OWF	Cluaran Deas Ear	6			82	82	82	82	82			
OWF	Courseulles-sur-mer	3	2	2								
OWF	Dogger Bank C	2			0	34	34	34				
OWF	Dieppe - Le Treport	3	2	2								
OWF	Dudgeon Ext	4				333	11					
OWF	Endurance	6		1	1	1						
OWF	Fecamp	3	2	2								
OWF	Forthwind	6			82	82	82	82	82			
OWF	Hollandse Kust Nord	2	14	14								
OWF	Hollandse Kust West	6			14	14						
OWF	Hornsea 3	3			21	21		38				
OWF	Hornsea 4	4					18	46	46			
OWF	Inch Cape	2	na	138								
OWF	Kilmichael point	6						37	37	37	37	37
OWF	Llyr 1	5	8	8	8	8	8	8				
OWF	Llyr 2	5	8	8	8	8	8	8				
OWF	Moray West	3		na	29							
OWF	Morven BP E1	6			82	82	82	82	82			
OWF	Muir Mhor	6									27	27
OWF	N-6.6	6					14	14				
OWF	N-6.7	6					14	14				
OWF	N-9.1	6						14	14			
OWF	N-9.2	6						14	14			
OWF	Nordsren II Vest	6		7	7							
OWF	Nordsren III Vest	6		7	7							

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	Parc Eolien	6			2	2	2					
OWF	Pentland	4		14	40	40	40					
Tidal	PTEC	3		0	0							
OWF	Rampion 2	5		4	6	6	6	6	6			
OWF	SeaGreen Alpha	2	na	137								
OWF	SeaGreen Bravo	2	na	155								
OWF	Seagreen Charlie (Berwick Bank)	4		142	82	82						
OWF	Shelmalere	6	37	37	37	37	37	37				
OWF	Sherringham Ext	4				333	7					
OWF	Sofia	2			na	36						
Tidal	West Anglesey Demo	3			0	0	0	0	0	0	0	0
OWF	West of Orkney	6							20	20	20	
SS	Seismic Survey 1	7	42	42	42	42	42	42	42	42	42	42
SS	Seismic Survey 2	7	42	42	42	42	42	42	42	42	42	42
SS	Seismic Survey 3	7	42	42	42	42	42	42	42	42	42	42
SS	Seismic Survey 4	7	42	42	42	42	42	42	42	42	42	42

Table 11.47: Total number of minke whales disturbed by underwater noise across the Tiers. Results including lower Tier projects with lower data confidence are denoted by grey text.

	the Project alone		**the Project** + T1-3		**the Project** + T1-4		**the Project** + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2022	0	0.0%	23	0.1%	23	0.1%	244	1.2%
2023	0	0.0%	467	2.3%	623	3.1%	863	4.3%
2024	0	0.0%	67	0.3%	189	0.9%	720	3.6%
2025	0	0.0%	108	0.5%	896	4.5%	1413	7.0%
2026	21	0.1%	55	0.3%	131	0.7%	661	3.3%
2027	17	0.1%	89	0.4%	135	0.7%	765	3.8%
2028	17	0.1%	17	0.1%	99	0.5%	668	3.3%
2029	17	0.1%	17	0.1%	53	0.3%	315	1.6%
2030	0	0.0%	0	0.0%	36	0.2%	325	1.6%
2031	0	0.0%	0	0.0%	0	0.0%	269	1.3%
Min 2026-29	**17**	**0.1%**	**17**	**0.1%**	**53**	**0.3%**	**315**	**1.6%**
Max 2026-29	**21**	**0.1%**	**89**	**0.4%**	**135**	**0.7%**	**765**	**3.8%**
Max 2022-31	**21**	**0.1%**	**467**	**2.3%**	**896**	**4.5%**	**1413**	**7.0%**

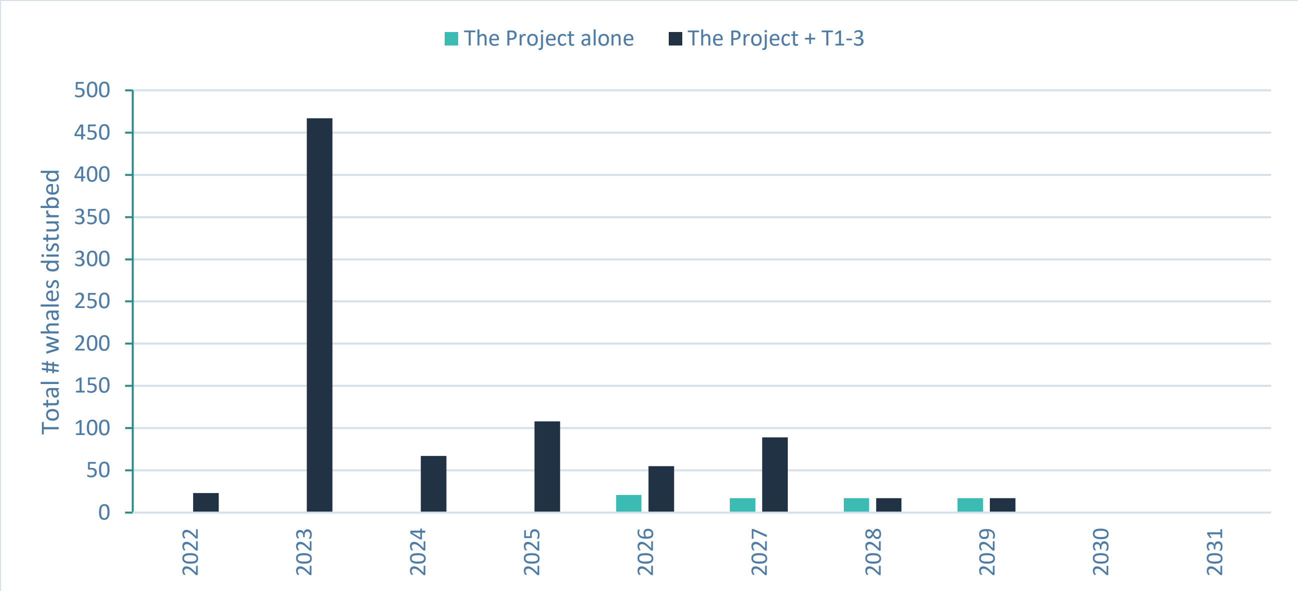

Figure 11.29: Cumulative underwater noise disturbance estimates to minke whales for the Project alone and the Project in addition to Tier 1-3 projects.

Harbour seal – Disturbance from underwater noise

11.8.64 All 17 OWF projects in the harbour seal MU (including the Project) and two seismic surveys were included in the harbour seal CEA. Where PEIR/ES numbers were unavailable, the seal habitat preference map was used to estimate the seal density for each specific project.

11.8.65 The potential number of harbour seals disturbed per day by project is provided in Table 11.48.

11.8.66 A summary of the total disturbance impact to harbour seals per day by Tier is provided in Table 11.49.

11.8.67 A summary of the total disturbance impact to harbour seals per day across all projects in Tier 1-3 is provided in Figure 11.30.

11.8.68 Across all years considered in the CEA (2022-2031 inclusive), and all Tiers (1-7), the period with highest level of predicted disturbance to harbour seals is in 2025, which is a year before offshore UXO clearance is anticipated to commence at the Project.

11.8.69 When considering the potential impact from the Project in addition to all Tier 1-3 projects (those consented and thus with higher levels of data confidence), the highest level of predicted disturbance to harbour seals across the MU is in 2026, when the Project is expected to be conducting UXO clearance activities. At this time, a maximum of 280 harbour seals (5.8% MU) may be disturbed per day, of which, 99% is disturbance from the Project (assuming all Tier 1-3 projects are constructing at the same time, and that disturbance is additive across projects i.e. no overlapping disturbance footprints).

11.8.70 There are significant levels of precaution built into this CEA which makes the resulting estimates highly precautionary and unrealistic. The assumption of an EDR of 26km from UXO clearance and piling is highly precautionary. The EDR of 26km was recommended for harbour porpoise, which is considerably more sensitive to underwater noise and disturbance than harbour seals (Booth *et al.*, 2019), and therefore over-estimates the number of harbour seals that may be disturbed. If these UXO disturbance values are removed or lowered then there would be a significantly lower CEA result. Therefore, taking into account the over-precaution in the results, impacts are likely not enough to affect the population trajectory over a generational scale, and thus the magnitude of the cumulative increase in disturbance from underwater noise is Medium (adverse).

11.8.71 The sensitivity of harbour seals to disturbance from both piling and UXO clearance has been assessed as Low. The same has been assumed here for disturbance from seismic surveys.

11.8.72 Therefore, the effect significance of disturbance to harbour seals from the cumulative impact of underwater noise is **Minor (not significant)** in EIA terms.

Table 11.48: Number of harbour seals potentially disturbed by underwater noise by project (UXO and piling)

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	The Project						276	25	25	25		
OWF	Dogger Bank C	2			0	na	na	na				
OWF	Dudgeon Ext	4				238	18					
OWF	East Anglia 1N	3				17	1	1	1			
OWF	East Anglia 2	3			15	2	2	2				
OWF	East Anglia 3	3			1	0	0	0				
OWF	Endurance	6		0	0	0						
OWF	Five Estuaries	4					38	2	2	2	2	
OWF	Hornsea 3	3			3	3		5				
OWF	Hornsea 4	4					11	5	5			
OWF	Norfolk Boreas	3				208	1	1	1			
OWF	Norfolk Vanguard E	3		212	1	1						
OWF	Norfolk Vanguard W	3		212	1	1						
OWF	North Falls	6				4	4	4	4			
OWF	Rampion 2	5		na	0	0	0	0	0			
OWF	Sheringham Ext	4				344	38					
OWF	Sofia	2			0	na						
SS	Seismic Survey 1	7	364	364	364	364	364	364	364	364	364	364
SS	Seismic Survey 2	7	364	364	364	364	364	364	364	364	364	364

Table 11.49: Total number of harbour seals disturbed by underwater noise across the Tiers. Results including lower Tier projects with lower data confidence are denoted by grey text.

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2022	0	0.0%	0	0.0%	0	0.0%	452	9.3%
2023	0	0.0%	424	8.7%	424	8.7%	876	18.1%
2024	0	0.0%	21	0.4%	21	0.4%	473	9.7%

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2025	0	0.0%	232	4.8%	814	16.8%	1270	26.2%
2026	276	5.7%	280	5.8%	385	7.9%	841	17.3%
2027	25	0.5%	34	0.7%	41	0.8%	497	10.2%
2028	25	0.5%	27	0.6%	34	0.7%	490	10.1%
2029	25	0.5%	25	0.5%	27	0.6%	479	9.9%
2030	0	0.0%	0	0.0%	2	0.0%	454	9.4%
2031	0	0.0%	0	0.0%	0	0.0%	452	9.3%
Min 2026-29	25	0.5%	25	0.5%	27	0.6%	479	9.9%
Max 2026-29	276	5.7%	280	5.8%	385	7.9%	841	17.3%
Max 2022-31	276	5.7%	424	8.7%	814	16.8%	1270	26.2%

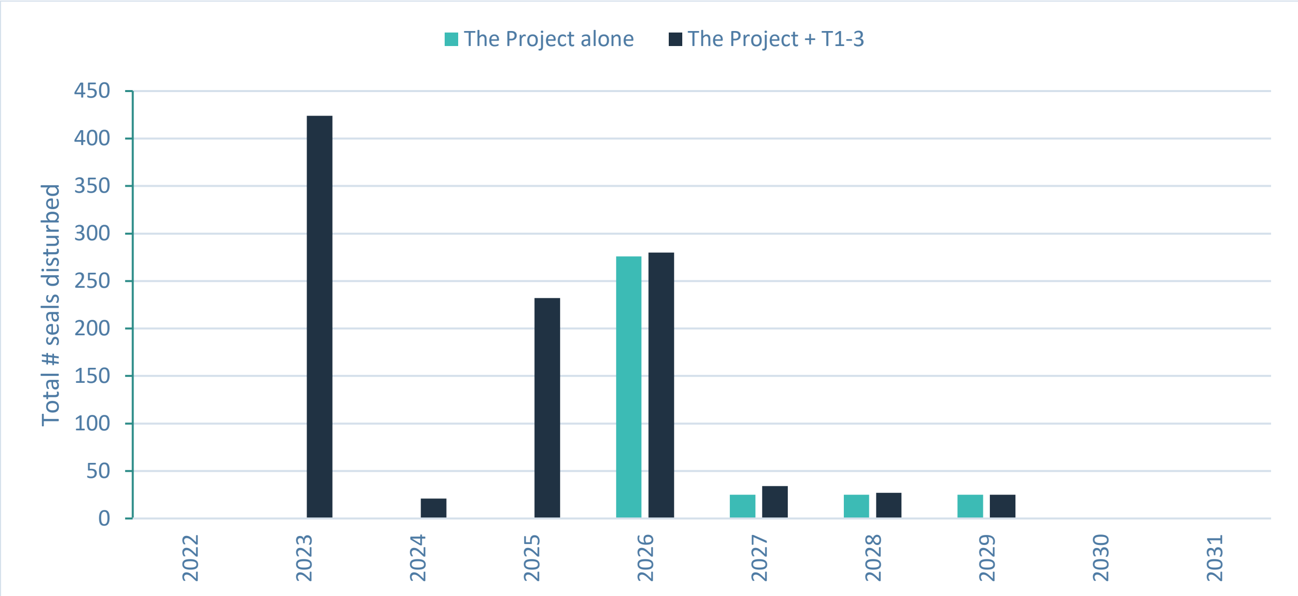

Figure 11.30: Cumulative underwater noise disturbance estimates to harbour seals for the Project alone and the Project in addition to Tier 1-3 projects.

Grey seal – Disturbance from underwater noise

11.8.73 All 19 OWF projects in the grey seal MU (including the Project) and two seismic surveys were included in the grey seal CEA. Where PEIR/ES numbers were unavailable, the seal habitat preference map was used to estimate the seal density for each specific project.

11.8.74 The potential number of grey seals disturbed per day by project is provided in Table 11.50.

11.8.75 A summary of the total disturbance impact to grey seals per day by Tier, is provided in Table 11.51.

11.8.76 A summary of the total disturbance impact to grey seals per day across all projects in Tier 1-3 is provided in Figure 11.31.

11.8.77 Across all years considered in the CEA (2022-2031 inclusive), and all Tiers (1-7), the period with highest level of predicted disturbance to grey seals is in 2025, which is a year before offshore UXO clearance is anticipated to commence at the Project.

11.8.78 When considering the potential impact from the Project in addition to all Tier 1-3 projects (those consented and thus with higher levels of data confidence), the highest level of predicted disturbance to grey seals across the MU is in 2026, when pre-construction UXO clearance is occurring at the Project. In this year, a maximum of 1,852 grey seals (3.5% MU) may be disturbed per day, of which, 97% is disturbance from the Project (assuming all Tier 1-3 projects are constructing at the same time, and that disturbance is additive across projects i.e. no overlapping disturbance footprints).

11.8.79 There are significant levels of precaution built into this CEA which makes the resulting estimates highly precautionary and unrealistic. The assumption of an EDR of 26km from UXO clearance and piling is highly precautionary. The EDR of 26km was recommended for harbour porpoise, which is considerably more sensitive to underwater noise and disturbance than grey seals (Booth *et al.*, 2019), and therefore over-estimates the number of grey seals that may be disturbed. If these UXO disturbance values are removed or lowered then there would be a significantly lower CEA result. Therefore, taking into account the over-precaution in the results, impacts are likely not enough to affect the population trajectory over a generational scale, and thus the magnitude of the cumulative increase in disturbance from underwater noise is Medium (adverse).

11.8.80 The sensitivity of grey seals to disturbance from both piling and UXO clearance has been assessed as Negligible. The same has been assumed here for disturbance from seismic surveys.

11.8.81 Therefore, the effect significance of disturbance to grey seals from the cumulative impact of underwater noise is **Minor (not significant)** in EIA terms.

Table 11.50: Number of grey seals potentially disturbed by underwater noise by project (UXO and piling)

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	The Project						1805	377	377	377		
OWF	Blyth Demo	3	1553	1553	1553	1553						
OWF	Dogger Bank C	2				195	0					
OWF	Dudgeon Ext	4				929	163					
OWF	East Anglia 1N	3				64	2	2	2			
OWF	East Anglia 2	3			85	43	43	43				
OWF	East Anglia 3	3			151	0	0	0				
OWF	Endurance	6		274	274	274						
OWF	Five Estuaries	4					225	112	112	112	112	
OWF	Hollandse Kust West	6			27	27						
OWF	Hornsea 3	3			98	98		49				

Type	Project	Tier	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
OWF	Hornsea 4	4					2028	1489	1489			
OWF	Norfolk Boreas	3				344	2	2	2			
OWF	Norfolk Vanguard E	3		340	4	4						
OWF	Norfolk Vanguard W	3		340	4	4						
OWF	North Falls	6				243	243	243	243			
OWF	Rampion 2	5		na	2	2	2	2	2			
OWF	Sherringham Ext	4				1072	119					
OWF	Sofia	2			266	2						
SS	Seismic Survey 1	7	958	958	958	958	958	958	958	958	958	958
SS	Seismic Survey 2	7	958	958	958	958	958	958	958	958	958	958

Table 11.51: Total number of grey seals disturbed by underwater noise across the Tiers. Results including lower Tier projects with lower data confidence are denoted by grey text.

	the Project alone		the Project + T1-3		the Project + T1-4		the Project + T1-7	
	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU	Disturbed	% MU
2022	0	0.0%	1553	2.9%	1553	2.9%	3469	6.5%
2023	0	0.0%	2233	4.2%	2233	4.2%	4423	8.3%
2024	0	0.0%	2161	4.1%	2161	4.1%	4380	8.3%
2025	0	0.0%	2112	4.0%	4308	8.1%	6770	12.8%
2026	1805	3.4%	1852	3.5%	4387	8.3%	6548	12.4%
2027	377	0.7%	473	0.9%	2074	3.9%	4235	8.0%
2028	377	0.7%	381	0.7%	1982	3.7%	4143	7.8%
2029	377	0.7%	377	0.7%	489	0.9%	2405	4.5%
2030	0	0.0%	0	0.0%	112	0.2%	2028	3.8%
2031	0	0.0%	0	0.0%	0	0.0%	1916	3.6%
Min 2026-29	377	0.7%	377	0.7%	489	0.9%	2405	4.5%
Max 2026-29	1805	3.4%	1852	3.5%	4387	8.3%	6548	12.4%
Max 2022-31	1805	3.4%	2233	4.2%	4387	8.3%	6770	12.8%

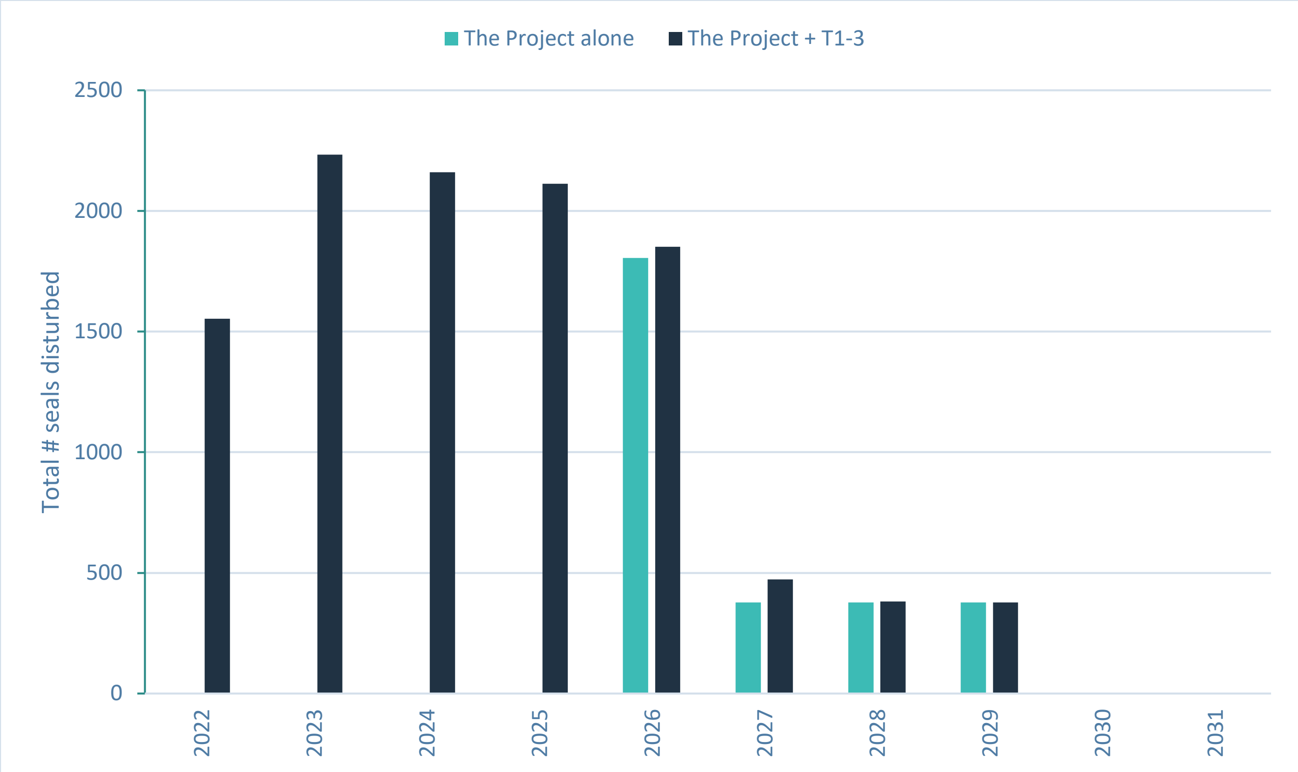

Figure 11.31: Cumulative underwater noise disturbance estimates to grey seals for the Project alone and the Project in addition to Tier 1-3 projects.

Disturbance from vessels

11.8.82 It is extremely difficult to reliably quantify the level of increased 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.

11.8.83 Although some OWF vessels (such as crew transport and supply vessels) may transit the windfarm at higher speeds, they often travel in repeated/predictable routes within the site. Many other vessels (e.g. jack-up vessels and pilot or attending vessels) travel more slowly within the windfarm site or spend long periods of time jacked-up, at anchor (minimizing movement and acoustic signature from engines) or using dynamic positioning systems (minimizing movement, although still generating noise). Unfortunately, there are very few species-specific studies covering these vessel types that capture vessel movement patterns as well as their acoustic signatures and the corresponding response of marine mammals.

11.8.84 Vessel routes to and from offshore windfarms and other projects will, for the majority, use existing vessel routes for pre-existing vessel traffic which marine mammals will be accustomed to. They may also have become habituated to the volume of regular vessel movements and therefore the additional risk is predominantly confined to construction sites. The vessel movements for offshore windfarms are likely to be limited and slow, resulting in less risk of disturbance to marine mammal receptors. In addition, most projects are likely to adopt VMPs (or comply with exiting Marine Wildlife Watching Codes) in order to minimise any potential effects on marine mammals.

11.8.85 Seismic surveys do not use existing vessel routes, so may risk adding vessel presence to novel areas; however, these are slow-moving and operate their own mitigation measures to protect marine mammals (for example, see JNCC *et al.*, 2010; 2017 – while mitigating for PTS the measures outlined in these guidance documents will also reduce disturbance impacts). Therefore, increases in disturbance from vessels from offshore projects are likely to be small in relation to current and ongoing levels of shipping.

11.8.86 For all marine mammal receptors, the cumulative impact of increased disturbance from vessels is predicted to be of local spatial extent, long-term duration (vessel presence is expected throughout the lifespan of a windfarm), intermittent (vessel activity will not be constant) and reversible (disturbance effects are temporary). Therefore, the magnitude of vessel disturbance is considered to be Low (adverse), indicating that the potential is for short-term and/or intermittent behavioural effects, with survival and reproductive rates very unlikely to be impacted to the extent that the population trajectory would be altered. It is anticipated that any animals displaced from the area will return when vessel disturbance has ended.

11.8.87 The sensitivity of marine mammal species to vessel disturbance has been assessed as Negligible.

11.8.88 Therefore, the effect significance of vessel disturbance to marine mammals from the cumulative impact of underwater noise is **Negligible (not significant)** in EIA terms.

11.9 Inter-relationships

11.9.1 Inter-relationships are considered to be the impacts and associated effects of different aspects of the proposal on the same receptor. These are considered to be:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the Project (construction, O&M and decommissioning); to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages; and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. Effect may interact to produce different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects may be short-term, temporary or transient effects, or incorporate longer term effects.

11.9.2 A description of the likely inter-related effects arising from the Project on marine mammal ecology is provided below:

- Collision risk from vessel activity in the area (impact 9);

- Disturbance from vessel activity (impact 10);
- Changes to marine mammal prey species (impact 11); and
- Changes to water quality (impact 12).

11.9.3 The effects to marine mammals from the above impacts have been assessed as **negligible** (adverse) significance to **minor** (adverse) significance. Overall, no inter-relationships have been identified where an accumulation of residual impacts on marine mammals and the relationship between those impacts gives rise to a need for additional mitigation beyond the embedded mitigation already considered. The impact of inter-relationships between marine mammals and collision risk, vessel disturbance, changes to water quality and prey species has been assessed as **not significant**.

11.10 Transboundary Effects

11.10.1 Transboundary effects are defined as those effects upon the receiving environment of other European Economic Area (EEA) states, whether occurring from the Project alone, or cumulatively with other projects in the wider area.

11.10.2 There may be behavioural disturbance or displacement of marine mammals from the Project as a result of underwater noise. 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 the Project could extend into waters of other EEA states. The Project is located in proximity to other states (e.g., French, Dutch and Belgian waters) and therefore there is the potential for transit of certain species between areas.

11.10.3 The mobile nature of marine mammals also results in the potential for transboundary effects to occur. Whilst each species has been assessed within the relevant MU for the Project array, the MUs under which each species has been assessed varies greatly in the area covered. Furthermore, the respective MUs do not represent closed populations. This means that impacts, whilst localised, could potentially affect other MUs if mixing between the assessed populations occurs

11.10.4 Any transboundary impacts that do occur as a result of the Project are predicted to be short-term and intermittent, with the recovery of marine mammal populations to affected areas following the completion of construction activities.

11.10.5 The magnitude of the impact has been assessed as negligible to low (adverse) and the sensitivity of receptors as negligible to low. Therefore, the significance of behavioural disturbance leading to transboundary effects is concluded to be of **minor (not significant)** in terms of the EIA regulations.

11.11 Conclusions

11.11.1 This chapter has assessed the potential effects on marine mammal receptors arising from the Project. The range of potential impacts and associated effects considered has been informed by scoping responses, as well as reference to existing policy and guidance. The impacts considered include those brought about directly (e.g., by the presence of infrastructure at the seabed), as well as indirectly (e.g., SSC and impacts on prey species). Potential impacts considered in this chapter, alongside any mitigation and residual effects are listed below in Table 11.52.

11.11.2 The impacts on relevant receptors from all stages of the Project were assessed, including impacts from underwater noise (piling and UXO clearance), vessel collisions and disturbance, increased SSC and indirect impacts on prey species.

11.11.3 Throughout the construction, operation and decommissioning phases, all impacts assessed were found to have either negligible, or minor effects on marine mammal receptors within the study area (i.e., **not significant** in EIA terms). The assessment of cumulative impacts from the Project and other developments and activities, including offshore windfarms, concluded that the effects of any cumulative impacts would be of **minor** (**not significant)** in EIA terms.

Table 11.52: Summary of effects on marine mammals

Description of impact	Effect	Additional mitigation measures	Residual impact
Construction			
Impact 1: UXO clearance - PTS	Minor significance of effect for minke whale Negligible significance of effect for all other species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 2: UXO clearance – disturbance	Minor significance of effect for harbour porpoise, minke whale, harbour seals and grey seals Negligible significance of effect for bottlenose dolphin, and white-beaked dolphin		No significant adverse residual effects
Impact 3: Pile driving – PTS	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 4: Pile driving – TTS	No assessment of significance		No significant adverse residual effects
Impact 5: Piling - disturbance	Minor significance of effect for harbour porpoise Negligible significance of effect for all other species		No significant adverse residual effects
Impact 6: PTS from other construction activities	Minor significance of effect for minke whale Negligible significance of effect for all other species	Not Applicable – no additional mitigation identified	No significant adverse residual effects

Description of impact	Effect	Additional mitigation measures	Residual impact
Impact 7: TTS from other construction activities	No assessment of significance	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 8: Disturbance from other construction activities	Minor significance of effect for cetacean species Negligible significance of effect for pinniped species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 9: Vessel collisions	Minor significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 10: Vessel disturbance	Minor significance of effect for cetacean species Negligible significance of effect for pinniped species		No significant adverse residual effects
Impact 11: Indirect impacts on prey	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 12: Water quality impacts	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 13: Disturbance at haul out sites	Minor significance of effect for harbour seals and grey seals	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Operation and Maintenance			
Impact 14: Operational noise – PTS and disturbance	Minor significance of effect for minke whale Negligible significance of effect for all other species	Not Applicable – no additional mitigation identified	No significant adverse residual effects

Description of impact	Effect	Additional mitigation measures	Residual impact
Impact 15: Vessel collisions	Minor significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 16: Vessel disturbance	Negligible significance of effect for all species		No significant adverse residual effects
Impact 17: Indirect impacts on prey	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Decommissioning			
Impact 18: Underwater noise from decommissioning	Minor to Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 19: Vessel collisions	Minor significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 20: Vessel disturbance	Negligible significance of effect for all species		No significant adverse residual effects
Impact 21: Indirect impacts on prey	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Impact 22: Water quality impacts	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Cumulative			
Disturbance from underwater noise	Minor significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects
Disturbance from vessels	Negligible significance of effect for all species	Not Applicable – no additional mitigation identified	No significant adverse residual effects

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