Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Environmental Statement

Volume 1

Chapter 10 - Marine Mammal Ecology

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Glossary of Acronyms

µPa	micro pascal
ADD	Acoustic Deterrent Device
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
BAP	Biodiversity Action Plan
BEIS	Department for Business, Energy and Industrial Strategy
BSH	German Federal Maritime and Hydrographic Agency
BSI	British Standards Institution
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CES	Coastal East Scotland
CGNS	Celtic and Greater North Seas
CI	Confidence Interval
CIA	Cumulative Impact Assessment
CIEEM	Chartered Institute of Ecology and Environmental Management
CIS	Celtic and Irish Sea
CPOD	Cetacean Porpoise Detector
CSIP	Cetacean Stranding’s Investigation Programme
CTV	Crew Transfer Vessel
CV	Coefficient of Variation
DAERA	Department of Agriculture, Environment and Rural Affairs
dB	decibel
DCO	Development Consent Order
DECC	Department for Energy and Climate Change (now BEIS)
Defra	Department for Environment, Food and Rural Affairs
DEP	Dudgeon Offshore Wind Farm Extension Project
DEPONS	Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea
DOW	Dudgeon Offshore Wind Farm
DOWL	Dudgeon Offshore Wind Farm Limited
E	East
EC	European Commission
EDR	Effective Deterrence Range

EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMF	Electromagnetic Fields
EMODnet	European Marine Observation and Data Network
EPP	Evidence Plan Process
EPS	European Protected Species
EQT	Effective Quiet Threshold
ES	Environmental Statement
ETG	Expert Topic Group
EU	European Union
FAD	Fish Aggregation Device
FCS	Favourable Conservation Status
GBS	Gravity Based Structure
Gescha	Effects of noise-mitigated offshore pile driving on harbour porpoise abundance in the German Bight
GNS	Greater North Sea
HDD	Horizontal Directional Drilling
HF	High-Frequency
HRA	Habitats Regulations Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
Hz	Hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
INSPIRE	Impulsive Noise Propagation and Impact Estimator
IPC	Infrastructure Planning Commission
iPCOD	interim Population Consequences of Disturbance
IPMP	In Principle Monitoring Plan
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
kg	kilogram
kHz	kilohertz
kJ	kilojoule
km	kilometre

km^2	kilometre squared
km/h	kilometres per hour
lb	pound
LF	Low Frequency
m	meter
m/s	meters per second
MCZ	Marine Conservation Zone
MF	Medium-Frequency
ML	Marine Licence
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MMObs	Marine Mammal Observers
MPS	Marine Policy Statement
MSR	The Marine Strategy Regulations
MTD	Marine Technical Directorate
MU	Management Units
MW	Megawatt
N	North
NE	North East
NEQ	Net Explosive Quantity
NMFS	National Marine Fisheries Service
NNR	National Nature Reserve
NOAA	National Oceanic and Atmospheric Administration
NPL	National Physical Laboratory
NPS	National Policy Statements
NS	North Sea
NSIPs	Nationally Significant Infrastructure Projects
OSP	Offshore Substation Platform
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment
OWF	Offshore Wind Farm
PCW	Phocid Carnivores in Water
PEIR	Preliminary Environmental Information Report
PEMP	Project Environmental Management Plan

PINS	Planning Inspectorate
PTS	Permanent Threshold Shift
PW	Pinnipeds in water
RIAA	Report to Inform Appropriate Assessment
RMS	Root Mean Square
RoC	Review of Consents
SAC	Special Area of Conservation
SBP	Sub-Bottom Profilers
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
SCOS	Special Committee on Seals
SD	Standard Deviation
SE	South-East
SEL	Sound Exposure Level
SEL_{ss}	Sound Exposure Level from Single Strike
SEL_{cum}	Cumulative Sound Exposure Level
SEP	Sheringham Shoal Offshore Wind Farm Extension Project
SIP	Site Integrity Plan
SMRU	Sea Mammal Research Unit
SNBCs	Statutory Nature Conservation Bodies
SNS	Southern North Sea
SoS	Secretary of State
SOW	Sheringham Shoal Offshore Wind Farm
SPA	Special Protection Area
SPL	Sound Pressure Level
SPL_{peak}	peak Sound Pressure Level
$SPL_{peak\ to\ peak}$	peak to peak Sound Pressure Level
SSC	Suspended Sediment Concentration
TNT	Trinitrotoluene
TSHD	Trailing Suction Hopper Dredger
TTS	Temporary Threshold Shift
TWT	The Wildlife Trust
UK	United Kingdom
USBL	Ultra-Short Baseline

UXO	Unexploded Ordnance
VHF	Very High Frequency
WDC	Whale and Dolphin Conservation
WS	West Scotland
WWT	The Wildfowl and Wetlands Trust

Glossary of Terms

Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
DEP North array area	The wind farm array area of the DEP offshore site located to the north of the existing Dudgeon Offshore Wind Farm
DEP offshore site	The Dudgeon Offshore Wind Farm Extension consisting of the DEP wind farm site, interlink cable corridors and offshore export cable corridor (up to mean high water springs).
DEP South array area	The wind farm array area of the DEP offshore site located to the south of the existing Dudgeon Offshore Wind Farm
DEP wind farm site	The offshore area of DEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area. This is also the collective term for the DEP North and South array areas.
Designated site	Sites designated for nature conservation under the Habitats Directive and Birds Directive. This includes candidate Special Areas of Conservation (cSAC), Sites of Community Importance, Special Areas of Conservation (SAC) and Special Protection Areas (SPA) and is defined in regulation 8 of the Conservation of Habitats and Species Regulations 2017.
Evidence Plan Process (EPP)	A voluntary consultation process with specialist stakeholders to agree the approach, and information to support, the Environmental Impact Assessment (EIA) and Habitats Regulations Assessment (HRA) for certain topics.
Expert Topic Group (ETG)	A forum for targeted engagement with regulators and interested stakeholders through the EPP.
Horizontal directional drilling (HDD)	Trenchless technique used to install cables – in this case referring to the installation of the export cables at the landfall.
Horizontal directional drilling (HDD) zones	The areas within the onshore cable route which would house HDD entry or exit points.
Infield cables	Cables which link the wind turbine generators to the offshore substation platform(s).

Interlink cables	Cables linking two separate project areas. This can be cables linking: 1) DEP South array area and DEP North array area 2) DEP South array area and SEP 3) DEP North array area and SEP 1 is relevant if DEP is constructed in isolation or first in a phased development. 2 and 3 are relevant where both SEP and DEP are built.
Integrated Grid Option	Transmission infrastructure which serves both extension projects.
Landfall	The point at the coastline at which the offshore export cables are brought onshore, connecting to the onshore cables at the transition joint bay above mean high water.
Offshore cable corridors	This is the area which will contain the offshore export cables or interlink cables, including the adjacent Offshore Temporary Works Area.
Offshore export cable corridor	This is the area which will contain the offshore export cables between offshore substation platform/s and landfall, including the adjacent Offshore Temporary Works Area.
Offshore export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall. 220 – 230kV
Offshore substation platform (OSP)	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbine generators and convert it into a more suitable form for export to shore.
Offshore Temporary Works Area	An Offshore Temporary Works Area within the offshore Order Limits in which vessels are permitted to carry out activities during construction, operation and decommissioning encompassing a 200m buffer around the wind farm sites and a 750m buffer around the offshore cable corridors. No permanent infrastructure would be installed within the Offshore Temporary Works Area.
Order Limits	The area subject to the application for development consent, including all permanent and temporary works for SEP and DEP.

Peak pressure	The highest pressure above or below ambient that is associated with a sound wave.
Permanent Threshold Shift (PTS)	A permanent total or partial loss of hearing sensitivity caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity.
Sequential piling	A scenario where one pile is installed after another pile in the same 24 hour period (e.g. two monopiles in the same 24 hour period or four pin-piles in the same 24 hour period).
Sheringham Shoal Offshore Wind Farm Extension site	Sheringham Shoal Offshore Wind Farm Extension lease area.
Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
SEP offshore site	Sheringham Shoal Offshore Wind Farm Extension consisting of the SEP wind farm site and offshore export cable corridor (up to mean high water springs).
SEP wind farm site	The offshore area of SEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area.
Simultaneous piling	A scenario where two piles are installed at the same time at different locations.
Single piling	A scenario where one pile is installed in a 24 hour period.
Sound Exposure Level (SEL)	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Sound Pressure Level (SPL)	The sound pressure level or SPL is an expression of the sound pressure using the decibel (dB) scale, and the standard reference pressures of 1 μPa for water and 20 μPa for air.
Study area	Area where potential impacts from the project could occur, as defined for each individual EIA topic.
The Applicant	Equinor New Energy Limited

Unweighted sound level	Sound levels which are 'raw' or have not been adjusted in any way, for example to account for the hearing ability of a species.
UXO charge weight	Quantity of contained explosive. This is different from the overall size / weight of the UXO.
UXO high-order detonation	Where the full charge weight of the UXO is detonated with a donor charge.
UXO low-order clearance	Where the full charge weight of the UXO is NOT detonated.
Weighted sound level	A sound level which has been adjusted with respect to a 'weighting envelope' in the frequency domain, typically to make an unweighted level relevant to a particular species. Examples of this are the filters used by Southall *et al*. (2019) for marine mammals.

10. MARINE MAMMAL ECOLOGY

10.1 Introduction

1. This chapter of the Environmental Statement (ES) considers the potential impacts of the proposed Sheringham Shoal Extension Offshore Wind Farm Project (SEP) and Dudgeon Extension Offshore Wind Farm Project (DEP) on marine mammals. The chapter provides an overview of the existing environment for the proposed offshore development area, followed by an assessment of the potential impacts and associated mitigation for the construction, operation, and decommissioning phases of SEP and DEP.

2. This assessment has been undertaken with specific reference to the relevant legislation and guidance, of which the primary source are the National Policy Statements (NPS). Details of these and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Impact Assessment (CIA) are presented in **Chapter 5 EIA Methodology** and **Section 10.4**.

3. The assessment should be read in conjunction with following linked chapters:

- **Chapter 2 Policy and Legislative Context;**
- **Chapter 4 Project Description**;
- **Chapter 5 EIA Methodology**;
- **Chapter 7 Marine Water and Sediment Quality**;
- **Chapter 8 Benthic Ecology**;
- **Chapter 9 Fish and Shellfish Ecology**; and
- **Chapter 13 Shipping and Navigation**.

4. Additional information to support the marine mammal assessment is included in:

- **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**;
- **Appendix 10.2 Underwater Noise Modelling Report**;
- **Appendix 10.3 Marine Mammal Cumulative Impact Assessment Screening**; and
- **Appendix 10.4 Marine Mammal Unexploded Ordnance (UXO) Assessment**.

10.2 Consultation

5. Consultation with regard to marine mammals has been undertaken in line with the general process described in **Chapter 5 EIA Methodology** and the **Consultation Report** (document reference 5.1). The key elements to date have included scoping, the ongoing Evidence Plan Process (EPP) via the Marine Mammal Expert Topic Group (ETG) and the Preliminary Environmental Information Report (PEIR).

6. Stakeholders represented on the Marine Mammal ETG are Natural England, the Marine Management Organisation (MMO), the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and The Wildlife Trust (TWT). At their request, Whale and Dolphin Conservation (WDC) have not been directly involved in the ETG to date, but are kept updated on SEP and DEP in general terms. **Appendix 1 Evidence Plan** (document reference 5.2.1) of the **Consultation Report** provides the Marine Mammal ETG agreement logs and meeting minutes.

7. The feedback received throughout this process has been considered in preparing the ES. This chapter has been updated following the consultation on the PEIR in order to produce the final assessment submitted with the Development Consent Order (DCO) application.

8. **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** provides a summary of the consultation responses and how they have been addressed in this chapter.

9. The consultation process is described further in **Chapter 5 EIA Methodology**. Full detail of the consultation process is presented in the **Consultation Report** (document reference 5.1), which has been submitted as part of the DCO application.

10. As agreed with stakeholders at ETG3 on the 20th July 2021, a separate Marine Licence (ML) application for UXO clearance will be submitted post-consent once detailed information on the locations and extent of UXO required to be cleared is known. An assessment of the potential impacts from UXO clearance at SEP and DEP is provided in **Appendix 10.4 Marine Mammal UXO Assessment** for information purposes only. The potential cumulative impacts from UXO clearance at other offshore wind farms during piling at SEP and DEP are assessed in **Section 10.7.1.2.6**.

10.3 Scope

10.3.1 Marine Mammal Species

11. Site characterisation has been undertaken using site specific data for SEP and DEP, as well as existing data from other offshore wind farms in the area and other available information for the region (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). The key species and therefore the focus of the assessments are:

- Harbour porpoise, *Phocoena phocoena;*
  - Present throughout the year, although there may be variations in seasonal occurrence.
- Bottlenose dolphin, *Tursiops truncatus*
  - Historically not common in the area, with limited data, however, with a recent increase in sightings along the coast, the species has been included on a precautionary basis.
- White-beaked dolphin, *Lagenorhynchus albirostris;*
  - Seasonal occurrence in low numbers.

- Minke whale, *Balaenoptera acutorostrata;*
  - Seasonal occurrence in low numbers.
- Grey seal, *Halichoerus grypus;*
  - Present throughout the year.
- Harbour seal, *Phoca vitulina;*
  - Present throughout the year.

10.3.2 Study Area

12. The study area for marine mammals has been defined on the basis that marine mammals are highly mobile and transitory in nature. It is, therefore, necessary to examine species occurrence not only within SEP and DEP, but also over the wider area.

13. For the marine mammal species in the assessments, the following study areas have been defined, based on the relevant Management Units (MUs) (Inter-Agency Marine Mammal Working Group (IAMMWG), 2022), current knowledge and understanding of the biology of each species (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**):

- Harbour porpoise: North Sea (NS) MU.
- Bottlenose dolphin: Greater North Sea (GNS) MU.
- White-beaked dolphin: Celtic and Greater North Seas (CGNS) MU.
- Minke whale: CGNS MU.
- Grey seal: South-east England, North-east England and the Wadden Sea region.
- Harbour seal: South-east England MU and the Wadden Sea region.

14. The status and activity of marine mammals known to occur within or adjacent to SEP and DEP are considered in the context of regional population dynamics at the scale of the wider North Sea, depending on the data available for each species and the extent of the agreed reference population.

15. SEP and DEP are located approximately 15.8km and 26.5km offshore (at the closest point to shore), respectively. Water depths at the SEP and DEP wind farm sites range from 14m below Lowest Astronomical Tide (LAT) in the northwest of the SEP wind farm site to 36m in the northwest of the DEP North array area.

16. There is the potential for seals from haul-out sites to move along the coast and offshore to forage in and around the proposed offshore sites. Key haul-out sites for both seal species within the vicinity of the SEP and DEP offshore sites include:

- Blakeney Point (at closest point is located 12km from the landfall location).
- Other haul-out sites are located at Horsey (44km at closest point), Scroby Sands (58km at closest point), the Wash (57km at closest point) and Donna Nook (66km at closest point) (see **Table 10-14** and **Table 10-16** for further details).

10.3.3 Realistic Worst-Case Scenario

10.3.3.1 General Approach

17. The final design of SEP and DEP will be confirmed through detailed engineering design studies that will be undertaken post-consent to enable the commencement of construction. In order to provide a precautionary but robust impact assessment at this stage of the development process, realistic worst-case scenarios have been defined in terms of the potential effects that may arise. This approach to EIA, referred to as the Rochdale Envelope, is common practice for developments of this nature, as set out in Planning Inspectorate Advice Note Nine: Rochdale Envelope (v3, 2018). The Rochdale Envelope for a project outlines the realistic worst-case scenario for each individual impact, so that it can be safely assumed that all lesser options will have less impact. Further details are provided in **Chapter 5 EIA Methodology**.

18. The realistic worst-case scenarios for the marine mammals assessment are summarised in **Table 10-1**. These are based on the project parameters described in **Chapter 4 Project Description**, which provides further details regarding specific activities and their durations.

19. In addition to the design parameters set out in **Table 10-1**, consideration is also given to:
    - How SEP and DEP will be built out as described in **Section 10.3.3.2** to **Section 10.3.3.4** below. This accounts for the fact that whilst SEP and DEP are the subject of one DCO application, it is possible that only one Project could be built out (i.e. build SEP or DEP in isolation) or that both of the Projects could be developed. If both are developed, construction may be undertaken either concurrently or sequentially.
    - A number of further development options which either depend on pre-investment or anticipatory investment, or that relate to the final design of the wind farms.
    - Whether one OSP or two OSPs are required.
    - The design option of whether to use all of the DEP North and DEP South array areas, or whether to use the DEP North array area only.

20. In order to ensure that a robust assessment has been undertaken, all development scenarios and options have been considered to ensure the realistic worst-case scenario for each topic has been assessed. Further details are provided in **Chapter 4 Project Description**.

21. Piled foundations for the wind turbines (monopiles or jackets with pin-piles) and Offshore Substation Platforms (OSP) (jackets with pin-piles) are considered the worst-case for marine mammals as a result of underwater noise levels. However, other options for the foundations are being considered, including screw piles, Gravity Based Structure (GBS) and suction buckets (see **Chapter 4 Project Description**).

22. For underwater noise impacts from piling, three scenarios have been considered in the assessments:

- Single piling – A scenario where only one pile is installed, either at SEP or at DEP, within a 24 hour period.
- Sequential piling – A scenario where one pile is installed after another pile in the same 24 hour period (e.g. two monopiles in the same 24 hour period or four pin-piles in the same 24 hour period).
- Simultaneous piling - A scenario where two piles are installed at the same time at different locations (i.e. one at SEP at the same time as one at DEP).

23. In relation to the different offshore design scenarios for SEP and DEP (i.e. one OSP or two OSPs), the worst-case has been included in **Table 10-1** and assessed in the impact assessment in **Section 10.6**, where relevant.

24. The potential impacts on marine mammals are:

- Underwater noise (including UXO clearance, piling, other construction activities, vessels, operational turbines, operation and maintenance and decommissioning activities);
- Any barrier effects from underwater noise;
- Any increased collision risk with vessels;
- Disturbance at seal haul-out sites;
- Disturbance of foraging seals at sea;
- Changes to water quality;
- Changes to prey resources; and
- Cumulative impacts.

10.3.3.2 Construction Scenarios

25. In the event that both SEP and DEP are built, the following principles set out the framework for how SEP and DEP may be constructed:

- SEP and DEP may be constructed at the same time, or at different times;
- If built at the same time both SEP and DEP could be constructed in four years;
- If built at different times, either Project could be built first;
- If built at different times, each Project would require a four year period of construction;
- If built at different times, the offset between the start of construction of the first Project, and the start of construction of the second Project may vary from two to four years;
- Taking the above into account, the total maximum period during which construction could take place is eight years for both Projects; and
- The earliest construction start date is 2025; and
- The earliest offshore construction could start is 2027, with the start of wind turbine and OSP foundations being installed (piling) at the beginning of 2028.

26. The impact assessment for marine mammals considers the following development scenarios in determining the worst-case scenario for each topic:

- Build SEP or build DEP in isolation – one OSP only; and
- Build SEP and DEP concurrently or sequentially – with either two OSPs, one for SEP and one for DEP, or with one OSP only to serve both SEP and DEP

27. For each of these scenarios it has been considered whether the build out of the DEP North and DEP South array areas, or the build out of the DEP North array area only, represents the worst-case for that topic. Any differences between SEP and DEP, or differences that could result from the manner in which the first and the second Projects are built (concurrent or sequential (and simultaneous or sequential piling) and the length of any gap) are identified and discussed where relevant in the impact assessment section of this chapter (**Section 10.6**). For each potential impact, where necessary, only the worst-case construction scenario for two Projects is presented, i.e. either concurrent or sequential. The justification for what constitutes the worst-case is provided, where necessary, in **Section 10.6**.

10.3.3.3 Operation Scenarios

28. Operation scenarios are described in detail in **Chapter 4 Project Description**. The marine mammal assessments consider the following three scenarios:

- Only SEP in operation;
- Only DEP in operation; and
- The two Projects operating at the same time, with a gap of two to four years between each Project commencing operation.

29. The operational lifetime of each Project is expected to be 40 years.

10.3.3.4 Decommissioning Scenarios

30. Decommissioning scenarios are described in detail in **Chapter 4 Project Description**. Decommissioning arrangements will be agreed through the submission of a Decommissioning Programme prior to construction, however for the purpose of this assessment it is assumed that decommissioning of SEP and DEP could be conducted separately, or at the same time and that any potential effects would be the same or less than for construction.

Table 10-1: Realistic Worst-Case Parameters for Marine Mammal Assessments

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
Construction				
Impact 1 & 2: Underwater noise during piling	Installation of up to **30 wind turbines** (between 17 and 30 ranging from 15MW to 26MW) and **one OSP** in the DEP North array area.	Installation of up to **23 wind turbines** (between 13 and 23 ranging from 15MW to 26MW) and **one OSP** in SEP wind farm site.	Installation of up to **53 wind turbines** (between 30 and 53 ranging from 15MW to 26MW) and **two OSPs** (one in the DEP North array area and one in the SEP wind farm site).	Maximum number of wind turbines and OSPs. Alternative foundation types are also considered but do not represent the worst-case for underwater noise. The worst-case scenario for SEP and DEP assumes 2 OSPs, one in the DEP North array area and one in the SEP wind farm site. The worst-case underwater noise modelling locations are in DEP South East and SEP East as described in **Section 10.6.1.1.2** and **Appendix 10.2 Underwater Noise modelling Report**.
	Options for piled foundations: • 1 monopile per wind turbine foundation; or • 4 pin-piles per wind turbine foundation; and • Up to 8 pin-piles per OSP. Proportion of foundations that are piled: 100%			Hammer piled foundations represent the worst-case scenario for underwater noise.
	Number of piled wind turbine foundations: • Up to **30 monopiles**; or	Number of piled wind turbine foundations: • Up to **23 monopiles**; or	Number of piled wind turbine foundations: • Up to **53 monopiles**; or	Worst-case is up to 53 monopiles plus 16 pin-piles; or up to 228 pin-piles based on

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
	• Up to **120 pin-piles**.	• Up to **92 pin-piles**.	• Up to **212 pin-piles**.	maximum number of piled foundations for 15MW wind turbines and up to two OSPs. The worst-case scenario for SEP and DEP assumes 2 OSPs, one in the DEP North array area and one in the SEP wind farm site.
	Up to **8 piles for OSP foundations** (1 OSP).	Up to **8 piles for OSP foundations** (1 OSP).	Up to **16 piles for OSP foundations** (2 OSPs).	
	Maximum **hammer energy for monopiles** • Up to **5,000kJ for 15MW** wind turbine • Up to **5,500kJ for 18+MW** wind turbine Maximum **hammer energy for pin-piles**: up to **3,000kJ**			The maximum hammer energy will not be required for all piles and would not be required for the entire duration to install a pile.
	Maximum **pile diameter for monopiles:** • Up to 13m for 15MW wind turbine • Up to 16m for 18+MW wind turbine Maximum **pile diameter for pin-piles**: • Up to **3m for 15MW** wind turbine • Up to **4m for 18+MW** wind turbine • Up to **3.5m for OSP**(s)			This is the worst-case, with the greatest potential underwater noise impact ranges for installation of monopiles or pin-piles.
	Duration of wind turbine foundation installation: **3 months**	Duration of wind turbine foundation installation: **3 months**	Duration of wind turbine foundation installation: **3 months for each Project over a period of up to 39**	Offshore construction works would require up to two years per Project (excluding thankpre-construction activities such as surveys), assuming SEP and

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
			months (based on sequential construction).	DEP were built at different times. However, the duration of piling for wind turbine foundations would be up to 3 months for each Project. This is the maximum duration of all offshore activities to install wind turbines, however, active piling will only be a relatively small duration within this overall period.
	Total piling time per wind turbine foundation (15MW or 18+MW): Monopiles: up to **120 hours** for 30 wind turbines (4 hours per wind turbine). or Pin-piles: up to **360 hours** for 30 wind turbines (3 hours per pin-pile x 4 piles per foundation = up to 12 hours per foundation).	**Total piling time** per wind turbine foundation (15MW or 18+MW): Monopiles: up to **92 hours** for 23 wind turbines (4 hours per wind turbine). or Pin-piles: up to **276 hours** for 23 wind turbines (3 hours per pin-pile x 4 piles per foundation = up to 12 hours per foundation).	**Total piling time** per wind turbine foundation (15MW or 18+MW): Monopiles: up to **212 hours** (9 days) for 53 wind turbines (4 hours per wind turbine). or Pin-piles: up to **636 hours** (26.5 days) for 53 wind turbines (3 hours per pin-pile x 4 piles per foundation = up to 12 hours per foundation).	The active piling time for pin-piles for all wind turbines is 2.5 hours (150 minutes). With soft-start and ramp-up (20 minutes) the total average piling time is 180 minutes per pin-pile, or 720 minutes per wind turbine.
	Total OSP piling time	**Total OSP piling time**	**Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation = up to 24	The worst-case scenario for SEP and DEP is a 2 OSP scenario because of the

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
	3 hours per pin-pile x 8 piles per foundation = up to **24 hours** per foundation.	3 hours per pin-pile x 8 piles per foundation = up to **24 hours** per foundation.	hours per foundation. Two OSPs = **48 hours**.	increased piling requirement compared to a 1 OSP scenario.
	Maximum total active piling time for wind turbines and OSP: **384 hours (16 days)**, based on pin-pile foundations for wind turbines and one OSP. For wind turbine monopiles and OSP pin-piles: 144 hours (6 days).	**Maximum total active piling time** for wind turbines and OSP: **300 hours (12.5 days)**, based on pin-pile foundations for wind turbines and one OSP. For wind turbine monopiles and OSP pin-piles: 116 hours (4.8 days).	**Maximum total active piling time** for wind turbines and OSPs: **684 hours (28.5 days)**, based on pin-pile foundations for wind turbines and two OSPs. For wind turbine monopile and OSP pin-piles: 260 hours (10.8 days).	Worst-case scenario is pin-piles for all wind turbines plus 2 OSPs.
	Activation of Acoustic Deterrent Device (ADD) For example: 10 minutes per pile, or 2,280 minutes (38 hours) for 228 pin-piles.			Indicative only.
	Potential for simultaneous piling at DEP.	Potential for simultaneous piling at SEP.	Potential for simultaneous piling between SEP and DEP depending on build scenario (see **Section 10.3.3.2**).	The worst-case for SEP and DEP has been assessed, based on simultaneous piling i.e. piling in SEP at the same time as piling in DEP, noting that simultaneous piling within SEP or DEP individually could occur but has not been assessed since it is not the worst-case.
	Number of monopiles to be installed sequentially in same 24 hour period = 2	Number of monopiles to be installed sequentially in same 24 hour period = 2	Number of monopiles to be installed sequentially in same 24 hour period = 2	Assessments have been based on a worst-case scenario of up 2 monopiles installed sequentially in the same 24 hour period or up to 4 pin-piles installed

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
	Number of pin-piles to be installed sequentially in same 24 hour period = 4	Number of pin-piles to be installed sequentially in same 24 hour period = 4	Number of pin-piles to be installed sequentially in same 24 hour period = 4	sequentially in the same 24 hour period.
Impact 3: Underwater noise during other construction activities (Underwater noise from activities such as sea bed preparations, cable installation and rock placement)	Sea bed clearance methods: Pre-lay grapnel run, boulder grab, plough, sand wave levelling (pre-sweeping), dredging			Dredging is considered to be the worst-case in terms of underwater noise levels.
	Cable installation methods: Jetting / ploughing / trenching / mechanical cutting			Assumed equal amounts of jetting and mechanical cutting.
	Underwater noise modelling for all construction activities and vessels			
	Wind farm site: Two wind farm array areas (DEP North array area and DEP South array area) = **114.8km^2**	**Wind farm site:** One wind farm array area = **97.0km^2**	**Wind farm sites:** Three wind farm areas = **211.8km^2** (DEP North and DEP South array areas and SEP wind farm site).	Maximum wind farm area(s).
	Export cable corridor: **96.8km^2**	**Export cable corridor:** **63.8km^2**	**Export cable corridor:** **160.6km^2**	
	Duration of offshore construction: **2 years** Duration of offshore export cable installation: **60 days**	Duration of offshore construction: **2 years** Duration of offshore export cable installation: **50 days**	Duration of offshore construction: **4 years** if built sequentially with a maximum gap of **3 years (7 years in total)** Duration of offshore export cable installation: **100 days**	Offshore construction works would require up to two years per Project (excluding pre-construction activities such as surveys), assuming SEP and DEP were built at different times. If built at the same time, offshore construction could be completed in two years. Accounting for the development scenarios

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
				described in **Section 10.3.3.2**, there could be a gap of up to one year between the completion of offshore construction works on the first Project and the start of offshore construction works on the second Project.
Impacts 4 & 6: Underwater noise and disturbance from vessels, and vessel collision risk	**Vessel movements:** • Maximum number of construction vessels on site at any one time: up to **16** vessels • Construction vessel trips to port: **603** over 2 year construction period	**Vessel movements:** • Maximum number of construction vessels on site at any one time: up to **16** vessels • Construction vessel trips to port: **603** over 2 year construction period	**Vessel movements:** • Maximum number of construction vessels on site at any one time: up to **25** (in total if both SEP and DEP constructed concurrently) • Construction vessel trips to port: **1,196** during 4 year construction period if constructed sequentially	Maximum number of construction vessels. The worst-case for SEP and DEP considers concurrent construction on account of increased construction activity in the study area at the same time. Construction port/s will not be confirmed until nearer the start of construction however it is anticipated that it will be Great Yarmouth.
Impact 5: Barrier effect from underwater noise	Maximum impact range from underwater noise assessments (worst-case parameters described above).			The maximum spatial area of potential impact, and duration of impacts, are considered to cause the worst-case barrier impact.
Impact 7: Disturbance at	Distance of SEP and DEP and vessel routes to seal haul-out sites as identified within **Section 10.5.5** and **10.5.6** for grey seal and harbour seal, respectively.			Construction port/s will not be confirmed until nearer the start of construction.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
seal haul-out sites				
Impact 8: Changes to prey resources (temporary habitat loss / disturbance; increased suspended sediments and sediment re-deposition; re-mobilisation of contaminated sediments; and underwater noise)	Impacts to prey species and habitat as described in **Chapter 9 Fish and Shellfish Ecology** and **Chapter 8 Benthic Ecology**.			
	Total sea bed disturbance within the DEP offshore site Worst-case scenario total temporary disturbance footprint for DEP in isolation = **5.12km²**	**Total sea bed disturbance within the SEP offshore site** Worst-case scenario total temporary disturbance footprint for SEP in isolation = **2.12km²**	**Total Disturbance within the SEP and DEP offshore sites** Worst-case scenario total temporary disturbance footprint for SEP and DEP = **7.87km²**	The worst-case scenario for maximum area of temporary habitat loss / disturbance of sea bed from offshore cable installation, sea bed preparation, jack-up vessels and HDD exit points). Worst-case area is based on 2 OSP scenario where both the DEP North and South array areas are developed.
	Worst-case scenario for total temporary increases in suspended sediment concentration (SSC) for DEP in isolation = **1,041,750m³**	Worst-case scenario for total temporary increases in SSC for SEP in isolation= **444,652m³**	Worst-case scenario for total temporary increases in SSC for SEP and DEP= **1,544,802m³**	The worst-case for increased suspended sediments and sediment re-deposition from sea bed preparation and cable trenching. Worst-case is for a 2 OSP scenario where both the DEP North and South array areas are developed.
	Remobilisation of contaminated sediments: As described for increased suspended sediments and sediment re-deposition.			
	Underwater noise parameters as outlined for construction noise-related impacts above and **Appendix 10.2 Underwater Noise Modelling Report** (UXO, piling, other construction activities and vessels).			As above for underwater noise.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
Impact 9: Changes to water quality (increased suspended sediments and sediment re-deposition; and re-mobilisation of contaminated sediments)	Impacts to water quality as described in **Chapter 7 Marine Water and Sediment Quality**. See worst-case for temporary increases in SSC and re-mobilisation of contaminated sediments as described for Impact 10.			
Operation and Maintenance				
Impact 1: Underwater noise from operational turbines	Turbine parameters (e.g. size and number) as outlined above and underwater noise parameters described in **Appendix 10.2 Underwater Noise Modelling Report**.			Underwater noise modelling for operational turbines.
Impact 2: Underwater noise from maintenance activities	Estimated timeframe for any cable repair, replacement or reburial works: • One export cable repair every 10 years (400m) • Up to 100m per export cable subject to reburial works every 10 years • One interlink cable repair every 10 years (800m); • Reburial of 1% of interlink cabling every 10 years (660m)	Estimated timeframe for any cable repair, replacement or reburial works: • One export cable repair every 10 years (400m) • Up to 100m per export cable subject to reburial works every 10 years • One infield cable repair every 10 years (2,500m in total)	Estimated timeframe for any cable repair, replacement or reburial works: • One export cable repair every 10 years (800m) • Up to 100m per export cable (200m in total) subject to reburial works every 10 years • One interlink cable repair every 10 years (800m);	

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
	• One infield cable repair every 10 years (2,500m in total) • Reburial of 1% of infield cabling every 10 years (1,350m)	• Reburial of 1% infield cabling every 10 years (900m)	• Reburial of 1% of interlink cabling every 10 years (1,540m) • Two infield cable repairs every 10 years (5,000m in total) • Reburial of 1% infield cabling every 10 years (2,250m)	
Impact 3 & 5: Underwater noise from vessels, and vessel collision risk	**Vessel movements:** • Maximum number of vessels on site at any one time: **6** • Operation and maintenance vessel trips to port per year: approximately **604** (although majority (600) will be (small operation and maintenance vessel (Crew Transfer Vessel (CTV)).	**Vessel movements:** • Maximum number of vessels on site at any one time: **6** • Operation and maintenance vessel trips to port per year: approximately **604** (although majority (600) will be (small operation and maintenance vessel (CTV)).	**Vessel movements:** • Maximum number of vessels on site at any one time: **7** (in total if both SEP and DEP constructed concurrently) • Operation and maintenance vessel trips to port per year: approximately **1,206** (although majority (1,200) will be (small operation and maintenance vessel (CTV)).	Where possible, SEP and DEP will use the existing operation and maintenance programme for Sheringham Shoal Offshore Wind Farm (SOW) and Dudgeon Offshore Wind Farm (DOW) respectively.
Impact 4: Barrier effect from underwater noise	Maximum impact range from operation and maintenance phase underwater noise assessments (as above).			The maximum spatial area of potential impact, and duration of impacts, are considered to

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
				cause the worst-case barrier impact.
Impact 6: Disturbance at seal haul-out sites	Distance of SEP and DEP to haul-out sites as identified within **Section 10.5.5** and **10.5.6** for grey seal and harbour seal, respectively.			
	Operation and maintenance base location: Great Yarmouth			Operation and maintenance activities could happen at any time of year.
Impact 7: Changes to prey resources (temporary habitat loss / disturbance; permanent habitat loss; introduction of wind turbine foundations, scour protection and hard substrate; increased suspended sediments and sediment re-deposition; re-mobilisation of contaminants from sea bed sediment; underwater	Impacts to prey species and habitat as described in **Chapter 9 Fish and Shellfish Ecology** and **Chapter 8 Benthic Ecology**.			
	Approximate total temporary disturbance footprint for DEP in isolation for operational lifetime (40 years) = **0.55km²**	Approximate total temporary disturbance footprint for SEP in isolation for operational lifetime (40 years) = **0.53km²**	Approximate total temporary disturbance footprint for SEP and DEP for operational lifetime (40 years) = **1.148km²**	The worst-case scenario for maximum area of temporary habitat loss / disturbance of sea bed from jack-up vessel deployments, cable repair, replacement and reburial footprint.
	See Operation Impact 2 in **Chapter 8 Benthic Ecology** **Total permanent habitat loss: 0.67km²**	See Operation Impact 2 in **Chapter 8 Benthic Ecology** **Total permanent habitat loss: 0.50km²**	See Operation Impact 2 in **Chapter 8 Benthic Ecology** **Total permanent habitat loss: 1.159km²**	The worst-case scenario for maximum area of permanent habitat loss / introduction of wind turbine foundations, OSP foundations, scour protection and hard substrate (including subsea cable surface protection and pipeline crossing).
	Temporary increases in SSC and any deterioration in water quality through the resuspension of contaminated sediment due to maintenance activities could result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities – same as temporary habitat loss / disturbance.			The worst-case scenario based on maximum area of temporary habitat loss / disturbance of sea bed (as above).
	Underwater noise parameters as outlined for operation noise-related impacts above and **Appendix 10.2 Underwater Noise Modelling Report** (operational turbines, maintenance activities, vessels).			As above for underwater noise.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP	Notes and Rationale
noise; and Electromagnetic Fields (EMF)).	**Offshore cables:** Up to **263km** of offshore cables comprising: • One High Voltage Alternating Current (HVAC) export cable up to **62km** in length • **135km** of infield cables (DEP North array area: 90km; DEP South: 45km) • Up to 3 parallel interlink cables between DEP South array area and OSP in DEP North: up to **66km** in length (combined) • Burial depth: 0.5 to 1m (excluding burial in sand waves up to 20m); and up to 1.0m for the export cables.	**Offshore cables:** Up to **130km** of cables comprising: • One HVAC export cable up to **40km** in length • **90km** of infield cables • No interlink cables Burial depth: same as DEP in isolation.	**Offshore cables:** Up to **448km**: • 2 HVAC export cables from SEP up to **80km** in length • Up to **225km** of infield cables (DEP North array area: 90km; DEP South array area 45km; SEP 90km) • Up to 7 interlink cables from DEP North array area (up to 5) and DEP South array area (up to 3) to OSP in SEP, up to **143km** total length • Burial depth: same as SEP or DEP in isolation.	Worst-case is a 2 OSP scenario where both the DEP North and South array areas are developed.
<u>Impact 8</u>: Changes to water quality	Impacts to water quality (as described in **Chapter 7 Marine Water and Sediment Quality**). Temporary increases in SSC and any deterioration in water quality through the resuspension of contaminated sediment due to maintenance activities could result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities – same as temporary habitat loss / disturbance for prey above.			
Decommissioning				
<u>Impact 1</u>: Underwater noise from foundation removal of wind	No final decision has yet been made regarding the final decommissioning policy for the offshore project infrastructure. It is also recognised that legislation and industry best practice change over time. However, the following infrastructure is likely be removed, reused or recycled where practicable: • Turbines including monopile, steel jacket and GBS foundations;			Assumed to be no worse than during construction.

<table>
<tr><th>Impact</th><th>DEP in Isolation</th><th>SEP in Isolation</th><th>SEP and DEP</th><th>Notes and Rationale</th></tr>
<tr><td>turbines and OSPs</td><td colspan="3" rowspan="7">OSPs including topsides and steel jacket foundations;
Offshore cables may be removed or left in situ depending on available information at the time of decommissioning; and
Cable protection in the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ).
The following infrastructure is likely to be decommissioned in situ depending on available information at the time of decommissioning:
Scour protection;
Offshore cables may be removed or left in situ; and
Crossings and cable protection outside the Cromer Shoal Chalk Beds MCZ.
The detail and scope of the decommissioning works will be determined by the relevant legislation and guidance at the time of decommissioning and will be agreed with the regulator.

For the purposes of the worst-case scenario, it is anticipated that the impacts will be no greater than those identified for the construction phase, as no piling will be required.</td><td rowspan="7">Decommissioning arrangements will be detailed in a Decommissioning Programme, which will be drawn up and agreed with the Department for Business, Energy and Industrial Strategy (BEIS) prior to construction.</td></tr>
<tr><td><u>Impact 2</u>: Underwater noise from other decommissioning activities</td></tr>
<tr><td><u>Impact 3</u>: Underwater noise from vessels, and vessel collision risk</td></tr>
<tr><td><u>Impact 4</u>: Barrier effect from underwater noise</td></tr>
<tr><td><u>Impact 5</u>: Disturbance at seal haul-out sites</td></tr>
<tr><td><u>Impact 6</u>: Changes to prey resources</td></tr>
<tr><td><u>Impact 6</u>: Changes to water quality</td></tr>
</table>

10.3.4 Summary of Mitigation

10.3.4.1 Mitigation Embedded in the Design

31. This section outlines the embedded mitigation relevant to the marine mammal assessment, which has been incorporated into the design of the Projects (**Table 10-2**). Where other mitigation measures are proposed, as outlined in **Section 10.3.4.2**, these are also detailed in the relevant impact assessments (**Section 10.6**).

32. A number of techniques and engineering designs / modifications are inherent as part of the Projects, where practical, during the pre-application phase, in order to avoid a number of impacts or reduce impacts as far as reasonably possible. This includes piling parameters, such as maximum hammer energy, duration of soft-start and ramp-up, strike rate and number of strikes. Embedding mitigation into the Project design is a type of primary mitigation and is an inherent aspect of the EIA process, such as minimum number of turbines and foundations, reduction in number of offshore platforms.

Table 10-2: Embedded Mitigation Measures

Parameter	Mitigation Measures Embedded into the Design of SEP and DEP
Underwater Noise	
Soft-start and ramp-up (part of Marine Mammal Mitigation Protocol (MMMP) for Piling Activities)	Each piling event would commence with a soft-start at a lower hammer energy followed, by a gradual ramp-up for at least 20 minutes to the maximum hammer energy required (the maximum hammer energy is only likely to be required at a few of the piling installation locations). The soft-start and ramp-up allows mobile species to move away from the area before the maximum hammer energy with the greatest noise impact area is reached. This commitment to soft-start and ramp-up is presented in the **Draft MMMP** (document reference 9.4).
Vessel collision risk	
Best practice to reduce vessel collision risk	Vessel movements, where possible, will follow set vessel routes and hence areas where marine mammals are accustomed to vessels, in order to reduce any increased collision risk. All vessel movements will be kept to the minimum number that is required to reduce any potential collision risk. Additionally, vessel operators will use good practice to reduce any risk of collisions with marine mammals. An outline **Project Environmental Management Plan (PEMP)** (document reference 9.10) has been submitted alongside the DCO application to set out the details of the measures that will be taken in relation to collision risk.
Water Quality	
Pollution prevention	As outlined in **Chapter 7 Marine Sediment and Water Quality**, Equinor is committed to the use of best practice techniques and due diligence regarding the potential for pollution throughout all construction, operation and maintenance, and decommissioning activities. An outline **PEMP** (document reference 9.10) has been submitted alongside the DCO application to set out the details of the measures that will be taken in relation to accidental pollution events. The final PEMP would be agreed with the MMO prior to construction.

10.3.4.2 Other Mitigation Measures

33. In addition to the embedded mitigation measures as outlined above, the Applicant has also committed to the following mitigation measures.

Table 10-3: Additional Mitigation Measures

Parameter	Additional Mitigation Measures
MMMP for Piling Activities	
MMMP for Piling Activities	The MMMP for piling will be developed in the pre-construction period and based upon best available information, methodologies, industry best practice, latest scientific understanding, current guidance and detailed project design. The MMMP for piling will be developed in consultation with the relevant Statutory Nature Conservation Bodies (SNCBs) and the MMO, detailing the proposed mitigation measures to reduce the risk of any physical or permanent auditory injury (PTS) to marine mammals during all piling operations. This will include details of the embedded mitigation, for the soft-start and ramp-up, as well as details of the mitigation zone and any additional mitigation measures required in order to minimise potential impacts of any physical or PTS, for example, the activation of ADD (e.g. for 10 minutes) prior to the soft-start. A **Draft MMMP** (document reference 9.4) has been submitted with the DCO application.
MMMP for UXO Clearance	
MMMP for UXO	A detailed MMMP will be prepared for UXO clearance during the pre-construction phase. The MMMP for UXO clearance will ensure there are adequate mitigation measures to minimise the risk of any physical or permanent auditory injury to marine mammals as a result of UXO clearance. The MMMP for UXO clearance will be developed in the pre-construction period, when there is more detailed information on the UXO clearance which could be required and the most suitable mitigation measures, based upon best available information and methodologies at that time. The MMMP for UXO clearance will be prepared in consultation with the MMO and relevant SNCBs. The MMMP for UXO clearance will include details of all the required mitigation measures to minimise the potential risk of PTS as a result of underwater noise during UXO clearance, for example, this would consider the options, suitability and effectiveness of mitigation measures such as, but not limited to: • Low-order clearance techniques, such as deflagration; • The use of bubble curtains if any high-order detonation is required (taking into consideration the environmental limitations); • All UXO clearance to take place in daylight and, when possible, in favourable conditions with good visibility (sea state 3 or less); • Establishment of a monitoring area with minimum of 1km radius. The observation of the monitoring area will be by dedicated and trained marine mammal observers (MMObs) during daylight hours and suitable visibility; • The activation of ADD; • The controlled explosions of the UXO will be undertaken by specialist contractors, using the minimum amount of explosive required in order to achieve safe disposal of the UXO; and • Other UXO clearance techniques, such as avoidance of UXO; or relocation of UXO. If more than one high-order detonation is required, other measures such as the use of scare charges; or multiple detonations, if UXO are

Parameter	Additional Mitigation Measures
	located in close proximity, will also be considered in consultation with the MMO and SNCBs. UXO clearance is not included in the DCO application, as currently not enough detailed information is available. Therefore, UXO clearance will be assessed through a separate Marine Licence (ML) application post consent, as agreed with the MMO and Natural England at ETG 3 on the 20th July 2021.
Site Integrity Plan (SIP)	
Site Integrity Plan (SIP) for the Southern North Sea (SNS) Special Area of Conservation (SAC)	In addition to the MMMPs for piling and UXO clearance, a SIP for the SNS SAC will be developed. The SIP will set out the approach to deliver any Project mitigation or management measures to reduce the potential for any significant disturbance of harbour porpoise in relation to the SNS SAC conservation objectives. The SIP is an adaptive management tool, which can be used to ensure that the most adequate, effective and appropriate measures, if required, are put in place to reduce the significant disturbance of harbour porpoise in the SNS SAC. The SIP will be developed in the pre-construction period and will be based upon best available information and methodologies at that time, in consultation with the relevant SNCBs and the MMO. An **In Principle SIP for the SNS SAC** (document reference 9.6) has been submitted with the DCO application.

10.4 Impact Assessment Methodology

10.4.1 Policy, Legislation and Guidance

10.4.1.1 National Policy Statements

34. The assessment of potential impacts upon marine mammals has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Project are:
- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) now BEIS, 2011a);
- NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b); and
- NPS for Electricity Networks Infrastructure (EN-5) (DECC, 2011c).

35. The specific assessment requirements for marine mammals, as detailed in the NPS (EN-3), are summarised in **Table 10-4** together with an indication of the section of the chapter where each is addressed.

36. It is noted that the NPS for Renewable Energy Infrastructure (EN-3) is in the process of being revised. A draft version was published for consultation in September 2021 (BEIS, 2021). A review of this draft version has been undertaken in the context of this ES chapter.

37. **Table 10-4** includes updates based on the draft version of NPS (EN-3) whereby relevant additional requirements not presented within the current NPS (EN-3) have been considered. A reference to the particular requirement's location within the draft NPS and to where within this ES chapter it has been addressed has also been provided.

38. Minor wording changes within the draft version which do not materially influence the NPS (EN-3) requirements have not been reflected in **Table 10-4**.

Table 10-4: NPS Assessment Requirements Relevant to Marine Mammals

NPS Requirement	NPS Reference	Section Reference
NPS for Renewable Energy Infrastructure (EN-3)		
There are specific considerations from piling noise which apply to offshore wind energy infrastructure proposals with regard to marine mammals, including cetaceans and seals, which have statutory protection. Offshore piling may reach noise levels which are high enough to cause injury, or even death, to marine mammals. If piling associated with an offshore wind farm is likely to lead to the commission of an offence (which would include deliberately disturbing, killing or capturing a European Protected Species), an application may have to be made for a wildlife licence to allow the activity to take place.	Paragraphs 2.6.90-2.6.91 of the NPS EN-3 (July 2011). See updated wording in draft EN-3 paragraph 2.28.1 and 2.28.2 (BEIS, 2021) below.	**Section 10.3.3** provides an overview of the worst-case scenario for possible piling works. **Sections 10.6.1.1** and **10.6.1.2** provide an assessment of pile driving (including noise modelling results). It is anticipated that an application for a European Protected Species / licence will be submitted post-consent.
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); and • Soft-start noise levels according to proposed hammer and pile design; and operational noise.	Paragraph 2.6.92 of the NPS EN-3 (July 2011). See updated wording in draft EN-3 paragraph 2.28.3 (BEIS, 2021) below.	**Section 10.5** and **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**, provide a description of the existing environment. **Section 10.6** details the assessment of impacts during construction, including pile driving. **Section 10.6.2** provides the assessment of operational noise. Cumulative impacts are assessed in **Section 10.7** and impacts on protected sites are assessed in the **RIAA** (document reference 5.4).

NPS Requirement	NPS Reference	Section Reference
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 above], the applicant should look at possible alternatives or appropriate mitigation before applying for a licence.	Paragraph 2.6.93 of the NPS EN-3 (July 2011). See updated wording in draft EN-3 paragraph 2.28.1 and 2.28.5 (BEIS, 2021) below.	**Section 10.6.1** details the assessment of impacts during construction, including pile driving and mitigation measures. SEP and DEP have discussed proposed piling activities through the Evidence Plan Process (EPP) as outlined in **Section 10.2**.
The IPC (Infrastructure Planning Commission) [now the Planning Inspectorate and the Secretary of State (SoS)] 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 [now SoS] may refuse the application. The conservation status of marine European Protected Species and seals are of relevance to the IPC [now SoS]. IPC [now SoS] should take into account the views of the relevant statutory advisors. Fixed submerged structures such as foundations are likely to pose little collision risk for marine mammals and the IPC [now SoS] is not likely to have to refuse to grant consent for a development on the grounds that offshore wind farm foundations pose a collision risk to marine mammals.	Paragraphs 2.6.94 to 2.6.96 of the NPS EN-3 (July 2011). See updated wording in draft EN-3 paragraph 2.28.9 and 2.28.10 (BEIS, 2021) below.	**Chapter 4 Project Description** describes the foundation options under consideration SEP and DEP. **Section 10.3.3** describes the worst-case scenario for marine mammals.
Monitoring of the surrounding area before and during the piling procedure can be undertaken. During construction, 24-hour working practices may be employed so that the overall construction programme and the potential for impacts to marine mammal communities are reduced in time.	Paragraphs 2.6.97 to 2.6.99 of the NPS EN-3 (July 2011). See updated wording in draft EN-3 paragraph 2.28.6 and 2.28.7 (BEIS, 2021) below.	An **Offshore IPMP** (document reference 9.5) and **Draft MMMP** (document reference 9.4) have been submitted with the DCO application. These plans will be developed in consultation with the relevant SNCBs and approved by the MMO post-

NPS Requirement	NPS Reference	Section Reference
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.		consent and will identify any necessary monitoring requirements.
The conservation status of marine European Protected Species and seals are of relevance to the IPC [now SoS].	Paragraph 2.6.95 of the NPS EN-3 (July 2011).	The conservation status of relevant marine mammal species is included in **Section 10.4.1.6**.
Monitoring of the surrounding area before and during the piling procedure can be undertaken.	Paragraph 2.6.97 of the NPS EN-3 (July 2011).	A **Draft MMMP** (document reference 9.4) has been submitted with the DCO application which details the marine mammal monitoring requirements during piling.
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 of the NPS EN-3 (July 2011).	Details on the construction programme are provided in **Section 10.3.3.2**.
Draft EN-3 NPS for Renewable Energy Infrastructure (EN-3) (BEIS, 2021)		
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. Therefore, 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.	Draft EN-3 paragraph 2.28.1 (BEIS, 2021).	**Section 10.6** provides an assessment of the underwater noise levels and maximum impact ranges that could cause injury or disturbance to marine mammals from UXO clearance, piling and other noise sources. A summary of the mitigation measures to reduce the potential impacts of underwater noise is provided in **Section 10.3.4**.

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

NPS Requirement	NPS Reference	Section Reference
		As outlined in **Section 10.4.1.5**, if required, a wildlife licence application will be submitted post-consent.
The development of offshore wind farms can also impact fish species, 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.	Draft EN-3 paragraph 2.28.2 (BEIS, 2021)	**Section 10.6** provides an assessment of the potential impacts from any indirect effects as a result of impacts on prey species and the risk of collision with construction and maintenance vessels.
Applicant's assessment 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 (e.g. SACs); • baseline noise levels; • predicted construction and soft start noise levels in relation to mortality, Permanent Threshold Shift (PTS) and 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; and • barrier risk.	Draft EN-3 paragraph 2.28.3 (BEIS, 2021).	**Section 10.5** and **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**, provide a description of the existing environment, including likely feeding areas and prey, seal haul-out sites, migration routes and protected areas. **Section 10.6** details the assessment of impacts for PTS, TTS and disturbance from underwater noise, including during construction from pile driving and soft-start noise levels. **Section 10.6.2** provides the assessment of operational noise. **Section 10.7** provides the cumulative impact assessment (CIA). **Section 10.6** details the assessment of collision risk and barrier risk.
The scope, effort and methods required for marine mammal surveys should be discussed with the relevant statutory nature conservation body.	Draft EN-3 paragraph 2.28.4 (BEIS, 2021).	The requirements of the marine mammal surveys were discussed with

NPS Requirement	NPS Reference	Section Reference
		the relevant SNCBs as part of the EPP, as outlined in **Section 10.2**.
The applicant should discuss any proposed noisy activities with the relevant body and must reference the JNCC underwater noise guidance (JNCC *et al*., 2020) in relation to noisy activities (alone and in-combination with other plans or projects) within HRA sites. 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 2.28.1 above, the applicant should look at possible alternatives or appropriate mitigation (detailed below).	Draft EN-3 paragraph 2.28.5 (BEIS, 2021)	The Applicant has discussed noisy activities through the EPP as outlined in **Section 10.2**. Reference has been made to the JNCC underwater noise guidance (JNCC *et al*., 2020) in relation to noisy activities (alone and in-combination with other plans or projects) for the assessment of effects on the SNS SAC in the **Report to Inform Appropriate Assessment** (RIAA) (document reference 5.4).
<u>Mitigation</u> 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.	Draft EN-3 paragraph 2.28.6 (BEIS, 2021)	The proposed mitigation is outlined in **Section 10.3.4** and the proposed monitoring is outlined in **Section 10.11**.
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.	Draft EN-3 paragraph 2.28.7 (BEIS, 2021)	Sot-start procedures are included in the embedded mitigation as outlined in **Section 10.3.4.1**.
Where noise impacts cannot be reduced to acceptable levels, other mitigation should be considered, including spatial/temporal restrictions on noisy activities, alternative foundation types, alternative installation methods and noise abatement technology. Review of up-to-date research should be undertaken and all potential mitigation options presented.	Draft EN-3 paragraph 2.28.8 (BEIS, 2021)	Mitigation to reduce the impacts from underwater noise are provided in the **Draft MMMP** (document reference 9.4) and **In Principle SIP for the SNS SAC** (document reference 9.6). As outlined in **Section 10.3.4.2**, these documents and the mitigation measures required will be developed in the pre-construction period and will be based upon best available information and

NPS Requirement	NPS Reference	Section Reference
		methodologies at that time, in consultation with the relevant SNCBs and MMO.
Secretary of State decision making The Secretary of State 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 to reasonably minimise significant impacts on marine mammals. Unless suitable noise mitigation measures can be imposed by requirements to any development consent the Secretary of State may refuse the application.	Draft EN-3 paragraph 2.28.9 (BEIS, 2021)	As outlined in **Section 10.3.4**, selection of the types of foundations, construction methods and mitigation measures are designed to reasonably minimise significant impacts on marine mammals.
The conservation status of cetaceans and seals are of relevance and the Secretary of State should be satisfied that cumulative and in-combination impacts on marine mammals have been considered.	Draft EN-3 paragraph 2.28.10 (BEIS, 2021)	The conservation status of relevant marine mammal species is included in **Section 10.4.1.6**. The cumulative impacts and in-combination effects on marine mammals have been assessed in **Section 10.7** of the ES and in the **RIAA** (document reference 5.4), respectively.

10.4.1.2 National and Regional Marine Policies

39. In addition to the NPS, there are a number of pieces of legislation, policy and guidance applicable to the assessment of marine mammals. These include:

- Legislation:
    - The Marine Strategy Regulations (MSR) SI 2010/1627 (Defra, 2010);
- Policy:
    - The Marine Policy Statement (MPS) (HM Government, 2011); and
    - The East Inshore and East Offshore Marine Plans (HM Government, 2014).

40. Further detail is provided in **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** and **Chapter 2 Policy and Legislative Context**.

10.4.1.3 National and International Legislation for Marine Mammals

41. **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** provides an overview of national and international legislation in relation to marine mammals.

10.4.1.4 Guidance Documents for Marine Mammals

42. The principal guidance documents used to inform the assessment of potential impacts on marine mammals include, but are not limited to:

- The Protection of Marine EPS from Injury and Disturbance: Draft Guidance for the Marine Area in England and Wales and the UK Offshore Marine Area (Joint Nature Conservation Committee (JNCC *et al.*, 2010);
- Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine (Chartered Institute of Ecology and Environmental Management (CIEEM), 2019);
- Environmental Impact Assessment for offshore renewable energy projects – guide (British Standards Institution (BSI), 2015);
- Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments Final Report (Sea Mammal Research Unit Ltd (SMRU Ltd) on behalf of The Crown Estate, 2010);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Centre for the Environment and Fisheries and Aquaculture Science (Cefas), 2011);
- Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC, Department of Agriculture, Environment and Rural Affairs (DAERA) and Natural England, 2020);

- A review of noise abatement systems for offshore wind farm construction noise, and the potential for their application in Scottish Waters (Verfuss *et al*., 2019);
- Reducing Underwater Noise (NIRAS, SMRU Consulting, and The Crown Estate, 2019);
- 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).

10.4.1.5 Protected Species and Marine Wildlife Licence Guidance

43. All cetacean species are listed as European Protected Species (EPS) under Annex IV of the Habitats Directive and are therefore protected from the deliberate killing (or injury), capture and disturbance throughout their range. Within the UK, The Habitats Directive is enacted through The Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017. Under these Regulations, it is an offence to:

- deliberately capture, injure or kill any cetacean species;
- to deliberately disturb them; or
- to damage or destroy a breeding site or resting place.

44. Grey and harbour seal are also protected under the Conservation of Habitats and Species Regulations 2017 and The Conservation of Offshore Marine Habitats and Species Regulations 2017, as well as Conservation of Seals Act 1970.

45. Further information is provided in **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**.

46. If required, a Marine Wildlife Licence[2] application will be submitted post-consent. At that point in time, the project design envelope will have been further refined through detailed design and procurement activities and further detail will be available on the techniques selected for construction, as well as the mitigation measures that will be in place following the development of MMMPs for piling and UXO clearance.

10.4.1.6 Favourable Conservation Status (FCS)

47. Member states report back to the European Union (EU) every six years on the Conservation Status of marine mammals. **Table 10-6** provides the current FCS of marine mammals species occurring in UK and adjacent waters, based on the most recent 2013-2018 reporting by JNCC in 2019.

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

Table 10-5: FCS Assessment of Marine Mammals Species in Annex IV of the Habitats Directive Occurring in UK and Adjacent Waters (JNCC, 2019) Relevant to SEP and DEP

Species	Favourable Conservation Status Assessment
Cetaceans	
Harbour porpoise *Phocoena phocoena*	Unknown
Bottlenose dolphin *Tursiops truncatus*	Unknown
White-beaked dolphin *Lagenorhynchus albirostris*	Unknown
Minke whale *Balaenoptera acutorostrata*	Unknown
Pinnipeds	
Grey seal *Halichoerus grypus*	Favourable
Harbour seal *Phoca vitulina*	Unfavourable-inadequate

10.4.2 Data and Information Sources

10.4.2.1 Site specific surveys

48. Site-specific aerial surveys were conducted for both marine mammals and seabirds. HiDef Aerial Surveying Limited ('HiDef') collected high resolution aerial digital still imagery for marine megafauna (combined with ornithology surveys) over both SEP and DEP, including 4km buffer. Further detail of the survey method is provided in **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**. The aerial surveys were conducted between May 2018 and April 2020. The surveys were conducted monthly, with two surveys per month between April 2019 and August 2019. In total, 24 months of data has been collected for SEP and DEP, over 29 individual survey days (further details are provided in **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**).

10.4.2.2 Other Available Sources

49. Other sources that have been used to inform the assessment are listed in **Table 10-6**.

Table 10-6:Other Available Data and Information Sources

Data set	Spatial coverage	Year	Notes
Small Cetaceans in the European Atlantic and North Sea (SCANS-III) data (Hammond *et al*., 2021).	North Sea and European Atlantic waters	Summer 2016	Provides information including abundance and density estimates of cetaceans in European Atlantic waters in summer

Data set	Spatial coverage	Year	Notes
			2016, including the proposed offshore development area.
MUs for cetaceans in UK waters (Inter-Agency Marine Mammal Working Group (IAMMWG), 2022).	UK waters	2021	Provides information on cetacean MUs for the proposed offshore development area.
Offshore Energy Strategic Environmental Assessment (including relevant appendices and technical reports) (Department of Energy and Climate Change (DECC) (now BEIS), 2016).	UK waters	2016	Provides information for the wider North Sea area.
The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area (Heinänen and Skov, 2015).	UK Exclusive Economic Zone (EEZ)	1994-2011	Data was used to determine harbour porpoise SAC sites. Provides information on harbour porpoise in the North Sea area.
Revised Phase III data analysis of Joint Cetacean Protocol (JCP) data resources (Paxton *et al*., 2016).	UK EEZ	1994-2011	Provides information on harbour porpoise in the North Sea area.
Distribution and abundance maps for cetacean species around Europe (Waggitt *et al*. (2019).	North-east Atlantic	1980-2018	Provides information on cetacean species for the wider North Sea area.
Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment (Gilles *et al*., 2016).	UK (SCANS II, Dogger Bank), Belgium, the Netherlands, Germany, and Denmark	2005-2013	Provides information for central and SNS area.
Distribution of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008 (The Wildfowl and Wetlands Trust (WWT), 2009).	UK areas of the North Sea	2001-2008	Provides information for on species in the North Sea area.
MARINElife surveys from ferries routes across the southern North Sea area (MARINElife, 2020).	Southern North Sea	2017-2020	Provides information on species in SNS area.
Sea Watch Foundation volunteer sightings off eastern England (Sea Watch Foundation, 2021).	East coast of England	2019-2021	Provides information on species sighted along east coast of England.

Data set	Spatial coverage	Year	Notes
UK seal at sea density estimates and usage maps (Russell *et al*., 2017).	North Sea	1988-2016	Provides information on abundance and absolute density estimates (i.e. number of seals) for seal species.
Habitat-based predictions of at-sea distribution for grey and harbour seals in the British Isles (Carter *et al*., 2020).	British Isles	1991-2019	Provides information on relative density (i.e. percentage of at-sea population) for seal species.
Seal telemetry data (e.g. Sharples *et al*., 2008; Russell and McConnell, 2014; Russell, 2016a).	North Sea	1988-2010; 2015	Provides information on movements and distribution of seal species.
Special Committee on Seals (SCOS) annual reporting of scientific advice on matters related to the management of seal populations (SCOS, 2020).	North Sea	2020	Provides information on seal species.
Counts of grey seal in the Wadden Sea (Brasseur *et al*., 2021).	Wadden Sea	Winter 2020 to Spring 2021	Counts of grey seal during pup and moult season.
Counts of harbour seal in the Wadden Sea (Galatius *et al*., 2021).	Wadden Sea	June and August 2020	Counts of harbour seal during pup and moult season.

10.4.3 Impact Assessment Methodology

50. **Chapter 5 EIA Methodology** provides a summary of the general impact assessment methodology applied to SEP and DEP. The following sections confirm the methodology used to assess the potential impacts on marine mammals.

51. A matrix approach is used to guide the assessment of impacts following best practice, EIA guidance and the approach previously agreed with stakeholders for other recent offshore wind farms (including Norfolk Vanguard, Norfolk Boreas and East Anglia ONE North, TWO and THREE).

52. In order to enable and facilitate a consistency of approach a matrix of definitions will be employed to structure the expertise and evidence led assessment of impacts. Receptor sensitivity for an individual from each marine mammal species have been defined within the ES, following the definitions set out in **Sections 10.4.3.1** and **10.4.3.2**.

10.4.3.1 Definitions

53. For each effect, the assessment identifies receptors sensitive to that effect and implements a systematic approach to understanding the impact pathways and the level of impacts on given receptors. The definitions of sensitivity and magnitude for the purpose of the marine mammal assessment are provided in **Table 10-7** and **Table 10-9** respectively.

54. The sensitivity of a receptor is determined through its ability to accommodate change and on its ability to recover if it is affected (**Table 10-7**). The sensitivity level of marine mammals to each type of impact is justified within the impact assessment and is dependent on the following factors:

- Adaptability – The degree to which a receptor can avoid or adapt to an effect;
- Tolerance – The ability of a receptor to accommodate temporary or permanent change without a significant adverse effect;
- Recoverability – The temporal scale over and extent to which a receptor will recover following an effect; and
- Value – A measure of the receptor importance, rarity and worth.

55. The sensitivity of marine mammals to impacts from pile driving noise is currently the impact of most concern across the offshore wind sector. The sensitivity to potential impacts of lethality, physical injury, auditory injury or hearing impairment, as well as behavioural disturbance or auditory masking will be considered for each species, using available evidence including published data sources.

Table 10-7: Definition of Sensitivity for a Marine Mammal Receptor

Sensitivity	Definition
High	Individual receptor has very limited capacity to avoid, adapt to, tolerate or recover from the anticipated impact.
Medium	Individual receptor has limited capacity to avoid, adapt to, tolerate or recover from the anticipated impact.
Low	Individual receptor has some tolerance to avoid, adapt to, tolerate or recover from the anticipated impact.
Negligible	Individual receptor is generally tolerant to and can tolerate or recover from the anticipated impact.

56. In addition, for some assessments the ‘value’ of a receptor may also be an element to add to the assessment where relevant – for instance if the receptor is designated or has an economic value.

57. The ‘value’ of the receptor forms an important element within the assessment, for instance, if the receptor is a protected species or habitat or has an economic value. It is important to understand that high value and high sensitivity are not necessarily linked within a particular impact. A receptor could be of high value but have a low or negligible physical/ecological sensitivity to an effect. Similarly, low value does not equate to low sensitivity and is judged on a receptor by receptor basis.

58. In the case of marine mammals, most species are protected by a number of international commitments as well as European and UK law and policy. All cetaceans in UK waters are EPS and, therefore, are internationally important. Harbour porpoise, bottlenose dolphin, grey seal and harbour seals are also afforded international protection through the designation of protected sites. As such, all species of marine mammal can be considered to be of high value.

59. **Table 10-8** provides definitions for the value afforded to a receptor based on its legislative importance. The value will be considered, where relevant, as a modifier for the sensitivity assigned to the receptor, based on expert judgement.

Table 10-8: Definitions of the Different Value Levels for Marine Mammals

Value	Definition
High	Internationally or nationally important Internationally protected species that are listed as a qualifying interest feature of an internationally protected site (i.e. Annex II protected species designated feature of a designated site) and protected species (including EPS) that are not qualifying features of a designated site.
Medium	Regionally important or internationally rare Protected species that are not qualifying features of a designated site but are recognised as a Biodiversity Action Plan (BAP) priority species either alone or under a grouped action plan, and are listed on the local action plan relating to the marine mammal study area.
Low	Locally important or nationally rare Protected species that are not qualifying features of a designated site and are occasionally recorded within the study area in low numbers compared to other regions.
Negligible	Not considered to be particularly important or rare Species that are not qualifying features of a designated site and are never or infrequently recorded within the study area in very low numbers compared to other regions.

60. The thresholds for defining the potential magnitude of effect that could occur from a particular impact will be determined using expert judgement, current scientific understanding of marine mammal population biology, and JNCC *et al.* (2010) draft guidance on disturbance to EPS species. The JNCC *et al.* (2010) EPS draft guidance suggests definitions for a ‘significant group’ of individuals or proportion of the population for EPS species. As such this guidance has been considered in defining the thresholds for magnitude of effects (**Table 10-9**).

61. The JNCC *et al.* (2010) draft guidance provides some indication on how many animals may be removed from a population without causing detrimental effects to the population at FCS. The JNCC *et al.* (2010) draft guidance also provides limited consideration of temporary effects, with guidance reflecting consideration of permanent displacement.

62. Temporary effects are considered to be of medium magnitude at greater than 5% of the reference population. JNCC *et al.* (2010) draft guidance considered 4% as the maximum potential growth rate in harbour porpoise, and the 'default' rate for cetaceans. Therefore, beyond natural mortality, up to 4% of the population could theoretically be permanently removed before population growth could be halted. In assigning 5% to a temporary impact in this assessment, consideration is given to uncertainty of the individual consequences of temporary disturbance.

63. Permanent effects with a greater than 1% of the reference population being affected within a single year are considered to be high in magnitude in this assessment. This is based on Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) and Department for Environment, Food and Rural Affairs (Defra) advice (Defra, 2003; ASCOBANS, 2015) relating to impacts from fisheries by-catch (i.e. a permanent effect) on harbour porpoise. A threshold of 1.7% of the relevant harbour porpoise population above which a population decline is inevitable has been agreed with Parties to ASCOBANS, with an intermediate precautionary objective of reducing the impact to less than 1% of the population (Defra, 2003; ASCOBANS, 2015).

Table 10-9: Definition of Magnitude for a Marine Mammal Receptor

Magnitude	Definition
High	Permanent irreversible change to exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that more than 1% of the reference population are anticipated to be exposed to the effect. OR Long-term effect for 10 years or more, but not permanent (e.g. limited to operational phase of the Projects). Assessment indicates that more than 5% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that more than 10% of the reference population are anticipated to be exposed to the effect.
Medium	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that between 0.01% and 1% of the reference population anticipated to be exposed to effect. OR Long-term effect for 10 years or more, but not permanent (e.g. limited to operational phase of the Projects). Assessment indicates that between 1% and 5% of the reference population are anticipated to be exposed to the effect. OR

Magnitude	Definition
	Temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that between 5% and 10% of the reference population anticipated to be exposed to effect.
Low	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that between 0.001% and 0.01% of the reference population anticipated to be exposed to effect. OR Long-term effect for 10 years or more, but not permanent (e.g. limited to operational phase of the Projects). Assessment indicates that between 0.01% and 1% of the reference population are anticipated to be exposed to the effect. OR Intermittent and temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that between 1% and 5% of the reference population anticipated to be exposed to effect.
Negligible	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that less than 0.001% of the reference population anticipated to be exposed to effect. OR Long-term effect for 10 years or more (but not permanent, e.g. limited to lifetime of the Projects). Assessment indicates that less than 0.01% of the reference population are anticipated to be exposed to the effect. OR Intermittent and temporary effect (limited to the construction phase of development or Project timeframe) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that less than 1% of the reference population anticipated to be exposed to effect.

10.4.3.2 Impact Significance

64. In basic terms, the potential significance of an impact is a function of the sensitivity of the receptor and the magnitude of the effect (see **Chapter 5 EIA Methodology** for further details). The determination of significance is guided by the use of an impact significance matrix, as shown in **Table 10-10**. Definitions of each level of significance are provided in **Table 10-11**.

65. Potential impacts identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. Appropriate mitigation has been identified, where possible, in consultation with the regulatory authorities and relevant stakeholders. The aim of mitigation measures is to avoid or reduce the overall impact in order to determine a residual impact upon a given receptor.

Table 10-10: Impact Significance Matrix

		Adverse Magnitude				Beneficial Magnitude			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	*Major*	*Major*	*Moderate*	*Minor*	*Minor*	*Moderate*	*Major*	*Major*
	Medium	*Major*	*Moderate*	*Minor*	*Minor*	*Minor*	*Minor*	*Moderate*	*Major*
	Low	*Moderate*	*Minor*	*Minor*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 10-11: Definition of Impact Significance

Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision making process.
Negligible	No discernible change in receptor condition.
No change	No impact, therefore no change in receptor condition.

10.4.4 Cumulative Impact Assessment Methodology

66. The cumulative impact assessment (CIA) considers other plans, projects and activities that may impact cumulatively with SEP and DEP. As part of this process, the assessment considers which of the residual impacts assessed for SEP and/or DEP on their own have the potential to contribute to a cumulative impact, the data and information available to inform the cumulative assessment and the resulting confidence in any assessment that is undertaken. **Chapter 5 EIA Methodology** provides further details of the general framework and approach to the CIA.

67. For the marine mammal assessment, the stages of project development have been adopted as 'tiers' of project development status within the cumulative impact assessment. These tiers are based on guidance issued by JNCC and Natural England in September (2013), as follows:

- Tier 1: built and operational projects;
- Tier 2: projects under construction;
- Tier 3: projects that have been consented (but construction has not yet commenced);

- Tier 4: projects that have an application submitted to the appropriate regulatory body that have not yet been determined;
- Tier 5: projects that the regulatory body are expecting to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects); and
- Tier 6: projects that have been identified in relevant strategic plans or programmes.

68. These tiers are used as they are considered more appropriate in comparison to the tiers in The Planning Inspectorate (2019a) Advice Note 17 for the types of projects and plans considered in this assessment, in particular for the offshore wind farm stages.

69. The types of plans and projects to be taken into consideration are:

- Other offshore wind farms;
- Other marine renewables (wave and tidal) developments;
- Aggregate extraction and dredging;
- Licenced disposal sites;
- Construction sub-sea cables and pipelines;
- Oil and gas development and decommissioning, including seismic surveys; and
- UXO clearance.

70. Commercial fishing activity is not considered in the CIA. Further information and justification is provided in **Appendix 10.3 Marine Mammal CIA Screening**.

71. The CIA is a two-part process in which an initial list of potential projects is identified with the potential to interact with the proposed projects based on the mechanism of interaction and spatial extent of the reference population for each marine mammal species. Following a tiered approach, the list of projects is then refined based on the level of information available for this list of projects to enable further assessment.

72. The plans and projects screened into the CIA are:

- Located in the marine mammal MU population reference area (defined for individual species in the assessment sections);
- Offshore projects and developments, if there is the potential for cumulative impacts during the construction, operational or decommissioning of the proposed projects; and
- Offshore wind farm developments, if the construction and/or piling period could overlap with the proposed construction and/or piling period of the projects, based on best available information on when the developments are likely to be constructed and piling.

73. The CIA will consider projects, plans and activities which have sufficient information available to undertake the assessment. Insufficient information will preclude a meaningful quantitative assessment, and it is not appropriate to make assumptions about the detail of future projects in such circumstances.

74. Given the fast moving nature of offshore development, it is likely that new projects relevant to the assessment will arise throughout the pre-application period. In order to finalise an assessment, it will be necessary to have a cut-off period after which no more projects will be included.

75. The project tiers considered in the CIA for marine mammals are outlined in **Table 10-12** and the CIA screening is provided in **Appendix 10.3 Marine Mammal CIA Screening**.

Table 10-12: Tiers in Relation to Project Category Which Have Been Screened Into the CIA

Project Category	UK	Other
Other offshore wind farms	Tier 1,2,3,4,5	Tier 1,2,3,4
Other renewable developments (tidal and wave)	Tier 1,2,3,4	Tier 1,2,3
Aggregate extraction and dredging	Tier 1,2,3	Screened out
Oil and Gas installations (including surveying)	Tier 1,2,3	Screened out
Navigation and shipping	Tier 1,2,3	Screened out
Planned construction of sub-sea cables and pipelines	Tier 1,2,3	Screened out

10.4.5 Transboundary Impact Assessment Methodology

76. The transboundary assessment (**Section 10.8**) considers the potential for transboundary effects to occur on marine mammal species. The highly mobile nature of marine mammals included within the assessments means that there is the potential for transboundary impacts since species might arise from within the Exclusive Economic Zone (EEZ) of European Economic Area (EEA) states.

77. **Chapter 5 EIA Methodology** provides further details of the general framework and approach to the assessment of transboundary effects.

78. For marine mammals, the potential for transboundary impacts has been addressed by considering the reference populations (MUs) and potential linkages to other countries (for example, as identified through seal telemetry studies).

79. The assessment of effects on transboundary Designated Sites is presented in the **RIAA** (document reference 5.4).

10.4.6 Assumptions and Limitations

80. Due to the large amount of data that has been collected for this and other nearby offshore wind farms, as well as other available data for marine mammals within the region, there is a good understanding of the existing environment. There are, however some limitations to data collected by marine mammal surveys, primarily due to the highly mobile nature of marine mammals and therefore the potential variability in usage of the site; each survey provides only a snapshot, as well as for any changes in distributions of marine mammal populations that have not yet been picked up by large scale surveys (such as the recent increase in bottlenose dolphin presence in the area). However, the surveys in the study area over the last decade show relatively consistent results.

81. There are also limitations in the detectability of marine mammals from aerial surveys, such as not being to detect those individuals that are submerged. **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** seeks to address these limitations by estimating a correction factor in order to determine estimated absolute density estimates from the site specific aerial surveys.

82. Where possible, an overview of the confidence of the data and information underpinning the assessment will be presented. Confidence will be classed as High, Medium or Low depending on the type of data (quantitative, qualitative or lacking) as well as the source of information (e.g. peer reviewed publications, grey literature) and its applicability to the assessment.

10.5 Existing Environment

83. As outlined in **Section 10.3.1**, the key marine mammal species are:

- Harbour porpoise
- Bottlenose dolphin
- White-beaked dolphin
- Minke whale
- Grey seal
- Harbour seal

84. **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** provides detailed information for each of the species, including details from the site-specific surveys, density estimates, abundance estimates, distribution, diet and seal haul-out sites, that are relevant for the assessments.

10.5.1 Harbour Porpoise

85. Within the SNS area, harbour porpoise are the most common marine mammal species. Heinänen and Skov (2015) identified that within the North Sea, water depth and hydrodynamic variables are the most important factors in harbour porpoise densities in species areas, in both winter and summer seasons. The sea bed sediments also play an important role in determining areas of high harbour porpoise density, as well as the number of vessels present in the area.

86. Distribution and abundance maps have been developed by Waggitt *et al.* (2019) for cetacean species around Europe. These maps were generated based on a collation of survey effort across the north-east Atlantic between 1980 and 2018, with a total of 1,790,375km of survey effort for cetaceans. All survey data was standardized to generate distribution maps at 10km resolution, with maps generated for each species included for each month of the year.

87. For harbour porpoise, the distribution maps show a clear pattern of high harbour porpoise density in the SNS, and the coasts of south-east England, for both January and July (Waggitt *et al*., 2019). Examination of this data, including all 10km grids that overlap with SEP and DEP, including export cable corridor areas, indicates an average annual density estimate of:

- 0.56 individuals per km^2 for SEP, DEP and the export cable corridor areas.

88. Results from the SCANS-III survey (undertaken in summer 2016; Hammond *et al*., 2021) also indicate that the occurrence of harbour porpoise is greater in the central and southern areas of the North Sea compared to the northern North Sea. The SEP and DEP wind farm sites and offshore export cable corridors are located in SCANS-III survey block O (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**) where:

- Abundance estimate = 53,485 harbour porpoise (95% Confidence Interval (CI) = 37,413-81,695); and
- Density estimate = 0.888 harbour porpoise/km^2 (Coefficient of Variation (CV) = 0.209).

89. Data from the SEP and DEP site specific surveys have also been used to generate abundance and density estimates for the sites with a 4km buffer (excluding offshore temporary works area) (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**).

90. Harbour porpoise was the most commonly sighted marine mammal species during the surveys, with a total of 442 individuals recorded through the 29 survey dates. A seasonal pattern of harbour porpoise abundance within the Projects is indicated within the results, with the highest numbers were generally recorded in the summer months, while lower numbers were recorded during winter. The highest numbers recorded in a single month was 67 in July 2019 (across two survey days) and 57 in May 2019 (also recorded across two survey days). The lowest number recorded in a survey month was during December 2019 (with just one individual), with two recorded during December 2018 and January 2019, as well as January and February 2020.

91. The average of the winter months, summer months, and annual density has then been calculated based on the maximum calculated for each month. **Table 10-13** shows the densities for harbour porpoise, based on all individuals that have the potential to be harbour porpoise.

Table 10-13: Maximum Harbour Porpoise Summer, Winter and Annual Density Estimate for SEP and DEP Survey Areas Plus 4km Buffer

Season	Maximum density estimate (corrected) for whole survey area	Maximum density estimate (corrected) for SEP + 4km buffer	Maximum density estimate (corrected) for DEP + 4km buffer
Average winter	0.65	0.52	0.85
Average summer	**1.46**	**0.63**	**2.43**
Average annual	1.05	0.57	1.64

92. As a precautionary approach, the average summer density estimates of harbour porpoise from the site specific surveys (**Table 10-13**) have been used in the impact assessments.

93. In addition to the density estimates, abundance estimates of harbour porpoise at SEP and DEP have been derived. The abundance estimates indicate a clear seasonal pattern in the abundance of harbour porpoise within the entire survey area, with higher numbers present in the summer months (**Plate 10-1**).

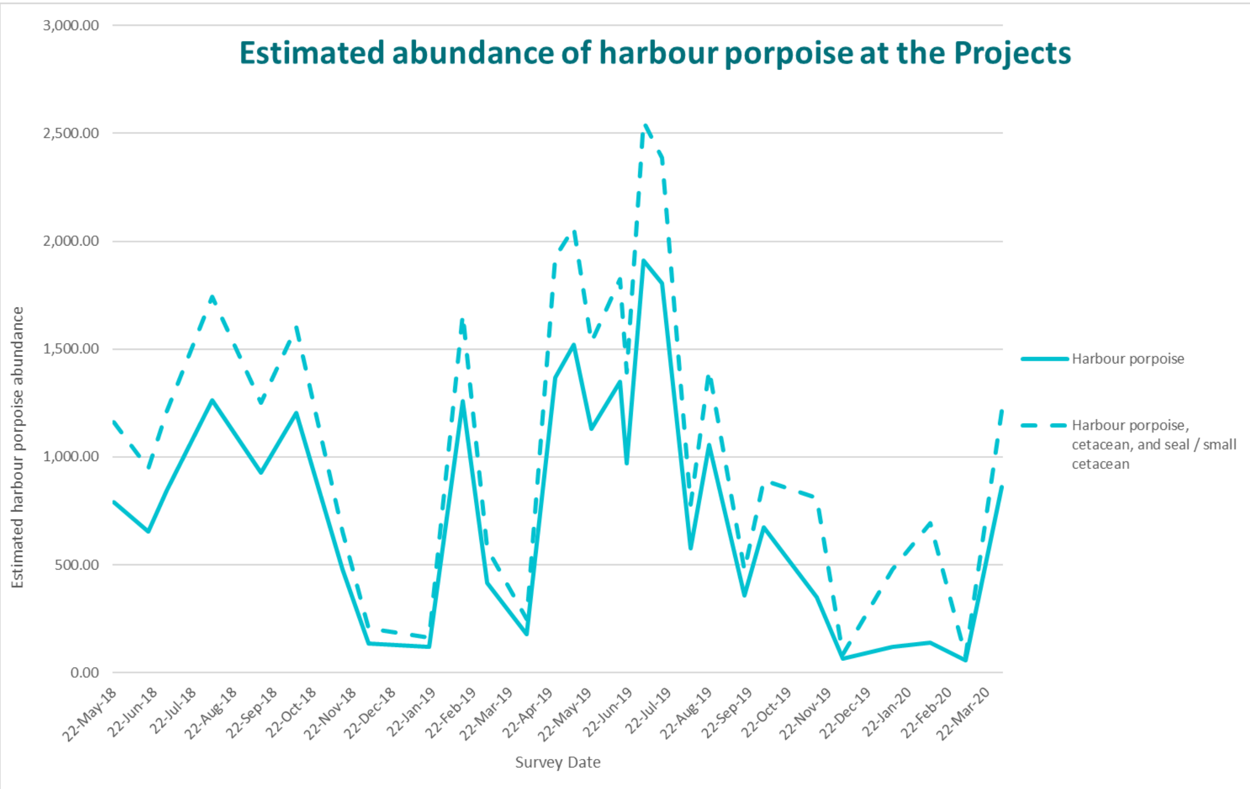

Plate 10-1: Estimated Abundance of Harbour Porpoise Within Whole Survey Area, Corrected for Bias

94. The distribution of harbour porpoise within SEP and DEP varied, with individuals present across the survey area (both SEP and DEP, with a 4km buffer), including within the existing Dudgeon and Sheringham Shoal offshore wind farms. There is no evident pattern of harbour porpoise distribution within the survey area, with no indication of a particular area of importance.

95. The Inter-Agency Marine Mammal Working Group (IAMMWG, 2022) define three MUs for harbour porpoise: North Sea (NS); West Scotland (WS); and the Celtic and Irish Sea (CIS). SEP and DEP offshore sites are located in the North Sea MU.

96. The IAMMWG estimate of harbour porpoise abundance in the North Sea MU is 346,601 (CV = 0.09; 95%; CI = 289,498 – 419,967; IAMMWG, 2022).

97. The reference population for harbour porpoise used in the assessments is the North Sea MU, which, based on the latest IAMMWG estimated abundance of 346,601 harbour porpoise (IAMMWG, 2022).

10.5.2 Bottlenose Dolphin

98. A resident population of bottlenose dolphin is present in the Moray Firth, with an estimated 209 individuals (95% CI = 198 – 230; Arso Civil *et al*., 2019) which are known to travel south along the Scottish coast. Historically, very few sightings of bottlenose dolphin were recorded further south of the Firth of Forth on the east coast of the UK, however, in recent years an increase in bottlenose dolphins in the north-east of England has been reported (Aynsley, 2017), with one individual from the Moray Firth population being recorded as far south as The Netherlands.

99. Bottlenose dolphin sightings have been made year-round along the north-east England coast (between 2013 and 2016; Aynsley, 2017), suggesting that there is no seasonal pattern to the increase in recent sightings numbers. A total of 48 of the individuals sighted within this period on the north-east coast were attributed to being part of the Moray Firth population using photo-identification.

100. The results of the JCP Phase III Report (Paxton *et al.*, 2016) identified that for bottlenose dolphin, densities are low across much of UK waters, with higher densities off the west coast of Wales, and within the Moray Firth. The density of bottlenose dolphin within the central and SNS, near to SEP and DEP is low, with less than 0.1 individuals per km^2 (97.5% CI = 0-0.1 – 0-0.1 per km^2) (Paxton *et al.*, 2016).

101. The SCANS-III survey shows a similar distribution pattern, with no bottlenose dolphin identified within survey block O, in which SEP and DEP including export cable corridor areas are located, with higher densities in survey block R off the east coast of Scotland (Hammond *et al.*, 2012).

102. For bottlenose dolphin, the distribution maps (Waggitt *et al.,* 2019) show a clear pattern of higher density to the western coastal areas of the UK, extending south to the Bay of Biscay. Densities of bottlenose dolphin in the North Sea are very low in comparison (Waggitt *et al.,* 2019). Examination of this data, including all 10km grids that overlap with SEP, DEP and export cable corridor areas, indicates an average annual density estimate of:

- 0.00013 individuals per km^2 for SEP, DEP and export cable corridor areas.

103. During the site-specific aerial surveys of both SEP and DEP including buffer area, undertaken from May 2018 to April 2020, no bottlenose dolphin were recorded.

104. As sightings of bottlenose dolphin have been increasingly reported along the north-east coast of England, as a precautionary approach they have also been included in the assessments.

105. For the entire SCANS-III survey area, bottlenose dolphin abundance in the summer of 2016 was estimated to be 19,201, with an overall estimated density of 0.0159/km^2 (CV = 0.242; 95% CI = 11,404 - 29,670; Hammond *et al*., 2021).

106. There is currently no density estimate for bottlenose dolphin in and around SEP or DEP (survey block O). The adjacent SCANS-III survey block R (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**), has abundance and density estimates for bottlenose dolphin (Hammond *et al*., 2021) of:

- Abundance estimate = 1,924 bottlenose dolphin (95% CI = 0 - 5,048); and
- Density estimate = 0.0298 bottlenose dolphin/km^2 (CV = 0.861).

107. The impact assessments for bottlenose dolphin are, as a precautionary approach, based on the SCANS-III survey density estimate for survey block R of 0.0298 bottlenose dolphin/km^2 (Hammond et al., 2021).

108. The IAMMWG (2022) define seven MUs for bottlenose dolphin (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). The SEP and DEP offshore sites are located in the Greater North Sea (GNS) MU. The GNS MU for bottlenose dolphin has an abundance estimate of 2,022 (CV= 0.75; 95% CI = 548 – 7,453; IAMMWG, 2022).

109. The reference population for bottlenose dolphin used in the assessments is the GNS MU, which, based on the latest IAMMWG estimated abundance of 2,022 bottlenose dolphin (IAMMWG, 2022).

110. The assessments have also been put into the context of the Coastal East Scotland (CES) MU, as there is the potential that bottlenose dolphin from this population are moving down the east coast of England. The CES MU has an estimated abundance of 224 bottlenose dolphin (CV = 0.023; 95% CI = 214 – 234; IAMMWG, 2022).

10.5.3 White-beaked Dolphin

111. The results of the JCP Phase III Report (Paxton *et al.*, 2016) identified that for white-beaked dolphin, densities are low across much of UK waters, with higher densities shown to be in the Hebrides and the northern North Sea. The density of white-beaked dolphin within the SNS (and near to SEP and DEP) is low, with a density of less than 0.1 individuals per km^2 across the southern and most of the northern North Sea (97.5% CI = 0-0.1 – 0-0.2 per km^2) (Paxton *et al.*, 2016).

112. The SCANS-III surveys show a similar distribution pattern, with no white-beaked dolphin identified within the SNS survey block L, and low but increasing densities with the more northerly North Sea survey blocks (O and R) (Hammond *et al*., 2021).

113. For white-beaked dolphin, the distribution maps (Waggitt *et al.,* 2019) show a clear pattern of higher density in the northern North Sea, and around the coasts of Scotland, with decreasing densities southwards of Scotland along the east coast of England. There is also a clear seasonal difference in the densities of white-beaked dolphin, with higher densities in July, particularly to the north of their range (Waggitt *et al*., 2019). Examination of this data, including all 10km grids that overlap with SEP, DEP and export corridor cable areas, indicates an average annual density estimate of:

- 0.006 individuals per km^2 for SEP, DEP and export cable corridor areas.

114. During the site-specific aerial surveys of both SEP and DEP, undertaken from May 2018 to April 2020, no white-beaked dolphin were recorded.

115. For the entire SCANS-III survey area, white-beaked dolphin abundance in the summer of 2016 was estimated to be 36,287 with an overall estimated density of 0.0300/km^2 (CV = 0.288; 95% CI = 18,694 - 61,869; Hammond et al., 2021). SEP and DEP are located in SCANS-III survey block O (Hammond et al., 2021):

- Abundance estimate = 143 white-beaked dolphin (95% CI = 0 - 490); and
- Density estimate = 0.002 white-beaked dolphin/km^2 (CV = 0.970).

116. For the impact assessments for white-beaked dolphin, the worse-case density estimate is used. For white-beaked dolphin the highest density estimate is from the distribution maps developed by Waggitt *et al.* (2019), with a density estimate of 0.006 individuals per km^2 for SEP and DEP, including export corridor areas.

117. There is a single MU for white-beaked dolphin, the Celtic and Greater North Seas (CGNS) MU (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). The reference population for white-beaked dolphin in the CGNS MU is 43,951 animals (CV = 0.22; 95% CI = 28,439 – 67,924; IAMMWG, 2022).

10.5.4 Minke Whale

118. The JCP Phase III Report (Paxton *et al.*, 2016) identified a total of 1,860 minke whale sightings within the UK offshore area. The density of minke whale was predicted to be highest along the northern coast of the UK, from Yorkshire north to the Kintyre Peninsula. The resultant density maps produced in the JCP Phase III Report (Paxton *et al.*, 2016) shows a minke whale density of less than 0.04 per km^2 for the SNS (97.5% CI = 0-0.02 – 0.08 per km^2), below the Humber Estuary and Flamborough Head.

119. For minke whale, the distribution maps (Waggitt *et al.,* 2019) show a clear pattern of higher density in the northern North Sea, and around the coasts of Scotland, Ireland and within the Celtic and Irish Seas, with decreasing densities southwards of Scotland along the east coast of England. There is a clear seasonal difference in the densities of minke whale, with higher densities in July, which is particularly evident in the north of their range (Waggitt *et al*., 2019). Examination of this data, including all 10km grids that overlap with SEP and DEP, including export corridor areas, indicates an average annual density estimate of:

- 0.0022 individuals per km^2 for SEP, DEP and export cable corridor areas.

120. During the SEP and DEP site specific aerial surveys (259 surveys undertaken between May 2018 and April 2020), a single minke whale was positively identified in July 2018 just north of DEP, resulting in a relative density estimate of 0.01 individuals per km^2. This is the same density estimate as for the SCANS-III survey (Hammond et al., 2021).

121. For the entire SCANS-III survey area, minke whale abundance in the summer of 2016 was estimated to be 13,101 with an overall estimated density of 0.0108/km^2 (CV = 0.345; 95% CI = 7,050 – 26,721; Hammond et al., 2021). The SEP and DEP offshore sites are located in SCANS-III survey block O (Hammond et al., 2021):

- Abundance estimate = 603 minke whale (95% CI = 109-1,670); and
- Density estimate = 0.0100 minke whale/km^2 (CV=0.621).

122. The impact assessments for minke whale are based on the SCANS-III survey density estimate for survey block O of 0.0100 minke whale/km^2 (Hammond et al., 2021).

123. There is single MU for minke whale, the CGNS MU (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). The reference population for minke whales in the CGNS MU is 20,118 animals (CV = 0.18; 95% CI = 14,061 – 28,786; IAMMWG, 2022).

10.5.5 Grey Seal

124. There is a considerable amount of movement of grey seals that occurs (as observed from telemetry data; see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**) among the different areas and regional subunits of the North Sea, and no evidence to suggest that grey seals on the North Sea coasts of Denmark, Germany, the Netherlands or France are independent from those in the UK (SCOS, 2020).

125. Compared with other times of the year, grey seals in the UK spend longer hauled out during their annual moult (between December and April) and during their breeding season, in eastern England, pupping occurs mainly between early November and mid-December (SCOS, 2020).

126. SEP and DEP are located approximately 15.8km and 26.5km offshore (at the closest point to shore), respectively. Principal grey seal haul-out sites are included in **Table 10-14**, which shows the approximate distance to the closest point of SEP and DEP, and the most recent grey seal count (August counts) for each location (SCOS, 2020).

Table 10-14: The Most Recent Grey Seal Count at Each of the Nearby Haul-Out Sites and the Distance to SEP and DEP

Haul-out site	Distance to SEP and DEP	Grey seal count
Blakeney Point National Nature Reserve (NNR)	12km from landfall 12km from export cable corridor 22km from SEP 38km from DEP	635 (2019 grey seal count; SCOS, 2020).

Haul-out site	Distance to SEP and DEP	Grey seal count
Horsey Corner	44km from landfall 44km from the export cable corridor 50km from SEP 50km from DEP	1,698 adults recorded at any one time (Friends of Horsey Seals, 2019); and 2,500 pups born over the 2020-2021 season (Friends of Horsey Seals, 2021). 119 (2019 grey seal count; SCOS, 2020).
The Wash	58km from landfall 58km from export cable corridor 57km from SEP 75km from DEP	540 (2019 grey seal count; SCOS, 2020).
Scroby Sands	59km from landfall 58km from the export cable corridor 64km from SEP 64km from DEP	1,333 (2019 grey seal count; SCOS, 2020).
Donna Nook	87km from landfall 86km from export cable corridor 66km from SEP 68km from DEP	5,265 (2019 grey seal count; SCOS, 2020).

127. A relatively low number of grey seal were recorded during the site-specific aerial surveys for SEP and DEP including buffer area, with a total of 31 individuals recorded during the 29 surveys, however, in addition a total of 198 unidentified seal species were recorded, as well as 36 seal / small cetacean species, a proportion of which are expected to be grey seal.

128. With the exception of a large spike in unidentified seal sightings in July 2019 (with a total of 62 grey seal over two survey days), numbers of grey seal, or individuals that could be grey seal (i.e. seal species and seal / small cetacean species) were relatively similar year-round, with small spikes in sightings number, but no clear change seasonally.

129. Due to the low number of grey seal sightings, absolute density and abundance estimates were not possible to derive from the site-specific surveys. However, relative density and abundance estimates were calculated (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). These provide site-specific information on the number of grey seal expected to be present at SEP and DEP, however, impact assessments will be based on absolute densities as derived from desk-based sources.

130. The average of the annual density has then been calculated based on the maximum calculated for each month. **Table 10-15** shows the densities based on all individuals that have the potential to be grey seal.

Table 10-15: Maximum Grey Seal Relative Density Estimates for SEP and DEP Survey Areas Plus 4km Buffer

Month	Maximum density estimate (corrected) for whole survey area	Maximum density estimate (corrected) for SEP + 4km buffer	Maximum density estimate (corrected) for DEP + 4km buffer
Average annual	0.472	0.518	0.552

131. In addition to the density estimates, abundance estimates of grey seal at SEP and DEP have been derived. These relative abundance estimates (**Plate 10-2**) indicate there is no clear seasonal pattern in the abundance of grey seal within the entire survey area, with the exception of a peak in grey seal sightings in July 2019.

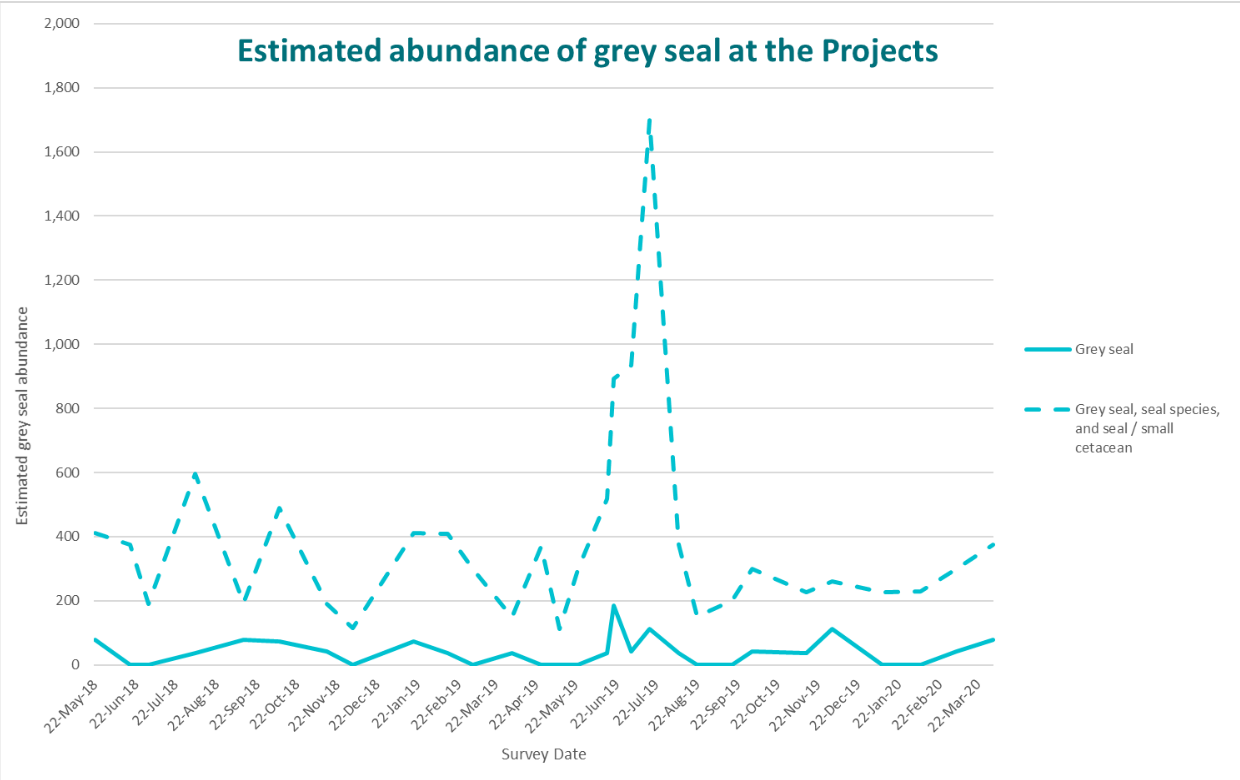

Plate 10-2: Estimated Abundance of Grey Seal Within the Survey Area, Corrected for Bias

132. Carter *et al*. (2020) provides habitat-based predictions of at-sea distribution for seals around the British Isles. The habitat preference approach predicted distribution maps provide estimates per species, on a 5 km x 5 km grid, of relative at-sea density for seals hauling-out in the British Isles. It is important to note that Carter *et al*. (2020) provides *relative density* (i.e. percentage of the total at-sea population in each grid at any one time), whereas previous usage maps (Russell *et al*., 2017) have presented *absolute density* (i.e. number of animals within each grid at any one time).

133. There are moderate relative densities of grey seal across DEP wind farm site (between 0.01% and 0.025% of the total population in each 25km^2 grid square); SEP wind farm site (between 0.01% and 0.025% of the total population); DEP cable corridors (between 0.01 and 0.025% of the total population); and mostly moderate relative densities of grey seal across the SEP cable corridor (between 0.01 and 0.025% of the total population), with one area of low moderate densities closer to the coastline (between 0.005 and 0.01% of the total population in each 25km^2 grid square) (Carter *et al*., 2020; see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**).

134. The Carter *et al.* (2020) seals at sea maps were produced by combining information about the movement patterns of electronically tagged seals with survey counts of seals at haul-out sites. The resulting maps show estimates of relative mean seal usage (seals per 5km x 5km grid cell) around the UK coastline). The relative density estimates can be converted to absolute density estimates using population scalars, as provided within the Carter *et al*. (2020) paper. See **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** for more information.

135. The grey seal density estimates for SEP and DEP have been calculated from the seal at sea usage maps (Carter *et al.,* 2020) based on the 5km x 5km grids that overlap with SEP and DEP, including the export cable corridor areas (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). The mean at-sea density estimates for these areas have been used in the assessments:

- SEP = 0.853 individuals per km^2;
- DEP = 0.739 individuals per km^2; and
- SEP, DEP and export cable corridors = 0.735 individuals per km^2.

136. In accordance with the agreed approach for other offshore wind farms, and as agreed during the 2nd ETG meeting on the 18th June 2020, the reference population extent for grey seal incorporates the south-east England MU, north-east England MU (IAMMWG, 2013; SCOS, 2020) and the Waddenzee population (Schop *et al.*, 2022), to take into account the wide ranging movement of grey seal as indicated by tagging studies (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**).

137. The reference population for grey seal is therefore currently based on the following most recent estimates for the:

- South-east (SE) England MU = 8,667 grey seal (SCOS, 2020);
- North-east (NE) England MU = 6,501 grey seal (SCOS, 2020); and
- Wadden Sea count = 8,948 grey seal (Schop *et al.*, 2022).

138. The total reference population for the assessment is 24,116 grey seal.

139. Assessments are in the context of the nearest MU as well as the wider reference population. As a worst-case it is assumed that all seals are from the nearest MU, the south-east England MU, although the more realistic assessment is based on wider reference population which takes into account the movement of seals.

10.5.6 Harbour Seal

140. SEP and DEP are located approximately 15.8km and 26.5km offshore (at the closest point to shore), respectively. Principal harbour seal haul-out sites are included in **Table 10-16**, which shows the approximate distance to the closest point of SEP and DEP, and the most recent harbour seal count (August counts) for each location (SCOS, 2020).

Table 10-16: The Most Recent Harbour Seal Count at Each of the Nearby Haul-Out Sites and the Distance to SEP and DEP

Haul-out site	Distance to SEP and DEP	Harbour seal count
Blakeney Point NNR	12km from landfall 12km from export cable corridor 22km from SEP 38km from DEP	329 (2019 harbour seal count; SCOS, 2020).
The Wash	58km from landfall 58km from export cable corridor 57km from SEP 75km from DEP	2,415 (2019 harbour seal count; SCOS, 2020).
Horsey	44km from landfall 44km from the export cable corridor 50km from SEP 50km from DEP	16 (2019 harbour seal count; SCOS, 2020).
Scroby Sands	59km from landfall 58km from the export cable corridor 64km from SEP 64km from DEP	193 (2019 harbour seal count; SCOS, 2020).
Donna Nook	87km from landfall 86km from export cable corridor 66km from SEP 68km from DEP	128 (2019 harbour seal count; SCOS, 2020).

141. A relatively low number of harbour seal were recorded during the site-specific aerial surveys, with a total of 21 individuals recorded through the 29 survey dates, however, in addition a total of 198 unidentified seal species were recorded, as well as 36 seal / small cetacean species, a proportion of which could be harbour seal (although the majority are expected to be grey seal).

142. With the exception of a large spike in unidentified seal sightings in June and July 2019 (with a total of 85 harbour seal over four survey days), and elevated numbers of harbour seal in August and October 2018, the number of individuals that could be harbour seal were relatively similar year-round, with small spikes in sightings number, with an indication of an increase in the summer periods.

143. Due to the low number of harbour seal sightings, absolute density and abundance estimates were not possible to derive from the site-specific surveys. However, relative density and abundance estimates were calculated (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). These provide site-specific information on the number of harbour seal expected to be present at SEP and DEP, however, impact assessments will be based on absolute densities as derived from desk-based sources.

144. The average of the annual density has then been calculated based on the maximum calculated for each month. **Table 10-17** shows the densities for all individuals that have the potential to be harbour seal.

Table 10-17: Maximum Harbour Seal Relative Density Estimates for SEP and DEP Survey Areas plus 4km Buffer

Month	Maximum density estimate (corrected) for whole survey area	Maximum density estimate (corrected) for SEP + 4km buffer	Maximum density estimate (corrected) for DEP + 4km buffer
Average annual	0.483	0.592	0.765

145. In addition to the density estimates as described above, abundance estimates of harbour seal at SEP and DEP have been derived. These abundance estimates (**Plate 10-3**) indicate increased sightings in the summer periods, with a peak in sightings in July 2019.

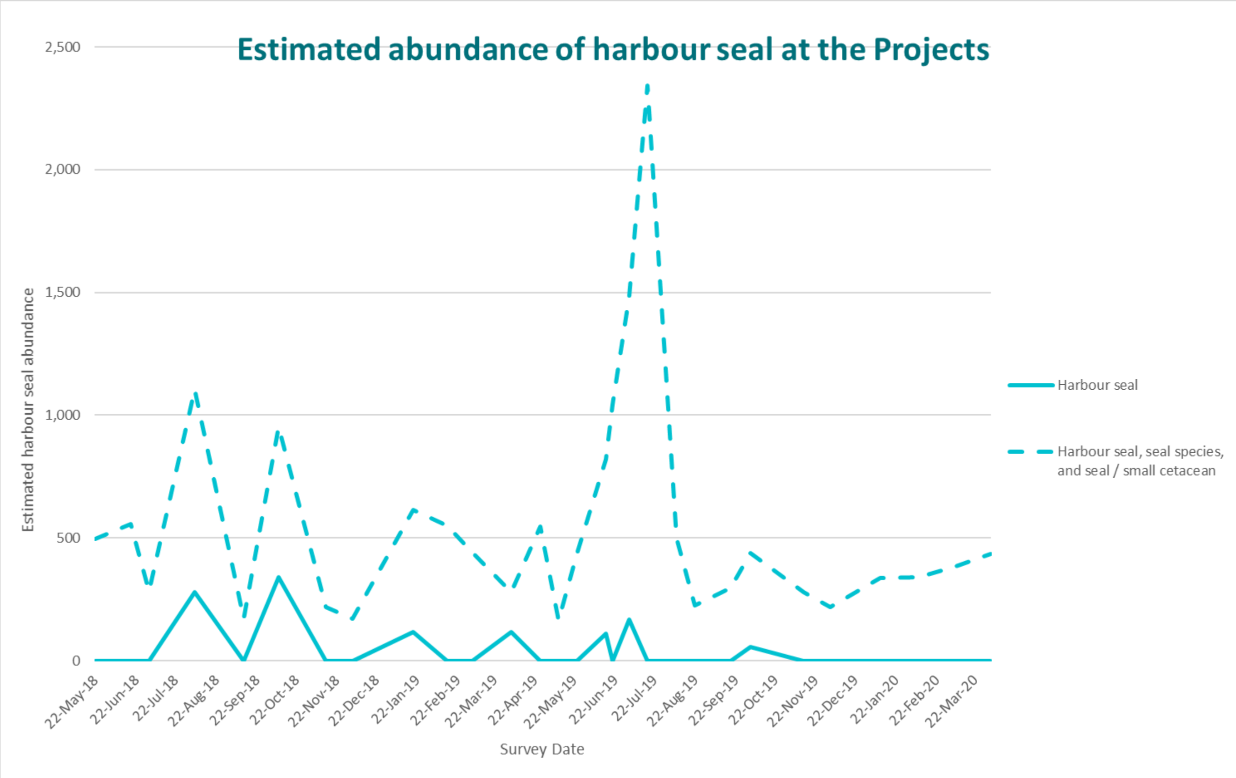

Plate 10-3: Estimated Abundance of Harbour Seal at SEP and DEP, Corrected for Bias

146. As outlined in **Section 10.5.5**, Carter *et al*. (2020) provides habitat-based predictions of at-sea distribution for harbour seal around the British Isles. The habitat preference approach predicted distribution maps provide estimates per species, on a 5 km x 5 km grid, of relative at-sea density for seals hauling-out in the British Isles. It is important to note that Carter *et al*. (2020) provides *relative density* (i.e. percentage of the total at-sea population in each grid at any one time), whereas previous usage maps (Russell *et al*., 2017) have presented *absolute density* (i.e. number of animals within each grid at any one time). The relative density estimates can be converted to absolute density estimates using population scalars, as provided within the Carter *et al*. (2020) paper. See **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data** for more information.

147. For the DEP wind farm site, there are lower relative densities in the areas furthest offshore (eastern areas of the DEP North and South array areas), with a very low relative density of harbour seals (between 0.001% and 0.005% of the total population in each 25km^2 grid square) and slightly higher in the areas closer to shore (between 0.005 and 0.01% of the total population in each 25km^2 grid square). There are moderate relative densities of harbour seal across the SEP wind farm site (between 0.01% and 0.025% of the total population). The relative density of harbour seals is low across most of the DEP export cable corridor (between 0.005% and 0.01% of the total population in each 25km^2 grid square), although slightly higher in the areas closer to shore (with a moderate relative density of between 0.01% and 0.025%). Similarly, for the SEP export cable corridor there are lower relative densities in the areas furthest offshore (eastern end of the export cable corridor), with a moderate relative density of harbour seals (between 0.01% and 0.025% of the total population in each 25km^2 grid square), and higher in the areas close to shore, with high relative densities (between 0.025 and 0.05% of the total population in each 25km^2 grid square) (Carter *et al*., 2020; see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**).

148. The harbour seal density estimates for SEP and DEP have been calculated from the latest seal at sea maps produced by SMRU (Carter *et al.,* 2020), based on the 5km x 5km grids that overlap with each Project area (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). The upper at-sea density estimates for these areas have been used in the assessment, as the worst-case:

- SEP = 0.274 individuals per km^2;
- DEP = 0.080 individuals per km^2; and
- SEP, DEP and all export cable corridors = 0.189 individuals per km^2.

149. In accordance with the agreed approach for other offshore wind farms, and as agreed during the 2nd ETG meeting on the 18th June 2020, the reference population extent for harbour seal will incorporate the south-east England MU (IAMMWG, 2013; SCOS, 2020) and the Waddenzee population (Galatius *et al.,* 2021).

150. The reference population for harbour seal is therefore currently based on the following most recent estimates for the:

- SE England MU = 3,752 harbour seal (SCOS, 2020); and
- Wadden Sea and Helgoland count = 26,838 harbour seal (Galatius *et al.,* 2021).

151. The total reference population for the assessment is 30,590 harbour seal.

152. Assessments are in the context of the nearest MU as well as the wider reference population. As a worst-case it is assumed that all seals are from the nearest MU, the south-east England MU, although the more realistic assessment is based on wider reference population which takes into account movement of seals.

153. As outlined in **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**, there are indications of a current decline in the numbers of harbour seal in The Wash. The assessments are based on the current harbour seal counts at the time of writing, however any assessments post-consent and pre-construction will be based on the latest harbour seal counts at that time to take account of any changes.

10.5.7 Summary of Marine Mammal Densities and Reference Populations for Assessments

154. **Table 10-18** and **Table 10-19** provide a summary of the reference populations and the density estimates for the marine mammal species used in the impact assessment.

155. To determine the magnitude of an impact the number of individuals that could be impacted is put into the context of the relevant reference population (see **Table 10-9** for definitions of magnitude).

Table 10-18: Summary of Marine Mammal Reference Populations used in the Impact Assessments

Species	Reference population extent	Population	Source
Harbour porpoise	NS MU	346,601	IAMMWG (2022)
Bottlenose dolphin	GNS MU	2,022	IAMMWG (2022)
	CES MU	224	IAMMWG (2022)
White-beaked dolphin	CGNS MU	43,951	IAMMWG (2022)
Minke whale	CGNS MU	20,118	IAMMWG (2022)
Grey seal	SE England MU	8,667	SCOS (2020)
	Wider reference population = SE England MU; NE England MU; Wadden Sea population	24,116 (8,667 + 6,501 + 8,948)	SCOS (2020); Schop *et al.* (2022)
Harbour seal	SE England MU	3,752	SCOS (2020)
	Wider reference population = SE England MU; Wadden Sea population	30,590 (3,752 + 26,838)	SCOS (2020); Galatius *et al.* (2021)

Table 10-19: Summary of Marine Mammal Density Estimates used in the Impact Assessments

Species	Area of density estimate	Density estimate (individuals per km^2)	Source
Harbour porpoise	SEP	Average summer: 0.63	Site specific surveys
	DEP	Average summer: 2.43	
	SEP, DEP and export cable corridor areas	Average summer: 1.46	
Bottlenose dolphin	SCANS-III Block R	0.0298	Hammond *et al*. (2021)
White-beaked dolphin	SEP, DEP and export cable corridor areas	0.006	Waggitt *et al.* (2019)
Minke whale	SCANS-III Block O	0.0100	Hammond *et al*. (2021)
Grey seal	SEP	0.853	Carter *et al.* (2020)
	DEP	0.739	
	SEP, DEP and export cable corridor areas	0.735	
Harbour seal	SEP	0.274	Carter *et al.* (2020)
	DEP	0.080	
	SEP, DEP and export cable corridor areas	0.189	

10.5.8 Climate Change and Natural Trends

156. The existing baseline conditions for marine mammals are considered to be relatively stable, for most species. The baseline environment of the SNS has been influenced by the oil and gas industry since the 1960s, fishing by various methods for hundreds of years and the construction and operation of offshore wind farms for over ten years (Kentish Flats in 2005; Lynn and Inner Dowsing in 2009). The baseline will continue to evolve as a result of global trends which include the effects of climate change.

157. The potential impacts of climate change on marine mammals can be direct, such as the effects of rising sea levels on seal haul-out sites, or species tracking a specific range of water temperatures in which they can physically survive. Indirect effects of climate change include changes in prey availability affecting distribution, abundance and migration patterns, community structure, susceptibility to disease and contaminants. Ultimately, these can impact on the reproductive success and survival of marine mammals and, hence, have consequences for populations (Learmonth *et al*., 2006)

158. For harbour porpoise in the North Sea, the latest SCANS-III survey results show no evidence for trends in abundance since the mid-1990s (Hammond et al., 2021). Despite no overall change in population size, large scale changes in the distribution of harbour porpoise were observed between SCANS-I in 1994 and SCANS-II in 2005, with the main concentration shifting from North eastern UK and Denmark to the SNS. Such large-scale changes in the distribution of harbour porpoise are likely the result of changes to the availability of their principal prey species, such as sandeel, within the North Sea (SCANS-II, 2008).

159. The observed distribution of harbour porpoises from the SCANS-III survey in summer 2016 was similar to that observed in SCANS-II in 2005 (Hammond *et al*., 2013). Although, one notable difference is that more sightings were made throughout the English Channel (block C) in 2016 than previous surveys (Hammond et al., 2021). The progressive spread of sightings into most of the Channel over the past two decades indicates that harbour porpoise distribution has expanded, probably from the North Sea and the Celtic Sea, and now encompasses the entire Channel, at least in summer (Hammond et al., 2021).

160. The effects of climate change on harbour porpoise populations are still relatively unknown, however, it is expected that there will be impacts to the population through prey depletion and range shifts. Harbour porpoise habitat and population range is determined from their preferred prey availability, and therefore a change in prey range has the potential to cause a change in the distribution of harbour porpoise (Evans and Bjorge, 2013; Ransijn *et al*., 2019). As outlined above, a shift southward of harbour porpoise has been noted within the North Sea (Hammond et al., 2021), and it is possible that this was due to a loss of sandeel availability in the northern parts of the North Sea (Evans and Bjorge, 2013).

161. As outlined in **Section 10.5.2**, there has been an increasing range expansion of the bottlenose dolphin from the Moray Firth. With an increase in the number of dolphins using areas along the east coast of Scotland, such as St Andrews Bay and the Tay estuary, 300km south of the Moray Firth SAC (Arso Civil *et al*., 2019). There has also been a recent increase in bottlenose dolphins in the north-east of England (Aynsley, 2017), with one individual from the Moray Firth population being recorded as far south as The Netherlands.

162. As for harbour porpoise, SCANS found no evidence of a trend in abundance of white-beaked dolphin in the North Sea since the mid-1990s (Hammond et al., 2021). A review of the strandings data of white-beaked dolphin in the North Sea were collated and assessed by ASCOBANS (IJsseldijk *et al*., 2018) in order to determine temporal and spatial trends in the distributions of white-beaked dolphin in the south-western North Sea. Strandings data used within the review were from Belgium, Germany, the Netherlands and the UK, from 1991 to 2017. This review indicates that there has been a reduction in the abundance of white-beaked dolphin in the south-east coasts of the UK, with an increase in the north-east area (IJsseldijk *et al*., 2018). These changes probably reflect changes in prey distribution as a result of climate change.

163. SCANS found no evidence of a trend in abundance of minke whale in the North Sea since the mid-1990s (Hammond et al., 2021). However, a decade of acoustic observations in the western North Atlantic have shown important distributional changes over the range of baleen whales, mirroring known climatic shifts (Davies *et.al*., 2020). A decline in the reproductive success of humpback whales (*Megaptera novaeangliae*) could be linked to climate change, as a result of females being unable to accumulate the energy reserves necessary to maintain pregnancy and/or meet the energetic demands of lactation in years of poorer prey availability (Kershaw *et al*., 2020).

164. There has been a continual increase in the total UK grey seal pup production since regular surveys began in the 1960s (SCOS, 2020). Grey seal pup production at colonies in the North Sea increased rapidly up to 2016, with an annual increase of 7.5% per year from 2014 to 2018, slightly lower than the 11.5% growth between 2010 and 2016 (SCOS, 2020). The majority of the increase in the North Sea has been due to the continued rapid expansion of newer colonies on the mainland coasts in Berwickshire, Lincolnshire, Norfolk and Suffolk. Interestingly, these colonies are all at easily accessible sites on the mainland, where grey seals have probably not bred in significant numbers since before the last ice age (SCOS, 2020).

165. Overall, the UK population of harbour seal has increased since the late 2000s and is close to the previous high observed during the 1990s (SCOS, 2020). However, there are significant differences in the population dynamics between seal management units, with general declines in counts of harbour seals in several regions around Scotland and more recently in the South-east. Recent trends, i.e. those that incorporate the last 10 years show significant growth in both MUs on the east coast of England up to 2018, but the 2019 count was approximately 27.6% lower than the mean of the previous 5 years in the SE England MU (SCOS, 2020). The 2019 decrease follows a period when growth rates had decreased to zero, possibly indicating that the population in SE England MU was approaching its carrying capacity, means that it may be the first indication of a population decline (SCOS, 2020).

166. In The Wash between 2006 and 2012 the counts of harbour seal approximately doubled and increased by 50% for East Anglia as a whole. Since 2012 the counts in these areas have been almost constant. The 2018 count was the second highest ever recorded in The Wash and was consistent with the pattern of relatively stable population since 2010. However, the 2019 count was 27% lower than the 2012 to 2018 mean count (SCOS, 2020). Along the East Anglian coast, the 2018 count was 17% higher than the 2017 count and similar to the average for the preceding 5 years. This continues the pattern of high inter annual variability (SCOS, 2020). As outlined in SCOS (2020), these wide fluctuations are not unusual in the long term time series and despite the apparently wide inter-annual variation, the pup production has increased at around 5.6% per year since surveys began in 2001, although the rate of increase may have slowed and may be reaching an asymptote (SCOS, 2020).

167. For marine mammals, there are some changes evident as a result of climate change and it is reasonable to expect further such changes in the future and over the lifetime of SEP and DEP. However, the latest changes in population distribution and abundance have been taken into account in the assessments that have been undertaken.

10.6 Potential Impacts

168. Potential impacts for consideration and the applicable assessment methodologies were agreed with the stakeholders at the first ETG meeting (3rd December 2019).

169. Prior to construction, two separate MMMPs (one for piling and one for UXO clearance) designed to reduce the potential risk of physical and auditory injury from piling and UXO clearance will be prepared in consultation with the MMO and relevant SNCBs and will be based on the latest guidance and mitigation techniques (see **Section 10.3.4.1**). A combined **Draft MMMP** (document reference 9.4) for both UXO clearance and piling has been submitted with the DCO application.

10.6.1 Potential Impacts during Construction

170. Potential impacts during construction may arise through disturbance from activities during the installation of offshore infrastructure. Underwater noise during piling, as well as disturbance associated with underwater noise from other construction activities and the presence of vessels offshore, are considered. Potential displacement from important habitat areas and impacts on prey species are also considered.

171. The potential impacts during construction assessed for marine mammals are:

- Impact 1 & 2: Auditory injury and disturbance or behavioural impacts resulting from underwater noise during piling;
- Impact 3: Disturbance impacts resulting from underwater noise during other construction activities, including sea bed preparations, rock placement and cable installation;
- Impacts resulting from the deployment of construction vessels:
  - Impact 4: Underwater noise and disturbance from construction vessels; and
  - Impact 6: Vessel interaction (collision risk);
- Impact 5: Barrier effects as a result of underwater noise;
- Impact 7: Disturbance at seal haul-out sites;
- Impact 8: Changes to prey resource; and
- Impact 9: Changes to water quality.

172. The realistic worst-case scenario on which the assessments are based is outlined in **Table 10-1**.

10.6.1.1 Impact 1: Auditory Injury from Underwater Noise Associated with Piling

173. A range of foundation options are being considered for SEP and DEP, including monopiles, jackets (with pin-piles), screw piles, GBS and suction buckets (see **Section 10.3.3**). Of these, monopiles and jackets (with pin-piles) may require piling. As a worst-case scenario for underwater noise, it has been assumed that all foundations could be piled.

174. Impact piling is a source of high-level underwater noise. Underwater noise can cause both physiological (e.g. lethal, physical injury and auditory injury) and behavioural (e.g. disturbance and masking of communication) impacts on marine mammals.

175. Should a marine mammal be very close to the source, the high peak pressure sound levels have the potential to cause death or physical injury, with any severe injury potentially leading to death, if no adequate mitigation is in place. High exposure levels from underwater noise sources can cause auditory injury or hearing impairment taking the form of a permanent loss of hearing sensitivity (PTS) or a temporary loss in hearing sensitivity (TTS). The potential for auditory injury is not just related to the level of the underwater sound and its frequency relative to the hearing bandwidth of the animal, but is also influenced by the duration of exposure. The level of impact on an individual is a function of the SEL that an individual receives as a result of underwater noise.

176. The potential impact of underwater noise will depend on a number of factors which include, but are not limited to:

- The source levels of noise;
- Frequency relative to the hearing bandwidth of the animal (dependent upon species);
- Propagation range, which is dependent upon;
    - Sediment/sea floor composition; and
    - Water depth;
- Duration of exposure;
- Distance of the animal to the source; and
- Ambient noise levels.

10.6.1.1.1 Sensitivity of Marine Mammals

177. All species of cetaceans rely on sonar for navigation, finding prey and communication; they are therefore highly sensitive to permanent hearing damage (Southall *et al*., 2007). As such, sensitivity to PTS from pile driving noise is assessed as high for all cetacean species (**Table 10-20**). However, when considering the impact that any auditory injury has on an individual, the frequency range over which the auditory injury occurs must be considered. PTS would normally only be expected in the critical hearing bands in and around the critical band of the fatiguing sound (Kastelein *et al*., 2012). Auditory injury resulting from sound sources like piling (where most of the energy occurs at lower frequencies) is unlikely to negatively affect the ability of high-frequency cetaceans to communicate or echo-locate. PTS would not result in an individual being unable to hear but could result in some permanent change to hearing sensitivity.

178. Pinnipeds use sound both in air and water for social and reproductive interactions (Southall *et al*., 2007), but not for finding prey. Therefore, Thompson *et al*. (2012) suggest damage to hearing in pinnipeds may not be as sensitive as it could be in cetaceans. Pinnipeds also have the ability to hold their heads out of the water during exposure to loud noise, and potentially avoid PTS during piling. As such, sensitivity to PTS in harbour and grey seal is expected to be lower than cetacean species such as harbour porpoise, with the individual showing some tolerance to avoid, adapt to or accommodate or recover from the impact (for example, Russell *et al*., 2016b), but as a precautionary approach they are also considered as having high sensitivity in this assessment (**Table 10-20**).

179. Any PTS would be permanent and marine mammals within the potential impact area are considered to have very limited capacity to avoid such effects, and unable to recover from the effects (see **Table 10-7**).

180. All marine mammal species are assessed as having medium sensitivity to TTS (**Table 10-20**). A fleeing response is assumed to occur at the same noise levels as TTS. The response of individuals to a noise stimulus will vary and not all individuals will respond, however, for the purpose of this assessment, it is assumed that 100% of the individuals exposed to the noise stimulus will respond and flee the area.

181. Any TTS would be temporary, and individuals would recover from any temporary changes in hearing sensitivity after the noise source has ceased. However, as a precautionary approach, medium sensitivity to TTS assumes an individual has limited capacity to avoid, adapt to, tolerate or recover from the anticipated impact see (**Table 10-7**).

182. Marine mammals may exhibit varying intensities of behavioural response at different noise levels. These include orientation or attraction to a noise source, increased alertness, modification of characteristics of their own sounds, cessation of feeding or social interaction, alteration of movement / diving behaviour, temporary or permanent habitat abandonment. The response can vary due to exposure level, the hearing sensitivity of the individual, context, previous exposure history or habituation, motivation and ambient noise levels (e.g. Southall *et al*., 2007).

183. The response of individuals to a noise stimulus will vary and not all individuals will respond; however, for the purpose of this assessment, it is assumed that at the disturbance range, 100% of the individuals exposed to the noise stimulus will respond and be displaced from the area. However, it is unlikely that all individuals would be displaced from the potential disturbance area, therefore this a very precautionary approach.

184. The sensitivity of marine mammals to disturbance is considered to be medium in this assessment as a precautionary approach (**Table 10-20**). Marine mammals within the potential disturbance area are considered to have limited capacity to avoid such effects, although any disturbance to marine mammals would be temporary and they would be expected to return to the area once the disturbance had ceased (**Table 10-7**).

Table 10-20: Summary of Marine Mammal Sensitivity to Noise Impacts from Pile Driving

Species	PTS	TTS	Disturbance
Harbour porpoise	High	Medium	Medium

Species	PTS	TTS	Disturbance
Bottlenose dolphin	High	Medium	Medium
White-beaked dolphin	High	Medium	Medium
Minke whale	High	Medium	Medium
Grey seal	High	Medium	Medium
Harbour seal	High	Medium	Medium

10.6.1.1.2 Underwater Noise Modelling

185. Underwater noise modelling was carried out by Subacoustech to estimate the noise levels likely to arise during piling and determine the potential impacts on marine mammals using the INSPIRE v5.1 (Impulsive Noise Propagation and Impact Estimator) subsea noise propagation model (**Appendix 10.2 Underwater Noise Modelling Report**). The INSPIRE model is a semi-empirical noise propagation model based on the use of a combination of numerical modelling and actual measured underwater noise data. It was designed to calculate the propagation of noise in shallow, mixed water, typical of both conditions around the UK (see **Appendix 10.2 Underwater Noise Modelling Report** for further details).

186. The modelling considers a wide array of input parameters, including variations in bathymetry and source frequency content to ensure as detailed results as possible. It should also be noted that the results presented in this assessment are precautionary as the worst-case parameters have been selected for:

- Piling hammer energies;
- Soft-start, ramp-up profile and strike rate;
- Duration of piling; and
- Receptor swim speeds.

10.6.1.1.2.1 *Methodology*

Piling Locations

187. Modelling has been undertaken at four representative locations, covering the extents of the SEP and DEP wind farm sites, with two positions modelled within each wind farm site, including the deepest point (typically the worst-case location; i.e. the deepest location where piling can take place, which tends to give the greatest noise propagation) (**Appendix 10.2 Underwater Noise Modelling Report**):

- SEP East (E) location with a water depth of 21.3m;
- SEP North (N) location with a water depth of 18.6m;
- DEP North East (NE) location with a water depth of 23.2m; and
- DEP South East (SE) location with a water depth of 25.5m.

188. The worst-case scenario was based on the maximum impact range modelled for either location, and was used to inform the assessment of the maximum potential impacts on receptor groups, in order to provide a conservative assessment. The worst-case piling locations were used in the assessments.

Hammer Energy, Soft-start and Ramp-up

189. The underwater noise modelling is based on the following worst-case scenarios for monopiles and pin-piles:

- Monopile with maximum diameter of up to 16m, maximum hammer energy of up to 5,500kJ and maximum starting energy of 1,000kJ.
  - However, the most likely worst-case scenario (which has also been modelled) would be up to 4,500kJ with a starting hammer energy of 600kJ.
- Pin-pile with diameter of up to 3.5m for OSP and up to 4m for wind turbine jackets, maximum hammer energy of up to 3,000kJ and maximum starting hammer energy of 400kJ.

190. To determine the potential for PTS or TTS from cumulative sound exposure level (SEL_{cum}), the soft-start, ramp-up, hammer energy, total duration and strike rate are taken into account. The soft-start takes place over the first 30 minutes of piling at the starting hammer energy, after which the hammer energy will increase (ramp-up) to the maximum hammer energy required to safely install the pile.

191. As a worst-case scenario it is assumed that 100% maximum hammer energy will be required and applied for the remaining duration of the pile installation. However, maximum hammer energy is only likely to be required at a few of the piling installation locations and for shorter periods of time. Therefore, a most likely scenario has also been included for context, but again this is based on a precautionary approach of what could be required.

192. The main difference between the worst-case and most likely scenarios is that the most likely scenario uses lower hammer energies and utilises a soft-start procedure whereby single blows of the piling hammer occur at low energy, interspersed with pauses of several minutes before commencing a more continuous strike rate, before ramping up to maximum energy. The assessments are based on the worst-case scenario with results for the most-likely scenario provided in **Appendix 10.2 Underwater Noise Modelling Report**.

193. The soft-start, ramp-up and piling duration used to assess SEL_{cum} for monopiles and pin-piles are summarised in **Table 10-21**.

Table 10-21: Hammer Energy, Ramp-Up and Piling Duration

Parameter	Starting hammer energy	Ramp-up				Maximum hammer energy
Monopile – worst-case						
Monopile hammer energy	1,000kJ	1,500kJ	2,500kJ	3,500kJ	4,500kJ	5,500kJ

Parameter	Starting hammer energy	Ramp-up				Maximum hammer energy
Number of strikes	1,350	2,400	1,600	1,200	1,350	1,350
Strikes per minute	45	60	40	30	30	30
Duration (minutes)	30	40	40	40	45	45
Total duration	4 hours (9,250 total strikes)					
Pin-pile						
Pin-pile hammer energy	400	920	1,440	1,960	2,480	3,000
Number of strikes	1,200	1,200	1,200	1,200	900	900
Strikes per minute	40	40	40	40	30	30
Duration (minutes)	30	30	30	30	30	30
Total duration	3 hours (6,600 total strikes)					

Sequential piling

194. Underwater noise modelling has been undertaken to cover the possible option for more than one pile to be installed, one after the other, in the same 24 hour period. The South East (SE) location at DEP resulted in the largest ranges due to the deeper water at, and surrounding, that location. The East (E) location at SEP provide the worst-case impact ranges provided in **Appendix 10.2 Underwater Noise Modelling Report**.

195. The modelling was based on the worst-case for two monopiles installed sequentially or four pin-piles installed sequentially at the worst-case locations for each site:

- Installation of 2 monopiles at the SEP E location;
- Installation of 2 monopiles at the DEP SE location;
- Installation of 4 pin-piles at the SEP E location; and
- Installation of 4 pin-piles at the DEP SE location.

196. In addition, the option for where a monopile is installed at DEP, followed by a second monopile at SEP, in the same 24 hour period was also modelled:

- Installation of 1 monopile at DEP SE followed by 1 monopile at SEP E

197. Due to the uncertainty of what a receptor will do between piling operations it has been assumed that any additional piling will occur immediately after the previous installation, with no pause.

198. A fleeing receptor, such as marine mammals, will have travelled away from the noise source by the time the second pile installation starts, and as such increases in noise level compared to a single installation are not as pronounced when compared to simultaneous piling (see **Appendix 10.2 Underwater Noise Modelling Report** for further information).

Simultaneous piling

199. To take into account a concurrent construction scenario for SEP and DEP (see **Section 10.3.3.2**), underwater noise modelling has been undertaken for simultaneous piling of two piles installed at the same time, based on the following worst-case scenarios:

- Installation of monopiles at the SEP E location and DEP SE location;
- Installation of pin-piles (4m diameter) at the SEP E location and DEP SE location;
- Installation of a pin-pile (4m diameter) at the SEP E location and a monopile at the DEP SE location; and
- Installation of a monopile at the SEP E location and a pin-pile (4m diameter) at the DEP SE location.

200. All simultaneous modelling assumes that the two piling operations start at the same time.

201. When considering SEL_{cum} modelling, piling from multiple sources has the ability to increase impact ranges and areas significantly as it doubles the number of pile strikes (see **Appendix 10.2 Underwater Noise Modelling Report** for further information).

Noise Source Levels

202. Underwater noise modelling requires knowledge of the source level, which is the theoretical noise level at 1m from the noise source. The INSPIRE noise propagation model assumes that the noise acts as a single point source. The source level is estimated based on the pile diameter and the hammer energy imparted on the pile by the hammer. This is then adjusted depending on the water depth at the modelling location to allow for the length of pile in contact with the water, which can affect the amount of noise that is transmitted from the pile into its surroundings (further information is provided in **Appendix 10.2 Underwater Noise Modelling Report**).

203. The unweighted SPL_{peak} and SEL_{ss} source levels estimated for this assessment are summarised in **Table 10-22**.

Table 10-22: Unweighted SPL_{peak} and SEL_{ss} Source Levels Used in Underwater Noise Modelling for Monopiles and Pin-Piles

Source Level	Monopile (16m diameter, 5,500kJ)	Pin-pile (4m diameter, 3,000kJ)	Pin-pile (3.5m diameter, 3,000kJ)
SPL_{peak} source levels (dB re 1 µPa @ 1 m)	242.9	241.5 - 241.6 (depending on location)	241.4 - 241.5 (depending on location)

Source Level	Monopile (16m diameter, 5,500kJ)	Pin-pile (4m diameter, 3,000kJ)	Pin-pile (3.5m diameter, 3,000kJ)
SEL_{ss} source levels (dB re 1 µPa^2s @ 1 m)	224.1	222.2 - 222.4 (depending on location)	222.0 - 222.2 (depending on location)

Environmental Conditions

204. The inclusion of measured data for similar offshore piling operations in UK waters, allows the INSPIRE model to intrinsically account for various environmental conditions. This includes the differences that can occur with the temperature and salinity of water as well as the sediment type surrounding the site. Data from the European Marine Observation and Data Network (EMODnet) geology study show that the sea bed surrounding SEP and DEP is generally made up of sand and sandy gravel.

205. Digital bathymetry, also from the EMODnet, has been used for this modelling; mean tidal depth has been used throughout (**Appendix 10.2 Underwater Noise Modelling Report**).

Baseline noise levels

206. Background noise monitoring was undertaken as part of the Sheringham Shoal Offshore Wind Farm installation and during the operational phase, but at sufficient distance or under appropriate conditions that there was no influence from any piling, site traffic or operational turbines (NPL, 2010 and 2013). Measurements of background noise taken as part of the piling survey in 2010 showed the highest third-octave band noise levels in the 100Hz band of approximately 116 to 117 dB re 1µPa. NPL (2013) identified that "maximum third-octave band spectral noise levels are generally between around 95 and 120 dB re 1µPa^2/Hz". During this survey under low wind conditions when turbines were not operational, noise levels were generally below 95 dB in any third-octave band above 20Hz.

207. The measurements taken do show noise levels that are of the same order as baseline noise levels sampled elsewhere in the North Sea (Nedwell *et al*., 2003) and so are considered to be typical and realistic. Further information on background noise levels is provided in **Appendix 10.2 Underwater Noise Modelling Report**.

Thresholds and Criteria

208. Sound measurements underwater are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound.

209. The sound pressure level (SPL) is normally used to characterise noise and vibration of a continuous nature. The variation in sound pressure can be measured over a specific time period to determine the root mean square (RMS) level of the time varying acoustic pressure, therefore SPL (i.e. SPL_{RMS}) can be considered as a measure of the average unweighted level of the sound over the measurement period.

210. Peak SPLs (SPL_{peak}) are often used to characterise sound transients from impulsive sources, such as percussive impact piling. A peak SPL is calculated using the maximum variation of the pressure from positive to zero within the wave. This represents the maximum change in positive pressure (differential pressure from positive to zero) as the transient pressure wave propagates.

211. The sound exposure level (SEL) sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound source and the duration the sound is present in the acoustic environment (further details are provided in **Appendix 10.2 Underwater Noise Modelling Report**).

212. SEL_{ss} is the potential sound exposure level from a single strike of the hammer, e.g. one hammer strike at the starting hammer energy or maximum hammer energy applied.

213. SEL_{cum} is the cumulative sound exposure level over the duration of piling including the soft-start, ramp-up and time required to complete the installation of the pile (**Table 10-21**). To determine SEL_{cum} ranges for marine mammals, a fleeing animal model has been used. This assumes that the animal exposed to high noise levels will swim away from the noise source. For this, a constant swimming speed of 3.25m/s has been assumed for minke whale (Blix and Folkow, 1995), and as a precautionary approach for all other species a constant swimming speed of 1.5 m/s has been used, based on the average swimming speed for harbour porpoise mother calf pairs (Otani *et al*., 2000). This is considered a 'worst-case' scenario as marine mammals are expected to be able to swim faster. Further details on how SEL_{cum} is modelled is provided in **Appendix 10.2 Underwater Noise Modelling Report**.

214. The metrics and criteria that have been used to assess the potential impact of underwater noise on marine mammals are based on, at the time of writing, the most up to date publications and recommended guidance.

215. Southall *et al*. (2019) presents unweighted peak criteria (SPL_{peak}) for single strike, weighted sound exposure criteria for single strike (SEL_{ss}) and cumulative (i.e. more than a single sound impulse) weighted sound exposure criteria (SEL_{cum}) for both permanent auditory injury (PTS) where unrecoverable reduction in hearing sensitivity may occur and temporary auditory injury (TTS) where a temporary reduction in hearing sensitivity may occur.

216. Southall *et al*. (2019) categorises marine mammal species into hearing groups and applies filters to the unweighted noise to approximate the hearing sensitivities of the species to approximate for the specific hearing abilities and sensitivities of each group. This provided the weighted SEL criteria, which corrects the sound level based on the sensitivity of the receiver, for example, harbour porpoise are less sensitive to low frequency sound than minke whales. Southall *et al*. (2019) also includes criteria based on peak Sound Pressure Level (SPL_{peak}), which are unweighted and do not take species sensitivity into account. It is important to note that they are different criteria and as such they should not be compared directly. All decibel SPL values are referenced to 1µPa and all SEL values are referenced to $1µPa^2s$. Assessments have been based on the criteria with the greatest predicted impact ranges.

217. Note that the Southall *et al*. (2019) Marine Mammal Noise Exposure Criteria are the same as the National Marine and Fisheries Service (NMFS) (2018) criteria, although Southall *et al*. (2019) renames the species groupings: Medium-Frequency (MF) Cetaceans are now classed as High-Frequency (HF) Cetaceans, and previous HF Cetaceans as Very High Frequency (VHF) Cetaceans.

218. The Southall *et al*. (2019) thresholds and criteria used in the assessments are summarised in **Table 10-23**.

Table 10-23: Southall et al. (2019) Thresholds and Criteria used in the Underwater Noise Modelling and Assessments

Species	Species group	Impact	SPL_{peak} Unweighted (dB re 1 µPa) Impulsive	SEL_{ss} and SEL_{cum} Weighted (dB re 1 µPa^{2}s)	
				Impulsive	Non-impulsive
Harbour porpoise	Very High Frequency (VHF) cetacean	PTS	202	155	173
		TTS	196	140	153
Bottlenose dolphin and white-beaked dolphin	High Frequency (HF) cetacean	PTS	230	185	198
		TTS	224	170	178
Minke whale	Low Frequency (LF) cetacean	PTS	219	183	199
		TTS	213	168	179
Grey seal and harbour seal	Pinnipeds in water (PW)	PTS	218	185	201
		TTS	212	170	181

219. Southall *et al*. (2019) criteria is based on whether the noise source is considered impulsive or non-impulsive. Impulsive noises are defined as having high peak sound pressure, short duration, fast rise-time and broad frequency content at source, and non-impulsive sources as steady-state noise. Explosives, impact piling and seismic airguns are considered impulsive noise sources and sonars, vibro-piling, drilling and other low-level continuous noises are considered non-impulsive. However, a non-impulsive noise does not necessarily have to have a long duration.

220. As sound pulses propagate through the environment and dissipate, they lose their most injurious characteristics (e.g. rapid pulse rise time and high peak sound pressure) and become more like a "non-pulse" at greater distances. Active research is currently underway into the identification of the distance at which the pulse can be considered effectively non-impulsive (see **Appendix 10.2 Underwater Noise Modelling Report**). Both impulsive and non-impulsive criteria from Southall *et al*. (2019) have been included in the underwater noise modelling, however assessments have been based on the criteria with the greatest predicted impact ranges.

221. In addition, the unweighted impulsive single-strike criteria from Lucke *et al*. (2009) have also been used in the assessments for behavioural thresholds for harbour porpoise, which are based on impulsive seismic airgun stimuli. The criteria used are unweighted single strike SEL:

- Behavioural reaction in harbour porpoise at 145 dB re 1µPa^{2}s (SEL_{ss}).

Assumptions and Considerations

222. It should be noted and taken into account that the underwater noise modelling and assessment is based on 'worst-case' scenarios and precautionary approaches, this includes, but is not limited to:

- The maximum hammer energy to be applied and maximum piling duration is assumed for all piling locations; however, it is unlikely that maximum hammer energy applied, and duration will be required at the majority of piling locations.
- The maximum predicted impact ranges are based on the location with the greatest potential noise propagation range, and this was assumed as the worst-case for each piling location.
- Impact ranges modelled for a single strike are from the piling location and do not take into account (i) the distance marine mammals could move away from the piling location during mitigation measures, such as the use of ADDs to move marine mammals out of the area where there could be a risk of physical or auditory injury; or (ii) the potential disturbance and movement of marine mammals away from the site as a result of the vessels and set-up prior to mitigation.

223. The assumption that fleeing animals (harbour porpoise, white-beaked dolphin, bottlenose dolphin, grey seal and harbour seal) are swimming at a constant speed of 1.5m/s (based on swimming speed of harbour porpoise mother calf pairs; Otani *et al*., 2000), however, marine mammals are expected to swim much faster. For example, harbour porpoise have been recorded swimming at speeds of up to 4.3m/s (Otani *et al*., 2000) and, the swimming speed of a harbour porpoise during playbacks of pile driving sounds (SPL of 154 dB re 1µPa) was 1.97m/s (7.1km/h) and during quiet baseline periods the mean swimming speed was 1.2m/s (4.3km/h; Kastelein *et al*., 2018).

224. The assumption that animals are submerged 100% of the time which does not account for any time that an individual may spend at the surface or the reduced SELs near the surface where the animal would not be exposed to such high levels or for seals having their head out of the water.

225. Underwater noise modelling assumes that marine mammals will travel in the mid-water column where sound pressure levels are greatest. However, in reality animals would not be subjected to these high sound pressure levels at all times since they are likely to move up and down through the water column, and surface to breathe, where the sound pressure would drop to zero. A study by Teilmann *et al*. (2007) on diving behaviour of harbour porpoise in Danish waters suggests that animals spent 55% of their time in the upper 2m of the water column from April to August and over the whole year they spent 68% of their time in less than 5m depth. However, it should be noted that this study was conducted for “undisturbed” animals, which could show a different behaviour.

226. The swimming patterns of harbour porpoise undertaking direct travel are typically characterised by short submergence periods, compared to feeding animals (Watson and Gaskin, 1983). These short duration dives with horizontal travel suggest that travelling animals, such as harbour porpoise moving away from pile driving noise, would swim in the upper part of the water column. It would be anticipated, that during a fleeing response, from a loud underwater noise, such as piling, that their swimming behaviour may change with a reduction in deep dives. For example, during pile driving playback sounds to examine TTS, harbour porpoise showed behaviour response during the exposure periods, which included increased swimming speeds and jumping out of the water more (Kastelein *et al*., 2016).

227. Noise impact assessments assume that all animals within the noise contour may be affected to the same degree for the maximum worst-case scenario. For example, that all animals exposed to noise levels that induce behavioural avoidance will be displaced or all animals exposed to noise levels that are predicted as inducing PTS or TTS will suffer permanent or temporary auditory injury, respectively. However, a study looking at the proportion of trials at different SELs that result in TTS in exposed bottlenose dolphins suggests that to induce TTS in 50% of animals it would be necessary to extrapolate well beyond the range of measured SEL levels (Finneran *et al*., 2005). This suggests that for a given species, the potential effects follow a dose-response curve such that the probability of inducing TTS will decrease moving further away from the SEL threshold required to induce TTS. Further work by Thompson *et al*. (2013) has adopted this dose-response curve to produce a theoretical dose-response for PTS in harbour seal by scaling up Finneran *et al*. (2005) dose response curve for changes in levels of TTS at different SEL, where the probability of seals experiencing PTS increases from an SEL of 186 up to 240 dB re 1 μPa^2s; the point at which all animals are predicted to have PTS.

228. The soft-start and ramp-up is included as embedded mitigation (**Section 10.3.4.1**). The soft-start begins with a lower hammer energy before reaching maximum hammer energy, with the assumption that marine mammals will move out of the area as the hammer energy is increased and before there is the increased risk of PTS from the maximum hammer energy. However, research around the installation of jacket foundations in the Moray Firth found that received levels at any given distance were highest at low hammer energies (Thompson *et al*., 2020). Modelling highlighted that this was because noise from pin-pile installations was dominated by the strong negative relationship with pile penetration depth, with only a weak positive relationship with hammer energy (Thompson *et al*., 2020). Although the responses to ADD play-back indicated that disturbance was beyond that required to mitigate injury (Thompson *et al*., 2020).

10.6.1.1.2.2 *Results*

229. **Table 10-24** presents the underwater noise modelling results for the predicted impact ranges and areas for PTS from a single strike of the starting hammer energy, single strike from the maximum hammer energy and cumulative SEL for monopile and pin-piles at SEP and DEP (worst-case locations at each site).

230. **Table 10-25** presents the underwater noise modelling results for the predicted impact ranges and areas for TTS from a single strike of the starting hammer energy, single strike from the maximum hammer energy and cumulative SEL for monopile and pin-piles at SEP and DEP (worst-case locations for each site).

231. **Table 10-26** presents the underwater noise modelling results for the predicted impact ranges and areas for PTS and TTS from cumulative exposure during sequential piling at SEP and DEP.

232. **Table 10-27** presents the underwater noise modelling results for the predicted impact ranges and areas for PTS and TTS from cumulative exposure during simultaneous piling at SEP and DEP.

233. **Table 10-28:** presents the underwater noise modelling results for the predicted impact ranges and areas for behavioural response of harbour porpoise from a single strike of the starting hammer energy and single strike from the maximum hammer energy for monopile and pin-piles at SEP and DEP (worst-case locations for each site).

234. Single strike ranges are to the nearest 50m and cumulative impact ranges to the nearest 100m.

235. Maximum and minimum range for SEL_{cum} has been included, where applicable, to indicate the variation for each location. Results of all underwater noise modelling are provided in **Appendix 10.2 Underwater Noise Modelling Report**.

*Table 10-24: Predicted Impact Ranges (and Areas) at SEP and DEP for PTS from a Single Strike and from Cumulative Exposure (Maximum Impact Range and Area for Each Species used in Assessments are Indicated in **Bold**)*

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km²)		Pin-pile (4m diameter) Maximum impact range (km) and area (km²)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km²)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Harbour porpoise (VHF)	PTS from single strike (without mitigation)	SPL_{peak} Unweighted (202 dB re 1µPa) Impulsive	SEP	**0.27km (0.22km²)**	**0.51km (0.82km²)**	**0.13km (0.05km²)**	**0.44km (0.59km²)**	0.12km (0.04km²)	0.42km (0.54km²)
			DEP	**0.29km (0.27km²)**	**0.57km (1km²)**	**0.14km (0.06km²)**	**0.49km (0.72km²)**	0.13km (0.05km²)	0.47km (0.67km²)
		SEL_{ss} Weighted (155 dB re 1µPa²s) Impulsive	SEP	0.01km (0.03km²)	0.18km (0.1km²)	0.06km (0.01km²)	0.22km (0.14km²)	0.05km (<0.01km²)	0.16km (0.08km²)
			DEP	0.01km (0.03km²)	0.19km (0.11km²)	0.06km (0.01km²)	0.23km (0.16km²)	0.05km (<0.01km²)	0.16km (0.08km²)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (155 dB re 1µPa²s) Impulsive	SEP	N/A	3.4-**4.1km (43km²)**	N/A	1.2-1.8km (8.3km²)	N/A	1.2-**1.8km (8.5km²)**
			DEP	N/A	3.6-**4.9km (61km²)**	N/A	1.6-2.2km (13km²)	N/A	1.7-**2.3km (13km²)**
Bottlenose dolphin and white-beaked	PTS from single strike (without mitigation)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP	**<0.05km (<0.01km²)**	**<0.05km (<0.01km²)**	**<0.05km (<0.01km²)**	**<0.05km (<0.01km²)**	<0.05km (<0.01km²)	<0.05km (<0.01km²)
			DEP	**<0.05km (<0.01km²)**	**<0.05km (<0.01km²)**	**<0.05km (<0.01km²)**	**<0.05km (<0.01km²)**	<0.05km (<0.01km²)	<0.05km (<0.01km²)

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km²)		Pin-pile (4m diameter) Maximum impact range (km) and area (km²)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km²)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
dolphin (HF)		SEL_{ss} Weighted (185 dB re 1µPa²s) Impulsive	SEP	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)
			DEP	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (185 dB re 1µPa²s) Impulsive	SEP	N/A	**0.1km (<0.1km²)**	N/A	**<0.1km (<0.1km²)**	N/A	<0.1km (<0.1km²)
			DEP	N/A	**0.1km (<0.1km²)**	N/A	**0.1km (<0.1km²)**	N/A	<0.1km (<0.1km²)
Minke whale (LF)	PTS from single strike (without mitigation)	SPL_{peak} Unweighted (219 dB re 1µPa) Impulsive	SEP	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)
			DEP	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)
		SEL_{ss} Weighted (183 dB re 1µPa²s) Impulsive	SEP	**0.17km (0.09km²)**	**0.35km (0.38km²)**	**0.09km (0.02km²)**	**0.36km (0.39km²)**	0.07km (0.02km²)	0.28km (0.24km²)
			DEP	**0.19km (0.11km²)**	**0.39km (0.48km²)**	**0.09km (0.02km²)**	**0.33km (0.33km²)**	0.08km (0.02km²)	0.31km (0.3km²)
	PTS from cumulative	SEL_{cum} Weighted	SEP	N/A	3.6-**6.2km (92km²)**	N/A	1.6-**2.7km (18km²)**	N/A	1.6-2.7km (18km²)

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km^2)		Pin-pile (4m diameter) Maximum impact range (km) and area (km^2)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
	SEL (including soft-start and ramp-up)	(183 dB re 1µPa^{2}s) Impulsive	DEP	N/A	4.9-**8.3km (150km^2)**	N/A	2.4-**3.8km (33km^2)**	N/A	2.4-3.8km (33km^2)
Grey and harbour seal (PW)	PTS from single strike (without mitigation)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP	**<0.05km (0.01km^2)**	**0.05km (<0.01km^2)**	**0.05km (0.01km^2)**	**0.06km (0.01km^2)**	<0.05km (0.01km^2)	<0.05km (<0.01km^2)
			DEP	**<0.05km (0.01km^2)**	**0.05km (<0.01km^2)**	**0.05km (0.01km^2)**	**0.06km (0.01km^2)**	<0.05km (0.01km^2)	<0.05km (<0.01km^2)
		SEL_{ss} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	<0.05km (0.01km^2)	<0.05km (<0.01km^2)	<0.05km (<0.01km^2)	<0.05km (<0.01km^2)	<0.05km (0.01km^2)	<0.05km (<0.01km^2)
			DEP	<0.05km (<0.01km^2)	<0.05km (<0.01km^2)	<0.05km (<0.01km^2)	<0.05km (<0.01km^2)	<0.05km (0.01km^2)	<0.05km (<0.01km^2)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	N/A	0.4-**0.6km (0.84km^2)**	N/A	<0.1-0.13km (<0.1km^2)	N/A	0.1-**0.2km (<0.1km^2)**
			DEP	N/A	0.6-**0.7km (1.4km^2)**	N/A	0.13-0.18km (<0.1km^2)	N/A	**0.2km (<0.1km^2)**

N/A = Not Applicable

*Table 10-25: Predicted Impact Ranges (and Areas) at SEP and DEP for TTS from a Single Strike and from Cumulative Exposure (Maximum Impact Range and Area for Each Species used in the Assessments are Indicated in **Bold**)*

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km²)		Pin-pile (4m diameter) Maximum impact range (km) and area (km²)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km²)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Harbour porpoise (VHF)	TTS from single strike (without mitigation)	SPL_{peak} Unweighted (196 dB re 1µPa) Impulsive	SEP	0.63km (1.3km²)	1.2km (4.2km²)	0.3km (0.27km²)	0.99km (3.0km²)	0.28km (0.25km²)	0.96km (2.9km²)
			DEP	0.71km (1.6km²)	1.3km (5.3km²)	0.33km (0.33km²)	1.1km (3.9km²)	0.31km (0.3km²)	1.1km (3.7km²)
		SEL_{ss} Weighted (140 dB re 1µPa²s) Impulsive	SEP	0.68km (1.4km²)	**1.2km (4.7km²)**	0.37km (0.42km²)	**1.1km (3.6km²)**	0.36km (0.4km²)	1.1km (3.6km²)
			DEP	0.73km (1.6km²)	**1.3km (5.5km²)**	0.39km (0.46km²)	**1.2km (4.2km²)**	0.38km (0.45km²)	1.2km (4.1km²)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (140 dB re 1µPa²s) Impulsive	SEP	N/A	7.8-**16km (530km²)**	N/A	6.0-12km (300km²)	N/A	6.0-**12km (300km²)**
			DEP	N/A	9.7-**19km (750km²)**	N/A	9.2-14km (430km²)	N/A	7.5-**15km (440km²)**
Bottlenose dolphin and white-beaked dolphin (HF)	TTS from single strike (without mitigation)	SPL_{peak} Unweighted (224 dB re 1µPa) Impulsive	SEP	<0.05km (<0.01km²)	**<0.05km (<0.01km²)**	<0.05km (<0.01km²)	**<0.05km (<0.01km²)**	<0.05km (<0.01km²)	<0.05km (<0.01km²)
			DEP	<0.05km (<0.01km²)	**<0.05km (<0.01km²)**	<0.05km (<0.01km²)	**<0.05km (<0.01km²)**	<0.05km (<0.01km²)	<0.05km (<0.01km²)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km²)		Pin-pile (4m diameter) Maximum impact range (km) and area (km²)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km²)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
		SEL_{ss} Weighted (170 dB re 1µPa²s) Impulsive	SEP	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)
			DEP	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)	<0.05km (<0.01km²)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (170 dB re 1µPa²s) Impulsive	SEP	N/A	0.3-**0.4km (0.33km²)**	N/A	0.1km (<0.1km²)	N/A	<0.1-**0.2km (<0.1km²)**
			DEP	N/A	**0.4km (0.44km²)**	N/A	0.1km (<0.1km²)	N/A	0.1-**0.2km (<0.1km²)**
Minke whale (LF)	TTS from single strike (without mitigation)	SPL_{peak} Unweighted (213 dB re 1µPa) Impulsive	SEP	0.05km (<0.01km²)	0.1km (0.03km²)	0.06km (0.01km²)	0.1km (0.03km²)	<0.05km (<0.01km²)	0.08km (0.02km²)
			DEP	0.06km (<0.01km²)	0.11km (0.04km²)	0.06km (0.01km²)	0.1km (0.03km²)	<0.05km (<0.01km²)	0.09km (0.02km²)
		SEL_{ss} Weighted (168 dB re 1µPa²s) Impulsive	SEP	1.5km (7.1km²)	**2.7km (22km²)**	0.73km (1.6km²)	**2.8km (23km²)**	0.7km (1.5km²)	2.3km (16km²)
			DEP	1.7km (9.4km²)	**3.1km (30km²)**	0.84km (2.1km²)	**2.7km (22km²)**	0.81km (2.0km²)	2.6km (21km²)
	TTS from cumulative	SEL_{cum} Weighted	SEP	N/A	8.3-**20km (720km²)**	N/A	6.5-**14km (380km²)**	N/A	6.5-14km (370km²)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km^2)		Pin-pile (4m diameter) Maximum impact range (km) and area (km^2)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
	SEL (including soft-start and ramp-up)	(168 dB re 1µPa^{2}s) Impulsive	DEP	N/A	14-**25km** **(1,100km^2)**	N/A	11-**18km** **(590km^2)**	N/A	8.4-18km (590km^2)
Grey and harbour seal (PW)	TTS from single strike (without mitigation	SPL_{peak} Unweighted (212 dB re 1µPa) Impulsive	SEP	0.06km (<0.01km^2)	0.12km (0.04km^2)	0.07km (0.01km^2)	0.11km (0.03km^2)	<0.05km (<0.01km^2)	0.1km (0.03km^2)
			DEP	0.06km (<0.01km^2)	0.13km (0.05km^2)	0.07km (0.01km^2)	0.12km (0.04km^2)	<0.05km (<0.01km^2)	0.1km (0.03km^2)
		SEL_{ss} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.13km (0.05km^2)	**0.19km** **(0.11km^2)**	0.09km (0.02km^2)	**0.19km** **(0.11km^2)**	0.08km (0.02km^2)	0.17km (0.09km^2)
			DEP	0.14km (0.06km^2)	**0.21km** **(0.13km^2)**	0.09km (0.02km^2)	**0.2km** **(0.12km^2)**	0.08km (0.02km^2)	0.19km (0.11km^2)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	N/A	4.5-**7.7km** **(140km^2)**	N/A	2.8-**4.8km** **(56km^2)**	N/A	2.8-4.8km (55km^2)
			DEP	N/A	6.0-**9.7km** **(220km^2)**	N/A	3.9-**6.3km** **(90km^2)**	N/A	3.9-6.3km (90km^2)

N/A = Not Applicable

Table 10-26: Predicted Impact Ranges (and Areas) for PTS and TTS from Cumulative Exposure during Sequential Piling at SEP and DEP

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Two monopiles (16m diameter; 5,500kJ)	Four pin-pile (4m diameter; 3,000kJ)
				Impact range (km) and area (km^2)	Impact range (km) and area (km^2)
Harbour porpoise (VHF)	PTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (155 dB re 1µPa^{2}s) Impulsive	SEP	3.4-4.1km ($43km^2$)	1.5-1.8km ($8.3km^2$)
			DEP	3.9-4.9km ($60km^2$)	1.8-2.3km ($13km^2$)
			SEP & DEP	$170km^2$	Less than monopiles
	TTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP	11-16km ($530km^2$)	8.4-12km ($300km^2$)
			DEP	12-19km ($750km^2$)	9.3-15km ($440km^2$)
			SEP & DEP	$900km^2$	Less than monopiles
Bottlenose dolphin and white-beaked dolphin (HF)	PTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	<0.1km (<$0.1km^2$)	<0.1km (<$0.1km^2$)
			DEP	<0.1km (<$0.1km^2$)	<0.1km (<$0.1km^2$)
			SEP & DEP	impact areas do not overlap	Less than monopiles
	TTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.3-0.33km ($0.3km^2$)	0.1km (<$0.1km^2$)
			DEP	0.35-0.38km ($0.4km^2$)	0.1km (<$0.1km^2$)
			SEP & DEP	$17km^2$	Less than monopiles
Minke whale (LF)	PTS from cumulative SEL during sequential	SEL_{cum} Weighted (183 dB re 1µPa^{2}s)	SEP	4.8-6.2km ($91km^2$)	2.2-2.7km ($18km^2$)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Two monopiles (16m diameter; 5,500kJ)	Four pin-pile (4m diameter; 3,000kJ)
				Impact range (km) and area (km^2)	Impact range (km) and area (km^2)
	piling in same 24 hour period	Impulsive	DEP	5.7-8.3km ($150km^2$)	2.8-3.8km ($33km^2$)
			SEP & DEP	$320km^2$	Less than monopiles
	TTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (168 dB re $1\mu Pa^2s$) Impulsive	SEP	12-20km ($720km^2$)	9.2-14km ($380km^2$)
			DEP	14-25km ($1,100km^2$)	11-18km ($590km^2$)
			SEP & DEP	$1,200km^2$	Less than monopiles
Grey and harbour seal (PW)	PTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (185 dB re $1\mu Pa^2s$) Impulsive	SEP	0.45-0.5km ($0.7km^2$)	0.1-0.13km (<$0.1km^2$)
			DEP	0.6-0.68km ($1.3km^2$)	0.13-0.18km (<$0.1km^2$)
			SEP & DEP	$18km^2$	Less than monopiles
	TTS from cumulative SEL during sequential piling in same 24 hour period	SEL_{cum} Weighted (170 dB re $1\mu Pa^2s$) Impulsive	SEP	1.3-1.4km ($5.6km^2$)	3.8-4.8km ($56km^2$)
			DEP	6.7-9.7km ($220km^2$)	4.5-6.4km ($92km^2$)
			SEP & DEP	$370km^2$	Less than monopiles

Table 10-27: Predicted Impact Areas for PTS and TTS from Cumulative Exposure during Simultaneous Piling at SEP and DEP

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile (16m diameter; 5,500kJ) at each site	Pin-pile (4m diameter; 3,000kJ) at each site	Pin-pile at SEP and monopile at DEP	Monopile at SEP and pin-pile at DEP
				Impact area (km^2)	Impact area (km^2)	Impact area (km^2)	Impact area (km^2)
Harbour porpoise (VHF)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (155 dB re 1µPa^{2}s) Impulsive	SEP & DEP	260km^2	150km^2	210km^2	200km^2
	TTS from cumulative SEL during during simultaneous piling	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP & DEP	1,200km^2	840km^2	1,100km^2	1,000km^2
Bottlenose dolphin and white-beaked dolphin (HF)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap
	TTS from cumulative SEL during during simultaneous piling	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap
Minke whale (LF)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP & DEP	420km^2	200km^2	350km^2	290km^2
	TTS from cumulative SEL	SEL_{cum} Weighted	SEP & DEP	1,600km^2	1,000km^2	1,400km^2	1,200km^2

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile (16m diameter; 5,500kJ) at each site	Pin-pile (4m diameter; 3,000kJ) at each site	Pin-pile at SEP and monopile at DEP	Monopile at SEP and pin-pile at DEP
				Impact area (km^2)	Impact area (km^2)	Impact area (km^2)	Impact area (km^2)
	during during simultaneous piling	(168 dB re $1\mu Pa^2s$) Impulsive					
Grey and harbour seal (PW)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (185 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	$33km^2$	impact areas do not overlap	$27km^2$	$23km^2$
	TTS from cumulative SEL during during simultaneous piling	SEL_{cum} Weighted (170 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	$520km^2$	$330km^2$	$450km^2$	$410km^2$

Table 10-28: Predicted Impact Ranges (and Areas) for Behavioural Response in Harbour Porpoise from Piling at SEP and DEP

Species	Impact	Criteria and threshold (Lucke *et al.*, 2009)	Location	Monopile (16m diameter) Maximum impact range (km) and area (km^2)		Pin-pile (4m diameter) Maximum impact range (km) and area (km^2)		Pin-pile (3.5m diameter for OSPs) Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Harbour porpoise	Behavioural response from single strike (without mitigation)	SEL_{ss} Unweighted (145 dB re 1µPa^2s) Impulsive	SEP	16km (620km^2)	10-21km (980km^2)	12km (350km^2)	10-20km (840km^2)	11km (340km^2)	9.9-19km (820km^2)
			DEP	19km (850km^2)	13-25km (1,400km^2)	14km (480km^2)	12-23km (1,200km^2)	14km (470km^2)	12-23km (1,100km^2)

10.6.1.1.3 Magnitude for SEP or DEP in Isolation

10.6.1.1.3.1 *PTS*

236. PTS can occur instantaneously from acute exposure to high noise levels, such as single strike (SEL_{ss}) of the maximum hammer energy applied during piling. PTS can also occur as a result of prolonged exposure to increased noise levels, such as during the duration of pile installation (SEL_{cum}).

237. Assessments are based on high marine mammal sensitivity to PTS (**Section 10.6.1.1.1**).

PTS from First Strike of Soft-Start

238. The maximum predicted impact range for instantaneous PTS from the first strike of the soft-start without any mitigation is up to 0.29km for harbour porpoise for monopile with a starting hammer energy of 1,000kJ (**Table 10-24**).

239. An assessment of the maximum number of marine mammals for each species that could be at risk of instantaneous PTS from the first strike of the soft-start without any mitigation, based on worst-case, is presented in **Table 10-29**.

240. The magnitude of the potential impact without any mitigation is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal at SEP and DEP, with 0.001% or less of the relevant reference populations anticipated to be exposed to any permanent effect (**Table 10-29**).

Table 10-29: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from First Strike of Soft-Start for Monopile or Pin-Pile without Mitigation, based on Worst-Case at SEP and DEP

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with starting hammer energy of 1,000kJ		Pin-pile with starting hammer energy of 400kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise (VHF)	SPL_{peak} Unweighted (202 dB re 1µPa) Impulsive	SEP	0.14 (0.00004% of NS MU)	**Negligible**	0.03 (0.000009% of NS MU)	**Negligible**
		DEP	0.66 (0.00019% of NS MU)	**Negligible**	0.15 (0.000042% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible (negligible)**	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible (negligible)**
		DEP	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible**	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP	0.00006 (0.00000014% of CGNS MU)	**Negligible**	0.00006 (0.00000014% of CGNS MU)	**Negligible**
		DEP	0.00006 (0.00000014% of CGNS MU)	**Negligible**	0.00006 (0.00000014% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP	0.0009 (0.000004% of CGNS MU)	**Negligible**	0.0002 (0.000001% of CGNS MU)	**Negligible**
		DEP	0.001 (0.000005% of CGNS MU)	**Negligible**	0.0002 (0.000001% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with starting hammer energy of 1,000kJ		Pin-pile with starting hammer energy of 400kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Grey seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP	0.009 (0.000098% of SE MU; or 0.000035% of wider ref pop)	**Negligible (negligible)**	0.005 (0.000098% of SE MU; or 0.000035% of wider ref pop)	**Negligible (negligible)**
		DEP	0.0074 (0.000085% of SE MU; or 0.000031% of wider ref pop)	**Negligible (negligible)**	0.0009 (0.000085% of SE MU; or 0.000031% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP	0.0027 (0.000073% of SE MU; or 0.0000090% of wider ref pop)	**Negligible (negligible)**	0.0021 (0.000073% of SE MU; or 0.0000090% of wider ref pop)	**Negligible (negligible)**
		DEP	0.0008 (0.000021% of SE MU; or 0.0000026% of wider ref pop)	**Negligible (negligible)**	0.0024 (0.000021% of SE MU; or 0.0000026% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

PTS from Single Strike at Maximum Hammer Energy

241. The maximum predicted impact range for instantaneous PTS from a single strike of monopile or pin-pile with maximum hammer energy without any mitigation is up to 0.57km for harbour porpoise for monopile with a maximum hammer energy of 5,500kJ (**Table 10-24**).

242. An assessment of the maximum number of marine mammals for each species that could be at risk of instantaneous PTS from a single strike of monopile or pin-pile with maximum hammer energy without any mitigation, based on worst-case, is presented in **Table 10-30**.

243. The magnitude of the potential impact without any mitigation is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal at SEP and DEP, with 0.001% or less of the relevant reference populations anticipated to be exposed to any permanent effect (**Table 10-30**).

Table 10-30: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from Single Strike of Monopile or Pin-Pile at Maximum Hammer Energy without Mitigation, based on Worst-Case at SEP and DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise (VHF)	SPL_{peak} Unweighted (202 dB re 1µPa) Impulsive	SEP	0.52 (0.00015% of NS MU)	**Negligible**	0.37 (0.00011% of NS MU)	**Negligible**
		DEP	2.43 (0.0007% of NS MU)	**Negligible**	1.75 (0.0005% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible (negligible)**	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible (negligible)**
		DEP	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible**	0.0003 (0.000015% of GNS MU; 0.00013% of CES MU)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP	0.00006 (0.00000014% of CGNS MU)	**Negligible**	0.00006 (0.00000014% of CGNS MU)	**Negligible**
		DEP	0.00006 (0.00000014% of CGNS MU)	**Negligible**	0.00006 (0.00000014% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP	0.004 (0.000019% of CGNS MU)	**Negligible**	0.004 (0.000019% of CGNS MU)	**Negligible**
		DEP	0.005 (0.000024% of CGNS MU)	**Negligible**	0.003 (0.000016% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Grey seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP	0.009 (0.000098% of SE MU; or 0.000035% of wider ref pop)	**Negligible (negligible)**	0.009 (0.000098% of SE MU; or 0.000035% of wider ref pop)	**Negligible (negligible)**
		DEP	0.0074 (0.000085% of SE MU; or 0.000031% of wider ref pop)	**Negligible (negligible)**	0.0074 (0.000085% of SE MU; or 0.000031% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP	0.0027 (0.000073% of SE MU; or 0.000009% of wider ref pop)	**Negligible (negligible)**	0.0027 (0.000073% of SE MU; or 0.000009% of wider ref pop)	**Negligible (negligible)**
		DEP	0.0008 (0.000021% of SE MU; or 0.0000026% of wider ref pop)	**Negligible (negligible)**	0.0008 (0.000021% of SE MU; or 0.0000026% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species.

PTS from Cumulative Exposure of a Single Pile

244. The maximum predicted impact range for PTS from cumulative exposure (SEL_{cum}) during single pile installation of monopile or pin-pile with maximum hammer energy without any mitigation is up to 4.9km for harbour porpoise and 8.3km for minke whale for monopile with a maximum hammer energy of 5,500kJ (**Table 10-24**).

245. The SEL_{cum} is a measure of the total received noise over the whole piling operation. The SEL_{cum} range indicates the distance from the piling location that if the receptor were to start fleeing in a straight line from the noise source starting at a range closer than the modelled range it would receive a noise exposure in excess of the criteria threshold, and if the receptor were to start fleeing from a range further than the modelled range it would receive a noise exposure below the criteria threshold (see **Appendix 10.2 Underwater Noise Modelling Report** for further details).

246. The piling parameters for monopiles and pin-piles, including duration of soft-start, ramp-up procedure, strike rate, number of strikes and duration, were determined to reduce the potential impact ranges, as much as possible, for PTS from cumulative exposure.

247. An assessment of the maximum number of marine mammals for each species that could be at risk of PTS from cumulative exposure during installation of monopile or pin-pile with maximum hammer energy without any mitigation, based on worst-case for the maximum impact range, is presented in **Table 10-31**.

248. The magnitude of the potential impact for monopile with a maximum hammer energy of 5,500kJ without any mitigation is assessed as low at SEP or medium at DEP for harbour porpoise, negligible (low) for bottlenose dolphin, negligible for white-beaked dolphin at SEP or DEP, low for minke whale at SEP or DEP based on worst-case scenario. For grey seal the magnitude of the potential impact for monopile with a maximum hammer energy of 5,500kJ without any mitigation is assessed as low (low) at SEP or medium (low) at DEP and low (negligible) at SEP or DEP for harbour seal, based on worst-case scenario (**Table 10-31**).

249. The magnitude of the potential impact for pin-pile with a maximum hammer energy of 3,000kJ without any mitigation is assessed as low at SEP or DEP for harbour porpoise, negligible (low) for bottlenose dolphin, negligible for white-beaked dolphin at SEP or DEP, negligible at SEP or low at DEP for minke whale based on worst-case scenario. For grey seal the magnitude of the potential impact is low (negligible) at SEP and negligible (negligible) at DEP for grey seal and negligible (negligible) at SEP or DEP for harbour seal, based on worst-case scenario (**Table 10-31**).

250. It is important to note that assessment for PTS from cumulative exposure is highly precautionary, as outlined. There is also a lot of variation in the potential impact ranges for SEL_{cum} at each location and between locations (**Table 10-24**). For example, for harbour porpoise, the impact ranges for monopile hammer energy of 5,500kJ is 2.8-4.1km at SEP and is 3.6-4.9km at DEP. In addition, as previously outlined, the maximum hammer energy is only likely to be required at a few of the piling installation locations and for shorter periods of time. Therefore, the most likely scenario is a precautionary but more realistic scenario, with impact ranges for harbour porpoise of 0.08-2.2km at SEP and 1.6-2.5km at DEP (see **Appendix 10.2 Underwater Noise Modelling Report**).

Table 10-31: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from Cumulative Exposure (SEL_{cum}) During Installation of Monopile or Pin-Pile without Mitigation, Based on Worst-Case at SEP or DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise (VHF)	SEL_{cum} Weighted (155 dB re 1µPa^{2}s) Impulsive	SEP	27 (0.008% of NS MU)	**Low**	5 (0.002 of NS MU)	**Low**
		DEP	148 (0.04% of NS MU)	**Medium**	32 (0.009% of NS MU)	**Low**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (low)**	0.003 (0.000015% of GNS MU; 0.0013% CES MU)	**Negligible (low)**
		DEP	0.003 (0.00015% of GNS MU; 0.0016% CES MU)	**Negligible (low)**	0.003 (0.00015% of GNS MU; 0.0016% CES MU)	**Negligible (low)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.0006 (0.0000014% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**
		DEP	0.0006 (0.0000014% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Minke whale (LF)	SEL_{cum} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP	0.92 (0.005% of CGNS MU)	**Low**	0.18 (0.0009% of CGNS MU)	**Negligible**
		DEP	1.5 (0.007% of CGNS MU)	**Low**	0.33 (0.0016% of CGNS MU)	**Low**
Grey seal (PW)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.72 (0.008% of SE MU or 0.003% of wider ref pop)	**Low (low)**	0.09 (0.001% of ref pop (or 0.0004% of SE MU)	**Low (negligible)**
		DEP	1.03 (0.0012% of SE MU or 0.0043% of wider ref pop)	**Medium (low)**	0.074 (0.0009% of SE MU or 0.00031% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.23 (0.006% of SE MU or 0.0008% of wider ref pop)	**Low (negligible)**	0.027 (0.0007% of SE MU or 0.00009% of wider ref pop)	**Negligible (negligible)**
		DEP	0.11 (0.003% of SE MU or 0.0004% of wider ref pop)	**Low (negligible)**	0.008 (0.0002% of SE MU or 0.00003% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

PTS from Cumulative Exposure of Sequential Piling

251. The maximum predicted impact range for PTS from cumulative exposure (SEL_{cum}) during sequential piling of two monopiles at SEP or DEP or four pin-piles at SEP or DEP with maximum hammer energy without any mitigation is up to 4.9km for harbour porpoise and 8.3km for minke whale for two monopiles at DEP with a maximum hammer energy of 5,500kJ (**Table 10-26**).

252. The impact ranges and areas for PTS from cumulative exposure (SEL_{cum}) during sequential piling (**Table 10-26**) are virtually the same for PTS from cumulative exposure during a single pile installation (**Table 10-24**). This is because, a fleeing receptor, such as a marine mammal, will have travelled away from the noise source by the time the second pile installation starts.

253. An assessment of the maximum number of marine mammals for each species that could be at risk of PTS from cumulative exposure during installation of sequential piling of two monopiles at SEP or DEP or four pin-piles at SEP or DEP with maximum hammer energy without any mitigation, based on worst-case, is presented in **Table 10-32**.

254. The magnitude of the potential impact of PTS from sequential piling of two monopiles with a maximum hammer energy of 5,500kJ without any mitigation is assessed as low at SEP or medium at DEP for harbour porpoise, negligible (low) for bottlenose dolphin, negligible for white-beaked dolphin at SEP or DEP, low for minke whale at SEP or DEP. For grey seal the magnitude without any mitigation is assessed as low (low) at SEP or medium (low) at DEP and low (negligible) at SEP or DEP for harbour seal (**Table 10-32**).

255. The magnitude of the potential impact for PTS from sequential piling of four pin-pile with a maximum hammer energy of 3,000kJ without any mitigation is assessed as low at SEP or DEP for harbour porpoise, negligible (low) for bottlenose dolphin, negligible for white-beaked dolphin at SEP or DEP, negligible at SEP or low at DEP for minke whale, for grey seal the magnitude of the potential impact is low (negligible) at SEP and negligible (negligible) at DEP for grey seal and negligible (negligible) at SEP or DEP for harbour seal (**Table 10-32**).

Table 10-32: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from Cumulative Exposure (SEL_{cum}) During Sequential Piling, Based on Worst-Case at SEP or DEP

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Two monopiles (16m diameter; 5,500kJ)		Four pin-pile (4m diameter; 3,000kJ)	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise (VHF)	SEL_{cum} Weighted (155 dB re 1µPa^{2}s) Impulsive	SEP	27 (0.008% of NS MU)	**Low**	5 (0.002 of NS MU)	**Low**
		DEP	146 (0.04% of NS MU)	**Medium**	32 (0.009% of NS MU)	**Low**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (low)**	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (low)**
		DEP	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (low)**	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (low)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.0006 (0.0000014% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**
		DEP	0.0006 (0.0000014% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Two monopiles (16m diameter; 5,500kJ)		Four pin-pile (4m diameter; 3,000kJ)	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Minke whale (LF)	SEL_{cum} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP	0.91 (0.005% of CGNS MU)	**Low**	0.18 (0.0009% of CGNS MU)	**Negligible**
		DEP	1.5 (0.007% of CGNS MU)	**Low**	0.33 (0.0016% of CGNS MU)	**Low**
Grey seal (PW)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.72 (0.008% of SE MU or 0.003% of wider ref pop)	**Low (low)**	0.09 (0.001% of ref pop (or 0.0004% of SE MU)	**Low (negligible)**
		DEP	1.03 (0.012% of SE MU or 0.0043% of wider ref pop)	**Medium (low)**	0.074 (0.0009% of SE MU or 0.00031% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP	0.15 (0.004% of SE MU or 0.0003% of wider ref pop)	**Low (negligible)**	0.021 (0.0006% of SE MU or 0.00005% of wider ref pop)	**Negligible (negligible)**
		DEP	0.31 (0.008% of SE MU or 0.0007% of wider ref pop)	**Low (negligible)**	0.024 (0.0006% of SE MU or 0.00005% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.1.3.2 *TTS*

256. TTS can occur instantaneously from acute exposure to high noise levels, such as single strike (SEL_{ss}) of the maximum hammer energy applied during piling. TTS can also occur as a result of prolonged exposure to increased noise levels, such as during the duration of pile installation (SEL_{cum}).

257. All marine mammal species are assessed as having medium sensitivity to TTS (**Table 10-20**).

258. The underwater noise modelling results for the maximum predicted ranges (and areas) for TTS in marine mammals are presented in **Table 10-25**.

TTS from Single Strike at Maximum Hammer Energy

259. The maximum predicted impact range for TTS from a single strike of monopile with maximum hammer energy without any mitigation is up to 3.1km for minke whale and 1.3km for harbour porpoise (**Table 10-25**).

260. An assessment of the maximum number of marine mammals for each species that could be at risk of TTS from a single strike of monopile or pin-pile with maximum hammer energy without any mitigation, based on worst-case, is presented in **Table 10-33**.

261. The magnitude of the potential impact without any mitigation is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal at SEP or DEP, with 1% or less of the relevant reference populations anticipated to be exposed to any temporary effect (**Table 10-33**).

Table 10-33: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS from Single Strike of Monopile or Pin-Pile at Maximum Hammer Energy without Mitigation, Based on Worst-Case at SEP or DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour porpoise (VHF)	SEL_{ss} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP	3 (0.00085% of NS MU)	**Negligible**	2.3 (0.00065% of NS MU)	**Negligible**
		DEP	13.4 (0.0039% of NS MU)	**Negligible**	10.2 (0.0029% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (224 dB re 1µPa) Impulsive	SEP	0.0003 (0.000015% of GNS MU; 0.00013% CES MU)	**Negligible (negligible)**	0.0003 (0.000015% of GNS MU; 0.00013% CES MU)	**Negligible (negligible)**
		DEP	0.0003 (0.000015% of GNS MU; 0.00013% CES MU)	**Negligible (negligible)**	0.0003 (0.000015% of GNS MU; 0.00013% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (224 dB re 1µPa) Impulsive	SEP	0.00006 (0.00000014% of CGNS MU)	**Negligible**	0.00006 (0.00000014% of CGNS MU)	**Negligible**
		DEP	0.00006 (0.00000014% of CGNS MU)	**Negligible**	0.00006 (0.00000014% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (168 dB re 1µPa^{2}s)	SEP	0.22 (0.0011% of CGNS MU)	**Negligible**	0.23 (0.0011% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
	Impulsive	DEP	0.30 (0.0015% of CGNS MU)	**Negligible**	0.22 (0.0011% of CGNS MU)	**Negligible**
Grey seal (PW)	SEL_{ss} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.09 (0.0011% of SE MU; or 0.00039% of wider ref pop)	**Negligible (negligible)**	0.05 (0.0011% of SE MU; or 0.00039% of wider ref pop)	**Negligible (negligible)**
		DEP	0.096 (0.0011% of SE MU; or 0.00040% of wider ref pop)	**Negligible (negligible)**	0.0089 (0.00102% of SE MU; or 0.00037% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SEL_{ss} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.03 (0.0008% of SE MU; or 0.000099% of wider ref pop)	**Negligible (negligible)**	0.03 (0.0008% of SE MU; or 0.000099% of wider ref pop)	**Negligible (negligible)**
		DEP	0.01 (0.00028% of SE MU; or 0.000034% of wider ref pop)	**Negligible (negligible)**	0.01 (0.00026% of SE MU; or 0.000031% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

TTS from Cumulative Exposure of a Single Pile

262. The maximum predicted impact range for TTS from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile with maximum hammer energy without any mitigation is up to 19km for harbour porpoise and 25km for minke whale for the monopile worst-case with a maximum hammer energy of 5,500kJ (**Table 10-25**).

263. An assessment of the maximum number of marine mammals for each species that could be at risk of TTS from cumulative exposure during installation of monopile or pin-pile with maximum hammer energy without any mitigation, based on worst-case for the maximum impact range, is presented in **Table 10-34**.

264. The magnitude of the potential impact without any mitigation for monopiles and pin-piles is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin and, minke whale at SEP or DEP. For grey seal the magnitude is low (negligible) for monopiles at SEP or DEP and negligible (negligible) for pin-piles at SEP or DEP, harbour seal the magnitude is low (negligible) for monopiles at SEP and negligible (negligible) at DEP and for pin-piles at SEP or DEP(**Table 10-34**).

265. As outlined for PTS from cumulative exposure, the ranges indicate the distance that an individual would need to be from the noise source at the onset of the piling sequence to prevent a cumulative noise exposure which could lead to TTS. This is highly conservative because the assessment assumes the worst-case exposure levels for an animal in the water column, and does not take account of periods where exposure will be reduced, for example in seals when their heads are out of the water; or that the cumulative noise dose received by the marine mammal will be largely dependent on the swimming speed, and whether the animal moves away from the noise source rapidly as a flee response. The cumulative SEL dose does not take account of this and therefore is likely to overestimate the received noise levels.

Table 10-34: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS from Cumulative Exposure (SEL_{cum}) During Installation of Monopile or Pin-Pile without Mitigation, Based on Worst-Case at SEP or DEP

Species	**Criteria and threshold (Southall *et al.*, 2019)**	**Location**	**Monopile with maximum hammer energy of 5,500kJ**		**Pin-pile with maximum hammer energy of 3,000kJ**	
			Maximum number of individuals (% of reference population)	**Magnitude* (temporary impact)**	**Maximum number of individuals (% of reference population)**	**Magnitude* (temporary impact)**
Harbour porpoise (VHF)	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP	334 (0.1% of NS MU)	**Negligible**	189 (0.05% of NS MU)	**Negligible**
		DEP	1,823 (0.53% of NS MU)	**Negligible**	1,069 (0.3% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.01 (0.0005% of GNS MU; 0.0044% CES MU)	**Negligible (negligible)**	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (negligible)**
		DEP	0.013 (0.0006% of GNS MU; 0.0059% CES MU)	**Negligible (negligible)**	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.002 (0.000005% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**
		DEP	0.003 (0.000006% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (168 dB re 1µPa^{2}s) Impulsive	SEP	7.2 (0.04% of CGNS MU)	**Negligible**	3.8 (0.02% of CGNS MU)	**Negligible**
		DEP	11 (0.05% of CGNS MU)	**Negligible**	5.9 (0.03% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Grey seal (PW)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	119.4 (1.4 % of SE MU; or 0.5% of wider ref pop)	**Low (negligible)**	47.8 (0.6% of SE MU; or 0.2% of wider ref pop)	**Negligible (negligible)**
		DEP	162.6 (1.9% of SE MU; or 0.7% of wider ref pop)	**Low (negligible)**	66.5 (0.8% of SE MU; or 0.28% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	38.4 (1.0% of SE MU; or 0.1% of wider ref pop)	**Low (negligible)**	15.3 (0.4% of SE MU; or 0.05% of wider ref pop)	**Negligible (negligible)**
		DEP	17.6 (0.5% of SE MU; or 0.1% of wider ref pop)	**Negligible (negligible)**	7.2 (0.2% of SE MU; or 0.02% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

TTS from Cumulative Exposure of Sequential Piling

266. The maximum predicted impact range for TTS from cumulative exposure (SEL_{cum}) during sequential piling of two monopiles at SEP or DEP or four pin-piles at SEP or DEP with maximum hammer energy without any mitigation is up to 19km for harbour porpoise and 25km for minke whale for two monopiles at DEP with a maximum hammer energy of 5,500kJ (**Table 10-26**).

267. As for PTS, the impact ranges and areas for TTS from cumulative exposure (SEL_{cum}) during sequential piling (**Table 10-26**) are virtually the same for TTS from cumulative exposure during a single pile installation (**Table 10-25**). This is because, a fleeing receptor, such as a marine mammal, will have travelled away from the noise source by the time the second pile installation starts.

268. An assessment of the maximum number of marine mammals for each species that could be at risk of TTS from cumulative exposure during installation of sequential piling of two monopiles at SEP or DEP or four pin-piles at SEP or DEP with maximum hammer energy without any mitigation, based on worst-case, is presented in **Table 10-35**.

269. The magnitude of the potential impact without any mitigation for sequential piling of monopiles or pin-piles at SEP or DEP is assessed as negligible (negligible) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale and harbour seal at SEP or DEP. For grey seal the magnitude is negligible (negligible) for pin-piles at SEP or DEP, negligible for monopiles at SEP or low (negligible) for monopiles at DEP (**Table 10-35**).

Table 10-35: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS from Cumulative Exposure (SEL_{cum}) During Sequential Piling, Based on Worst-Case at SEP or DEP

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Two monopiles (16m diameter; 5,500kJ)		Four pin-pile (4m diameter; 3,000kJ)	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour porpoise (VHF)	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP	334 (0.1% of NS MU)	**Negligible**	189 (0.05% of NS MU)	**Negligible**
		DEP	1,823 (0.53% of NS MU)	**Negligible**	1,069 (0.3% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	0.009 (0.00044% of GNS MU; 0.004% CES MU)	**Negligible (negligible)**	0.003 (0.00015% of GNS MU; 0.0013% CES MU)	**Negligible (negligible)**
		DEP	0.012 (0.00059% of GNS MU; 0.0063% CES MU)	**Negligible (negligible)**	0.003 (0.00015% of GNS MU; 0.0016% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (170 dB	SEP	0.0018 (0.000004% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Two monopiles (16m diameter; 5,500kJ)		Four pin-pile (4m diameter; 3,000kJ)	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
	re $1\mu Pa^2s$) Impulsive	DEP	0.0024 (0.000005% of CGNS MU)	**Negligible**	0.0006 (0.0000014% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (168 dB re $1\mu Pa^2s$) Impulsive	SEP	7.2 (0.04% of CGNS MU)	**Negligible**	3.8 (0.02% of CGNS MU)	**Negligible**
		DEP	11 (0.05% of CGNS MU)	**Negligible**	5.9 (0.03% of CGNS MU)	**Negligible**
Grey seal (PW)	SEL_{cum} Weighted (170 dB re $1\mu Pa^2s$) Impulsive	SEP	4.8 (0.06% of SE MU; or 0.02% of wider ref pop)	**Negligible (negligible)**	47.8 (0.55% of SE MU; or 0.2% of wider ref pop)	**Negligible (negligible)**
		DEP	162.6 (1.88% of SE MU; or 0.67% of wider ref pop)	**Low (negligible)**	8.3 (0.1% of SE MU; or 0.03% of wider ref pop)	**Negligible (negligible)**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Two monopiles (16m diameter; 5,500kJ)		Four pin-pile (4m diameter; 3,000kJ)	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour seal (PW)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP	1.5 (0.04% of SE MU; or 0.0053% of wider ref pop)	**Negligible (negligible)**	15.3 (0.41% of SE MU; or 0.05% of wider ref pop)	**Negligible (negligible)**
		DEP	17.6 (0.471% of SE MU; or 0.06% of wider ref pop)	**Negligible (negligible)**	7.4 (0. 2% of SE MU; or 0.02% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.1.4 Impact Significance

270. For PTS, taking into account high marine mammal sensitivity (**Section 10.6.1.1.1**) and the potential magnitude of the effect (i.e. number of individuals as a percentage of the reference population; **Table 10-29**, **Table 10-30** and **Table 10-31**), the impact significance for permanent changes in hearing sensitivity (PTS) from a single strike of the maximum or starting hammer energy for monopiles or pin-piles without any mitigation has been assessed as minor for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-36**). For PTS from cumulative exposure without mitigation, the impact significance has been assessed as moderate to major for harbour porpoise, minor (moderate) for bottlenose dolphin, minor for white-beaked dolphin, moderate to minor for minke whale, major (moderate) to minor (minor) grey seal and moderate (minor) to minor (minor) for harbour seal (**Table 10-36**).

271. For TTS, taking into account medium marine mammal sensitivity (**Section 10.6.1.1.1**) and the potential magnitude of the effect (**Table 10-33** and **Table 10-34**), the impact significance for temporary changes in hearing sensitivity (TTS) from a single strike of the maximum hammer energy for monopiles or pin-piles has been assessed as minor for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-37**). For TTS from cumulative exposure, the impact significance has been assessed as minor for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and minor (moderate) for harbour seal (**Table 10-37**).

272. For sequential piling, the impact significance is the same as PTS or TTS from cumulative exposure during a single pile installation. That is, for PTS from cumulative exposure during sequential piling without mitigation, the impact significance has been assessed as moderate to major for harbour porpoise, minor (moderate) for bottlenose dolphin and white-beaked dolphin, moderate to minor for minke whale, major (moderate) to minor (minor) grey seal and moderate (minor) to minor (minor) for harbour se (**Table 10-36**). For TTS from cumulative exposure during sequential piling, the impact significance has been assessed as minor for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-37**).

10.6.1.1.5 Mitigation

273. The MMMP for piling (**Section 10.3.4**) would reduce the risk of PTS from the first strike of the soft-start; single strike of the maximum hammer energy; and cumulative PTS. The MMMP for piling will be developed post-consent in consultation with the MMO and other relevant organisations and will be based on the latest information, scientific understanding and guidance and detailed project design. The final MMMP for piling will be based on the **Draft MMMP** (document reference 9.4) submitted with the DCO application.

274. The proposed mitigation to reduce the risk of PTS would include establishing a monitoring zone and ADD activation prior to the soft-start commencing.

275. ADDs have proven to be effective mitigation for harbour porpoise, dolphin species, minke whale, grey and harbour seal (Sparling *et al.,* 2015; McGarry *et al.,* 2017, 2020). ADDs have been widely used as mitigation to deter marine mammals during offshore wind farm piling.

276. It is also important to note that Brandt *et al*. (2018) found that at seven German offshore wind farms in the vicinity (up to 2km) of the construction site, harbour porpoise detections declined several hours before the start of piling as a result of increased construction related activities and vessels. Similarly, studies in the Moray Firth during piling of the Beatrice offshore wind farm, indicate higher vessel activity within 1km was associated with an increased probability of response in harbour porpoise (Graham *et al*., 2019). This disturbance of marine mammals from the area around the construction site prior to piling would also reduce the risk of PTS.

277. The mitigation measures in the MMMP to reduce the risk of PTS would also reduce the number of marine mammals at risk of TTS.

10.6.1.1.6 Residual Impact Significance

278. The residual impact of the potential risk of PTS at either SEP or DEP to marine mammals as a result of underwater noise during piling would be **minor adverse (not significant)** for all species (**Table 10-36**), with the proposed mitigation (**Section 10.3.4**).

279. The residual impact of the potential risk of TTS at either SEP or DEP to marine mammals as a result of underwater noise during piling, would be **minor adverse (not significant)** for all species (**Table 10-37**).

Table 10-36: Assessment of Impact Significance for PTS in Marine Mammals from Underwater Noise During Piling of Monopile or Pin-Pile at Either SEP or DEP

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Harbour porpoise	PTS from single strike of starting hammer energy	SEP	High	Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS during piling from cumulative exposure for single or sequential piling	SEP		Low for both monopile and pin-pile	Moderate adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Medium for monopile Low for pin-pile	Major adverse for monopile Moderate for pin-pile		**Minor adverse**
		SEP	High	Negligible for both	Minor adverse for both	MMMP (**Section 10.3.4**)	**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Bottlenose dolphin	PTS from single strike of starting hammer energy			monopile and pin-pile	monopile and pin-pile		
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS during piling from cumulative exposure for single or sequential piling	SEP		Negligible (low) for both monopile and pin-pile	Minor (moderate) adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible (low) for both monopile and pin-pile	Minor (moderate) adverse for both monopile and pin-pile		**Minor adverse**
White-beaked dolphin	PTS from single strike of starting hammer energy	SEP	High	Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible for both	Minor adverse for both		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
				monopile and pin-pile	monopile and pin-pile		
	PTS from single strike of maximum hammer energy	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS during piling from cumulative exposure for single or sequential piling	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
Minke whale	PTS from single strike of starting hammer energy	SEP	High	Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	PTS during piling from cumulative exposure for single or sequential piling	SEP		Low for monopile Negligible for pin-pile	Moderate adverse for monopile Minor for pin-pile		**Minor adverse**
		DEP		Low for monopile Negligible for pin-pile	Moderate adverse for monopile Minor for pin-pile		**Minor adverse**
Grey seal	PTS from single strike of starting hammer energy	SEP	High	Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
	PTS during piling from cumulative exposure for single or sequential piling	SEP		Low (low) for monopile and Low (negligible) for pin-pile	Moderate (moderate) adverse for monopile and Moderate (minor) adverse pin-pile		**Minor adverse**
		DEP		Medium (low) for monopile and Negligible (negligible) pin-pile	Major (moderate) adverse for monopile and Minor (minor) adverse for pin-pile		**Minor adverse**
Harbour seal	PTS from single strike of starting hammer energy	SEP	High	Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	PTS from single strike of maximum hammer energy	SEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
	PTS during piling from cumulative exposure for single or sequential piling	SEP		Low (negligible) for monopile Negligible (negligible) for pin-pile	Moderate (minor) adverse for monopile Minor (minor) for pin-pile		**Minor adverse**
		DEP		Low (negligible) for monopile Negligible (negligible) for pin-pile	Moderate (minor) adverse for monopile Minor (minor) for pin-pile		**Minor adverse**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

Table 10-37: Assessment of Impact Significance for TTS in Marine Mammals from Underwater Noise During Piling of Monopile or Pin-Pile at SEP and DEP

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Harbour porpoise	TTS from single strike of maximum hammer energy	SEP	Medium	Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	TTS during piling from cumulative exposure	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
Bottlenose dolphin	TTS from single strike of maximum hammer energy	SEP	Medium	Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible (negligible)	Minor (minor) adverse for		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
				for both monopile and pin-pile	both monopile and pin-pile		
	TTS during piling from cumulative exposure for single or sequential piling	SEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
White-beaked dolphin	TTS from single strike of maximum hammer energy	SEP	Medium	Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	TTS during piling from cumulative exposure	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
Minke whale	TTS from single strike of maximum hammer energy	SEP	Medium	Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
	TTS during piling from cumulative exposure for single or sequential piling	SEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible for both monopile and pin-pile	Minor adverse for both monopile and pin-pile		**Minor adverse**
Grey seal		SEP	Medium	Negligible (negligible) for both	Minor (minor) adverse for both	MMMP (**Section 10.3.4**)	**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	TTS from single strike of maximum hammer energy			monopile and pin-pile	monopile and pin-pile		
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
	TTS during piling from cumulative exposure for single or sequential piling	SEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Low (negligible) for monopile Negligible (negligible) for pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
Harbour seal	TTS from single strike of maximum hammer energy	SEP	Medium	Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile	MMMP (**Section 10.3.4**)	**Minor adverse**
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	TTS during piling from cumulative exposure for single or sequential piling	SEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**
		DEP		Negligible (negligible) for both monopile and pin-pile	Minor (minor) adverse for both monopile and pin-pile		**Minor adverse**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.1.7 Impact Assessment for SEP and DEP

280. As outlined in **Section 10.3.3.2**, there is the potential that SEP and DEP could be constructed concurrently. Therefore, the worst-case for SEP and DEP being developed concurrently has been assessed, based on simultaneous piling i.e. piling in SEP at the same time as piling in DEP, noting that simultaneous piling within SEP or DEP individually could occur but has not been assessed since it is not the worst-case. In addition, sequential piling of one monopile installed at DEP, followed by a second monopile installed at SEP, in the same 24 hour period is also assessed.

281. The closest distance between SEP and DEP is 10.7km for DEP South array area and 11km for DEP North array area.

10.6.1.1.7.1 *PTS from SEP and DEP*

282. The following assessment is based on the results of the modelling for both SEP and DEP as presented in **Section 10.6.1.1.2.2** above.

283. The maximum predicted impact range for instantaneous PTS from the first strike of the soft-start without any mitigation is up to 0.29km for harbour porpoise for the monopile worst-case with a starting hammer energy of 1,000kJ (**Table 10-24**). Therefore, there would be no overlap between the two Projects and the assessments for the SEP or DEP in isolation are appropriate. As a worst-case the maximum number of marine mammals from each Project have been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-38**).

284. The magnitude of the potential impact for instantaneous PTS from the first strike of the soft-start without any mitigation at SEP and DEP is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, with 0.001% or less of the relevant reference populations anticipated to be exposed to any permanent effect (**Table 10-38**).

285. The maximum predicted impact range for instantaneous PTS from a single strike of monopile or pin-pile with maximum hammer energy without any mitigation is up to 0.57km for harbour porpoise for the monopile worst-case with a maximum hammer energy of 5,500kJ (**Table 10-24**). Therefore, there would be no overlap between the two Projects and the assessments for SEP or DEP in isolation are appropriate. As a worst-case the maximum number of marine mammals from each Project have been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-38**).

286. The magnitude of the potential impact for instantaneous PTS from single strike of the maximum hammer energy without any mitigation at SEP and DEP is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, with 0.001% or less of the relevant reference populations anticipated to be exposed to any permanent effect (**Table 10-39**).

287. The maximum predicted impact range for PTS from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile with maximum hammer energy without any mitigation is up to 4.9km for harbour porpoise and 8.3km for minke whale for the monopile worst-case with a maximum hammer energy of 5,500kJ (**Table 10-24**). Therefore, there would be no overlap between the two Projects and the assessments for SEP or DEP in isolation are appropriate. As a worst-case, the maximum number of marine mammals from each Project have been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-40**).

288. The magnitude of the potential impact for cumulative PTS without any mitigation for the installation of monopiles at SEP and DEP is assessed as medium for harbour porpoise for both monopiles and pin-piles, and negligible (low) for bottlenose dolphin and white-beaked dolphin for both monopiles and pin-piles. For minke whale, the magnitude is medium for monopiles and low for pin-piles. For grey seal, the magnitude is medium (low) for monopiles and low (negligible)for pin-piles. For harbour seal, the magnitude is negligible (low) for monopiles and pin-piles (**Table 10-40**).

Table 10-38: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from First Strike of Soft-Start for Monopile or Pin-Pile without Mitigation, Based on Worst-Case for SEP and DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ		Pin-pile with starting hammer energy of 400kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise (VHF)	SPL_{peak} Unweighted (202 dB re 1µPa) Impulsive	SEP & DEP	0.79 (0.00023% of NS MU)	**Negligible**	0.18 (0.00005% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP & DEP	0.0006 (0.00003% of GNS MU; 0.00027% CES MU)	**Negligible (negligible)**	0.0006 (0.00003% of GNS MU; 0.00027% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP & DEP	0.0001 (0.0000003% of CGNS MU)	**Negligible**	0.0001 (0.0000003% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.002 (0.00001% of CGNS MU)	**Negligible**	0.0004 (0.000002% of CGNS MU)	**Negligible**
Grey seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP & DEP	0.016 (0.00018% of SE MU or 0.000066 % of wider ref pop)	**Negligible (negligible)**	0.016 (0.00018% of SE MU or 0.000066 % of wider ref pop)	**Negligible (negligible)**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ		Pin-pile with starting hammer energy of 400kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP & DEP	0.004 (0.00009% of SE MU or 0.00001% of wider ref pop)	**Negligible (negligible)**	0.004 (0.00009% of SE MU or 0.00001% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal specie

Table 10-39: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from Single Strike of Monopile or Pin-Pile at Maximum Hammer Energy without Mitigation, Based on Worst-Case for SEP and DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise (VHF)	SPL_{peak} Unweighted (202 dB re 1µPa) Impulsive	SEP & DEP	2.95 (0.00085% of NS MU)	**Negligible**	2.12 (0.00061% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1µPa) Impulsive	SEP & DEP	0.0006 (0.00003% of GNS MU; 0.00027% CES MU)	**Negligible (negligible)**	0.0006 (0.00003% of GNS MU; 0.00032% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SPL_{peak} Unweighted	SEP & DEP	0.0001 (0.0000003% of CGNS MU)	**Negligible**	0.0001 (0.0000003% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
	(230 dB re 1µPa) Impulsive					
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.009 (0.000043% of CGNS MU)	**Negligible**	0.007 (0.000036% of CGNS MU)	**Negligible**
Grey seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP & DEP	0.016 (0.00018% of SE MU or 0.000066% of wider ref pop)	**Negligible (negligible)**	0.016 (0.00018% of SE MU or 0.000066% of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SPL_{peak} Unweighted (218 dB re 1µPa) Impulsive	SEP & DEP	0.004 (0.00009% of SE MU or 0.00001% of wider ref pop)	**Negligible (negligible)**	0.004 (0.00009% of SE MU or 0.00001% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal specie

Table 10-40: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS from Cumulative Exposure (SEL_{cum}) During Installation of Monopile or Pin-Pile without Mitigation, Based on Worst-Case for SEP and DEP

Species	**Criteria and threshold (Southall *et al.*, 2019)**	**Location**	**Monopile with maximum hammer energy of 5,500kJ**		**Pin-pile with maximum hammer energy of 3,000kJ**	
			Maximum number of individuals (% of reference population)	**Magnitude* (permanent impact)**	**Maximum number of individuals (% of reference population)**	**Magnitude* (permanent impact)**
Harbour porpoise (VHF)	SEL_{cum} Weighted (155 dB re 1µPa²s) Impulsive	SEP & DEP	175 (0.05% of NS MU)	**Medium**	37 (0.008% of NS MU)	**Medium**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (185 dB re 1µPa²s) Impulsive	SEP & DEP	0.006 (0.0003% of GNS MU; 0.0027% CES MU)	**Negligible (low)**	0.006 (0.0003% of GNS MU; 0.0027% CES MU)	**Negligible (low)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (185 dB re 1µPa²s) Impulsive	SEP & DEP	0.0012 (0.000003% of CGNS MU)	**Negligible**	0.0012 (0.000003% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (185 dB re 1µPa²s) Impulsive	SEP & DEP	2.42 (0.012% of CGNS MU)	**Medium**	0.51 (0.0025% of CGNS MU)	**Low**
Grey seal (PW)	SEL_{cum} Weighted (185 dB re 1µPa²s) Impulsive	SEP & DEP	0.52 (0.006% of SE MU or 0.007% of wider ref pop)	**Medium (low)**	0.16 (0.0018% of SE MU or 0.0007% of wider ref pop)	**Low (negligible)**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)	Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour seal (PW)	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.3 (0.0009% of SE MU or 0.001% of wider ref pop)	**Negligible (low)**	0.035 (0.0009% of SE MU or 0.0001% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.1.7.2 *TTS from SEP and DEP*

289. The following assessment is based on the results of the modelling for both SEP and DEP as presented in **Section 10.6.1.1.2.2** above.

290. The maximum predicted impact range for TTS from a single strike of monopile or pin-pile with maximum hammer energy without any mitigation is up to 3.1km for minke whale and 1.3km for harbour porpoise for the monopile worst-case with a maximum hammer energy of 5,500kJ (**Table 10-25**). Therefore, there would be no overlap between the two Projects and the assessments for the SEP or DEP in isolation are appropriate. As a worst-case, the maximum number of marine mammals from each Project have been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-41**).

291. The magnitude of the potential impact for instantaneous TTS from a single strike of monopile or pin-pile with maximum hammer energy without any mitigation at SEP and DEP is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, with 1% or less of the relevant reference populations anticipated to be exposed to any temporary effect (**Table 10-41**).

292. The maximum predicted impact range for TTS from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile with maximum hammer energy without any mitigation is up to 19km for harbour porpoise and 25km for minke whale for the monopile worst-case with a maximum hammer energy of 5,500kJ (**Table 10-25**). Therefore, there could be overlap between the maximum potential impact ranges for the two Projects. The following assessments have been based on the worst-case of no overlap in the impact areas and the maximum number of marine mammals from each Project, to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-42**).

293. Further modelling and assessments for sequential piling at SEP followed by DEP are provided in **Section 10.6.1.1.7.3**, and for simultaneous piling at SEP and DEP are provided in **Section 10.6.1.1.7.4**. These have been modelled due to the potential for overlapping impact areas if either sequential or simultaneous piling were to be undertaken.

294. The magnitude of the potential impact for cumulative TTS without any mitigation at SEP and DEP is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale and low (low) to low (negligible) for grey seal and low (negligible) and negligible (negligible) harbour seal (**Table 10-42**).

Table 10-41: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS from Single Strike of Monopile or Pin-Pile at Maximum Hammer Energy without Mitigation, based on Worst-Case for SEP and DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour porpoise (VHF)	SEL_{ss} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP & DEP	16.3 (0.0047% of NS MU)	**Negligible**	12.5 (0.0036% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (224 dB re 1µPa) Impulsive	SEP & DEP	0.0006 (0.00003% of GNS MU; 0.00027 % CES MU)	**Negligible (negligible)**	0.0006 (0.00003% of GNS MU; 0.00027 % CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (224 dB re 1µPa) Impulsive	SEP & DEP	0.0001 (0.00000027% of CGNS MU)	**Negligible**	0.0001 (0.00000027% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (168 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.52 (0.0026% of CGNS MU)	**Negligible**	0.45 (0.0022% of CGNS MU)	**Negligible**
Grey seal (PW)	SEL_{ss} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.19 (0.0022% of SE MU pop or 0.00079% of wider ref pop)	**Negligible (negligible)**	0.18 (0.0021 % of SE MU or 0.00076 % of wider ref pop)	**Negligible (negligible)**
Harbour seal (PW)	SEL_{ss} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.04 (0.0011 % of SE MU or 0.0001% of wider ref pop)	**Negligible (negligible)**	0.04 (0.0011% of SE MU or 0.00013% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

Table 10-42: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS from Cumulative Exposure (SEL_{cum}) during Installation of Monopile or Pin-Pile without Mitigation, Based on Worst-Case for SEP and DEP

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ		Pin-pile with maximum hammer energy of 3,000kJ	
			Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour porpoise (VHF)	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP & DEP	2,157 (0.6% of NS MU)	**Negligible**	1,259 (0.4% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.02 (0.001% of GNS MU; 0.01% CES MU)	**Negligible (negligible)**	0.006 (0.0003% of GNS MU; 0.0027% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.005 (0.00001% of CGNS MU)	**Negligible**	0.0012 (0.000003% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (168 dB re 1µPa^{2}s) Impulsive	SEP & DEP	18.2 (0.09% of CGNS MU)	**Negligible**	9.7 (0.05% of CGNS MU)	**Negligible**
Grey seal (PW)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	282.0 (3.25% of SE MU or 1.17% of wider ref pop)	**Low (low)**	114.3 (1.324% of SE MU or 0.74% of wider ref pop)	**Low (negligible)**
Harbour seal (PW)	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	56.0 (1.49% of SE MU or 0.18% of wider ref pop)	**Low (negligible)**	22.5 (0.60% of SE MU or 0.07% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.1.7.3 *Sequential Piling at SEP and DEP*

295. The maximum predicted impact area for PTS from cumulative exposure (SEL_{cum}) during sequential piling if one monopile is installed at DEP, followed by a second monopile installed at SEP, in the same 24 hour period is up to 170km^2 for harbour porpoise and 320km^2 for minke whale for monopiles with a maximum hammer energy of 5,500kJ (**Table 10-26**).

296. An assessment of the maximum number of marine mammals for each species that could be at risk of PTS from cumulative exposure during installation of sequential piling of two monopiles at SEP or DEP or four pin-piles at SEP or DEP with maximum hammer energy without any mitigation, based on worst-case, is presented in **Table 10-32**.

297. The magnitude of the potential impact of PTS from sequential piling of monopiles at DEP followed by SEP, with a maximum hammer energy of 5,500kJ without any mitigation is assessed as medium for harbour porpoise, minke whale, grey seal and harbour seal (**Table 10-43**).

298. For bottlenose dolphin and white-beaked dolphin there is no additional effect when the monopiles at SEP and DEP are installed sequentially, as the individual ranges are small enough that the distant site does not produce an influencing additional exposure. Therefore, for bottlenose dolphin and white-beaked dolphin the assessments for PTS from cumulative exposure (**Table 10-43**) are appropriate and the magnitude is negligible.

299. The magnitude of the potential impact of TTS from sequential piling of monopiles at DEP followed by SEP, with a maximum hammer energy of 5,500kJ without any mitigation is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, and minke whale, and low (negligible) for grey seal and harbour seal (**Table 10-43**).

Table 10-43: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS or TTS from Cumulative Exposure (SEL_{cum}) During Sequential Installation of Monopile at DEP Followed by Monopile at SEP, without Mitigation, Based on Worst-Case for SEP and DEP

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopiles (16m diameter; 5,500kJ)	
				Maximum number of individuals (% of reference population)	Magnitude*
Harbour porpoise (VHF)	PTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (155 dB re 1µPa^{2}s) Impulsive	SEP & DEP	248 (0.07% of NS MU)	**Medium**
	TTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP & DEP	1,314 (0.38% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	PTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	no in-combination effect, impact areas do not overlap	**Negligible**
	TTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.021 (0.001% of GNS MU; 0.009% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)	PTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	no in-combination effect, impact areas do not overlap	**Negligible**

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopiles (16m diameter; 5,500kJ)	
				Maximum number of individuals (% of reference population)	Magnitude*
	TTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	0.0042 (0.00001% of CGNS MU)	**Negligible**
Minke whale (LF)	PTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP & DEP	3.2 (0.016% of CGNS MU)	**Medium**
	TTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (168 dB re 1µPa^{2}s) Impulsive	SEP & DEP	12 (0.006% of CGNS MU)	**Negligible**
Grey seal (PW)	PTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	13.23 (0.15% of SE MU or 0.056% of wider ref pop)	**Medium (medium)**
	TTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	272.0 (3.14% of SE MU or 1.13% of wider ref pop)	**Low (low)**
Harbour seal (PW)	PTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	3.4 (0.09% of SE MU or 0.011% of wider ref pop)	**Medium (medium)**

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopiles (16m diameter; 5,500kJ)	
				Maximum number of individuals (% of reference population)	Magnitude*
	TTS from cumulative SEL during sequential piling at SEP and DEP in same 24 hour period	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	69.9 (1.86% of SE MU or 0.23% of wider ref pop)	**Low (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.1.7.4 *Simultaneous Piling at SEP and DEP*

300. The maximum predicted impact area for PTS from cumulative exposure (SEL_{cum}) during simultaneous piling at SEP and DEP is up to 260km^2 for harbour porpoise and 420km^2 for minke whale for monopiles with a maximum hammer energy of 5,500kJ (**Table 10-27**).

301. An assessment of the maximum number of marine mammals for each species that could be at risk of PTS from cumulative exposure during simultaneous piling of monopiles or pin-piles at SEP and DEP with maximum hammer energy without any mitigation, based on worst-case, is presented in **Table 10-44**.

302. The magnitude of the potential impact of PTS from simultaneous piling of monopiles or pin-piles at SEP and DEP, with a maximum hammer energy, without any mitigation and based on worst-case, is assessed as medium for harbour porpoise, minke whale, grey seal and harbour seal **Table 10-44**).

303. For bottlenose dolphin and white-beaked dolphin there is no additional effect for simultaneous piling at SEP and DEP, as the individual ranges are small enough that the distant site does not produce an influencing additional exposure. Therefore, for bottlenose dolphin and white-beaked dolphin the assessments for PTS and TTS from cumulative exposure (**Table 10-43** and **Table 10-42**) are appropriate and the magnitude is negligible.

304. The magnitude of the potential impact of TTS from simultaneous piling of monopiles or pin-piles at SEP and DEP, with a maximum hammer energy, without any mitigation and based on worst-case, is assessed as negligible for harbour porpoise and minke whale, and low (low) for grey seal and low (negligible) harbour seal (**Table 10-44**).

Table 10-44: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of PTS or TTS from Cumulative Exposure (SEL_{cum}) During Simultaneous Piling at SEP and DEP, without Mitigation and Based on Worst-Case Scenarios

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile (16m diameter; 5,500kJ) at each site	Pin-pile (4m diameter; 3,000kJ) at each site	Pin-pile at SEP and monopile at DEP	Monopile at SEP and pin-pile at DEP
				Maximum number of individuals (% of reference population) and Magnitude*			
Harbour porpoise (VHF)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (155 dB re 1µPa^{2}s) Impulsive	SEP & DEP	380 (0.11% of NS MU) **Medium**	219 (0.06% of NS MU) **Medium**	307 (0.09% of NS MU) **Medium**	321 (0.09% of NS MU) **Medium**
	TTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (140 dB re 1µPa^{2}s) Impulsive	SEP & DEP	1,752 (0.51% of NS MU) **Negligible**	1,226 (0.35% of NS MU) **Negligible**	1,606 (0.46% of NS MU) **Negligible**	1,460 (0.42% of NS MU) **Negligible**
Bottlenose dolphin and white-beaked dolphin (HF)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (185 dB re 1µPa^{2}s) Impulsive	SEP & DEP	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap
	TTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (170 dB re 1µPa^{2}s) Impulsive	SEP & DEP	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap	impact areas do not overlap
Minke whale (LF)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (183 dB re 1µPa^{2}s) Impulsive	SEP & DEP	4.2 (0.021% of CGNS MU) **Medium**	2 (0.01% of CGNS MU) **Medium**	3.5 (0.017% of CGNS MU) **Medium**	2.9 (0.014% of CGNS MU) **Medium**

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile (16m diameter; 5,500kJ) at each site	Pin-pile (4m diameter; 3,000kJ) at each site	Pin-pile at SEP and monopile at DEP	Monopile at SEP and pin-pile at DEP
				Maximum number of individuals (% of reference population) and Magnitude*			
	TTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (168 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	16 (0.08 of CGNS MU) **Negligible**	10 (0.05 of CGNS MU) **Negligible**	14 (0.07 of CGNS MU) **Negligible**	12 (0.06 of CGNS MU) **Negligible**
Grey seal (PW)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (185 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	24.3 (0.28% of SE MU or 0.10% of wider ref pop) **Medium (medium)**	impact areas do not overlap	19.8 (0.23% of SE MU or 0.08% of wider ref pop) **Medium (medium)**	16.9 (0.20% of SE MU or 0.07% of wider ref pop) **Medium (medium)**
	TTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (170 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	382 (4.41% of SE MU or 1.58% of wider ref pop) **Low (low)**	242.6 (2.80% of SE MU or 1.01% of wider ref pop) **Low (low)**	330.8 (3.82% of SE MU or 1.37% of wider ref pop) **Low (low)**	301.4 (3.48% of SE MU or 1.25% of wider ref pop) **Low (low)**
Harbour seal (PW)	PTS from cumulative SEL during simultaneous piling	SEL_{cum} Weighted (185 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	6.2 (0.17% of SE MU or 0.02% of wider ref pop) **Medium (medium)**	impact areas do not overlap	5.1 (0.14% of SE MU or 0.02% of wider ref pop) **Medium (medium)**	4.3 (0.12% of SE MU or 0.01% of wider ref pop) **Medium (medium)**
	TTS from cumulative SEL during during simultaneous piling	SEL_{cum} Weighted (170 dB re $1\mu Pa^2s$) Impulsive	SEP & DEP	98.3 (2.62% of SE MU or 0.32% of wider ref pop) **Low (negligible)**	62.4 (1.66% of SE MU or 0.20% of wider ref pop) **Low (negligible)**	85.1 (2.27% of SE MU or 0.28% of wider ref pop) **Low (negligible)**	77.5 (2.07% of SE MU or 0.25% of wider ref pop) **Low (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for the wider population for seal species

10.6.1.1.7.5 *Impact Significance for SEP and DEP*

305. The impact significance for PTS and TTS, based on maximum number of marine mammals that could be impacted as a result of underwater noise during piling for SEP and DEP, if they are developed concurrently is summarised in **Table 10-45** and **Table 10-46**.

10.6.1.1.7.6 *Mitigation*

306. For SEP and DEP, there would be no further mitigation proposed than that already proposed for SEP or DEP in isolation, as outlined in **Sections 10.6.1.1.5** and **10.3.4**.

10.6.1.1.7.7 *Residual Impact Significance for SEP and DEP*

307. Taking into account the proposed mitigation, the residual impact for PTS and TTS during piling at SEP and DEP would be **minor adverse (not significant)** (**Table 10-45** and **Table 10-46**).

Table 10-45: Assessment of Impact Significance for PTS in Marine Mammals from Underwater Noise during Piling for SEP and DEP

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Harbour porpoise	PTS from single strike of starting hammer energy	SEP & DEP	High	Negligible for monopile and pin-pile	Minor adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	PTS during piling from cumulative exposure	SEP & DEP		Medium for monopile and pin-pile	Major adverse		**Minor adverse**
	PTS from sequential piling	SEP & DEP		Medium for monopiles	Major adverse		**Minor adverse**
	PTS from simultaneous piling	SEP & DEP		Medium for monopiles and pin-piles	Major adverse		**Minor adverse**
Bottlenose dolphin	PTS from single strike of starting hammer energy	SEP & DEP	High	Negligible for monopile and pin-pile	Minor adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	PTS during piling from cumulative exposure	SEP & DEP		Negligible (low) for monopile and pin-pile	Minor (moderate) adverse		**Minor adverse**
	PTS from sequential piling	SEP & DEP		Negligible for monopiles	Minor adverse		**Minor adverse**
	PTS from simultaneous piling	SEP & DEP		Negligible for monopiles and pin-piles	Minor adverse		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
White-beaked dolphin	PTS from single strike of starting hammer energy	SEP & DEP	High	Negligible for monopile and pin-pile	Minor adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	PTS during piling from cumulative exposure	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	PTS from sequential piling	SEP & DEP		Negligible for monopiles	Minor adverse		**Minor adverse**
	PTS from simultaneous piling	SEP & DEP		Negligible for monopiles and pin-piles	Minor adverse		**Minor adverse**
Minke whale	PTS from single strike of starting hammer energy	SEP & DEP	High	Negligible for monopile and pin-pile	Minor adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	PTS during piling from cumulative exposure	SEP & DEP		Medium for monopile Low for pin-pile	Major adverse for monopile Moderate adverse for pin-pile		**Minor adverse**
	PTS from sequential piling	SEP & DEP		Medium for monopiles	Major adverse		**Minor adverse**
	PTS from simultaneous piling	SEP & DEP		Medium for monopiles	Major adverse for monopiles		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
				Low for pin-piles	Moderate adverse for pin-piles		
Grey seal	PTS from single strike of starting hammer energy	SEP & DEP	High	Negligible (negligible) for monopile and pin-pile	Minor (minor) adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP & DEP		Negligible (negligible) for monopile and pin-pile	Minor (minor) adverse		**Minor adverse**
	PTS during piling from cumulative exposure	SEP & DEP		Medium (low) for monopile Low (negligible) for pin-pile	Major (moderate) adverse for monopile Moderate (minor) adverse for pin-pile		**Minor adverse**
	PTS from sequential piling	SEP & DEP		Medium (medium) for monopiles	Major (major) adverse		**Minor adverse**
	PTS from simultaneous piling	SEP & DEP		Medium (medium) for monopiles and pin-piles	Major (major) adverse		**Minor adverse**
Harbour seal	PTS from single strike of starting hammer energy	SEP & DEP	High	Negligible (negligible) for monopile and pin-pile	Minor (minor) adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	SEP & DEP		Negligible (negligible) for monopile and pin-pile	Minor (minor) adverse		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	PTS during piling from cumulative exposure	SEP & DEP		Medium (low) for monopile Negligible (negligible) for pin-pile	Major (minor) adverse for monopile Minor (minor) adverse for pin-pile		**Minor adverse**
	PTS from sequential piling	SEP & DEP		Medium (medium) for monopiles	Major (major) adverse		**Minor adverse**
	PTS from simultaneous piling	SEP & DEP		Medium (medium) for monopiles and pin-piles	Major (major) adverse		**Minor adverse**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

Table 10-46: Assessment of Impact Significance for TTS in Marine Mammals from Underwater Noise During Piling for SEP and DEP

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Harbour porpoise	TTS from single strike of maximum hammer energy	SEP & DEP	Medium	Negligible for monopile and pin-pile	Mino adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	TTS from sequential piling	SEP & DEP		Negligible for monopiles	Minor adverse		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	TTS from simultaneous piling	SEP & DEP		Negligible for monopiles and pin-piles	Minor adverse		**Minor adverse**
Bottlenose dolphin	TTS from single strike of maximum hammer energy	SEP & DEP	Medium	Negligible for monopile and pin-pile	Minor adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	TTS from sequential piling	SEP & DEP		Negligible for monopiles	Minor adverse		**Minor adverse**
	TTS from simultaneous piling	SEP & DEP		Negligible for monopiles and pin-piles	Minor adverse		**Minor adverse**
White-beaked dolphin	TTS from single strike of maximum hammer energy	SEP & DEP	Medium	Negligible for monopile and pin-pile	Mino adverse r	MMMP (**Section 10.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	TTS from sequential piling	SEP & DEP		Negligible for monopiles	Minor adverse		**Minor adverse**
	TTS from simultaneous piling	SEP & DEP		Negligible for monopiles and pin-piles	Minor adverse		**Minor adverse**
Minke whale	TTS from single strike of maximum hammer energy	SEP & DEP	Medium	Negligible for monopile and pin-pile	Minor adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	SEP & DEP		Negligible for monopile and pin-pile	Minor adverse		**Minor adverse**
	TTS from sequential piling	SEP & DEP		Negligible for monopiles	Minor adverse		**Minor adverse**
	TTS from simultaneous piling	SEP & DEP		Negligible for monopiles and pin-piles	Minor adverse		**Minor adverse**
Grey seal	TTS from single strike of maximum hammer energy	SEP & DEP	Medium	Negligible (negligible) for monopile and pin-pile	Minor (minor) adverse	MMMP (**Section 10.3.4**)	**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	TTS during piling from cumulative exposure	SEP & DEP		Low (low) for monopile and Low (negligible) pin-pile	Minor (minor) adverse		**Minor adverse**
	TTS from sequential piling	SEP & DEP		Low (low) for monopiles	Minor (minor) adverse		**Minor adverse**
	TTS from simultaneous piling	SEP & DEP		Low (low) for monopiles and pin-piles	Minor (minor) adverse		**Minor adverse**
Harbour seal	TTS from single strike of maximum hammer energy	SEP & DEP	Medium	Negligible (negligible) for monopile and pin-pile	Minor (minor) adverse	MMMP (**Section 10.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	SEP & DEP		Low (negligible) for monopile and Negligible (negligible) pin-pile	Minor (minor) adverse r		**Minor adverse**
	TTS from sequential piling	SEP & DEP		Low (negligible) for monopiles	Minor (minor) adverse		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
	TTS from simultaneous piling	SEP & DEP		Low (negligible) for monopiles and pin-piles	Minor (minor) adverse		**Minor adverse**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and the wider population for seal species

10.6.1.2 Impact 2: Disturbance from Underwater Noise Associated with Piling Activities

308. There are currently no agreed thresholds or criteria for the behavioural response and disturbance of marine mammals, therefore it is not possible to conduct underwater noise modelling to predict impact ranges.

309. For marine mammals a fleeing response is assumed to occur at the same noise levels as TTS. Therefore, the potential impact range and areas for TTS presented in **Table 10-25**, with the estimated number and percentage of reference populations in **Section 10.6.1.1.3** providing an indication of possible fleeing response.

10.6.1.2.1 Sensitivity

310. All marine mammal species are assessed as having medium sensitivity disturbance (**Table 10-20**).

10.6.1.2.2 Magnitude for SEP or DEP in Isolation

10.6.1.2.2.1 *Disturbance During ADD Activation*

311. The assessments of the potential disturbance during any ADD activation is indicative only, as the final requirements for mitigation in the MMMP will be determined prior to construction.

312. As outlined in **Section 10.3.4**, mitigation to reduce the risk of PTS could include activation of ADDs for a minimum of 10 minutes or up to 20 minutes prior to the soft-start commencing.

313. During 10 minute ADD activation, it is predicted that harbour porpoise, bottlenose dolphin, white-beaked dolphin, grey seal and harbour seal would move at least 0.9km from the ADD location (based on a precautionary marine mammal swimming speed of 1.5m/s; Otani *et al*., 2000), resulting in a potential disturbance area of 2.54km^2. Minke whale would move at least 1.95km from the ADD location during 10 minute activation (based on a precautionary marine mammal swimming speed of 3.25m/s; Blix and Folkow, 1995), resulting in a potential disturbance area of 11.95km^2.

314. The magnitude of the potential impact is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, with 1% or less of the relevant reference populations anticipated to be temporarily disturbed (**Table 10-47**).

315. During 20 minute ADD activation, harbour porpoise, bottlenose dolphin, white-beaked dolphin, grey seal and harbour seal would move at least 1.8km from the ADD location (based on a precautionary marine mammal swimming speed of 1.5m/s; Otani *et al*., 2000), resulting in a potential disturbance area of 10.18km^2. Minke whale would move at least 3.9km from the ADD location during 10 minute activation (based on a precautionary marine mammal swimming speed of 3.25m/s; Blix and Folkow, 1995), resulting in a potential disturbance area of 47.78km^2.

316. The magnitude of the potential impact is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, with 1% or less of the relevant reference populations anticipated to be temporarily disturbed (**Table 10-47**).

317. The ADD activation for 10 or 20 minutes would ensure marine mammals are beyond the maximum impact range for instantaneous PTS from single strike of the starting hammer energy or maximum hammer energy for monopiles and pin-piles (**Table 10-24**). ADD activation for 10 or 20 minutes prior to the soft-start would also reduce the number of marine mammals at risk of PTS from cumulative exposure.

318. Maximum total ADD activation time to install all piles, based on worst-case scenarios is as follows:

- SEP:
  - 23 monopiles = 4 hours for 10 minute ADD activation prior to each soft-start (or 8 hours for 20 minute ADD activation); or
  - 92 pin-piles, however, anticipated 4 pin-piles for jacket foundation of each wind turbine to be installed in sequence, therefore ADDs only activated once per foundation (23 foundations) = 4 hours for 10 minute ADD activation (or 8 hours of 20 minute ADD activation); and
  - eight pin-piles for offshore sub-station, anticipated 4 pin-piles would be installed in sequence and ADDs activated prior to each group of 4 pin-piles = 20 minutes for 10 minute ADD activation (or 40 minutes for 20 minute activation).
- DEP:
  - 30 monopiles = 5 hours for 10 minute ADD activation prior to each soft-start (or 10 hours for 20 minute ADD activation); or
  - 120 pin-piles, however, anticipated 4 pin-piles for jacket foundation of each wind turbine to be installed in sequence, therefore ADDs only activated per foundation (30 foundations) = 5 hours for 10 minute ADD activation (or 10 hours for 20 minute ADD activation); and
  - eight pin-piles for offshore sub-station, anticipated 4 pin-piles would be installed in sequence and ADDs activated prior to each group of 4 pin-piles = 20 minutes for 10 minute ADD activation (or 40 minutes for 20 minute activation).

Table 10-47: Maximum Number of Individuals (and % of Reference Population) that Could be at Disturbed during 10 or 20 Minute ADD Activation at SEP and DEP Prior to Piling

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 20 minute ADD activation	
		Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour porpoise	SEP	1.6 (0.00046% of NS MU)	**Negligible**	6.41 (0.0019% of NS MU)	**Negligible**
	DEP	6.17 (0.0018% of NS MU)	**Negligible**	24.74 (0.0071% of NS MU)	**Negligible**
Bottlenose dolphin	SEP	0.08 (0.0037 of GNS MU; 0.034% CES MU)	**Negligible (negligible)**	0.30 (0.015 of GNS MU; 0.27% CES MU)	**Negligible (negligible)**
	DEP	0.08 (0.0037% of GNS MU; 0.034% CES MU)	**Negligible (negligible)**	0.30 (0.015% of GNS MU; 0.27% CES MU)	**Negligible (negligible)**
White-beaked dolphin	SEP	0.02 (0.000035% of CGNS MU)	**Negligible**	0.06 (0.00014% of CGNS MU)	**Negligible**
	DEP	0.02 (0.000035% of CGNS MU)	**Negligible**	0.06 (0.00014% of CGNS MU)	**Negligible**
Minke whale	SEP	0.12 (0.00059% of CGNS MU)	**Negligible**	0.48 (0.0024% of CGNS MU)	**Negligible**
	DEP	0.12 (0.00059% of CGNS MU)	**Negligible**	0.48 (0.0024% of CGNS MU)	**Negligible**
Grey seal	SEP	2.17 (0.025% of SE MU or 0.009% of wider ref pop)	**Negligible (negligible)**	8.68 (0.10% of SE MU or 0.036% of wider ref pop)	**Negligible (negligible)**
	DEP	1.88 (0.0022% of SE MU or 0.0078% of wider ref pop)	**Negligible (negligible)**	7.52 (0.087% of SE MU or 0.031% of wider ref pop)	**Negligible (negligible)**

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 20 minute ADD activation	
		Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour seal	SEP	0.70 (0.019% of SE MU or 0.0023% of wider ref pop)	**Negligible (negligible)**	2.79 (0.074% of SE MU or 0.0091% of wider ref pop)	**Negligible (negligible)**
	DEP	0.20 (0.005% of SE MU or 0.0007% of wider ref pop)	**Negligible (negligible)**	0.81 (0.022% of SE MU or 0.0027% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.2.2.2 *Disturbance of Marine Mammals from Piling Activities*

319. The Gescha 2 study (Effects of noise-mitigated offshore pile driving on harbour porpoise abundance in the German Bight 2014-2016; Rose *et al.,* 2019) analysed the impact from the construction of 11 offshore wind farms in Germany on harbour porpoise in the German North Sea and adjacent Dutch waters, from 2014 to 2016. This study also included analysis of previously completed surveys within the Gescha 1 study, which studied the impact from the construction of eight German offshore wind farms from 2009 to 2013. The study involved the deployment of Cetacean Porpoise Detectors (CPODs) and digital aerial surveys in order to monitor harbour porpoise presence and abundance during the construction of these Projects, alongside the measurement of noise levels associated with piling at both 750m and 1,500m from source. The piling activities monitored in this study were mostly undertaken with noise abatement systems in order to reduce disturbance impacts on harbour porpoise.

320. The Gescha 2 study (Rose *et al.,* 2019) found that noise levels recorded during piling were predominantly below the limit of 160dB at 750m (the German Federal Maritime and Hydrographic Agency (BSH) mandatory noise limit for German waters), and were 9dB lower than the noise levels recorded during the Gescha 1 study, due to advancement in noise abatement methods. The study also found that noise levels were 15dB less using noise abatement than for noise levels from unmitigated piling. It was expected that the improved efficiency of noise abatement for piling, and therefore the overall reduced noise levels, would lead to a reduction in disturbance impacts on harbour porpoise, however, this was not the case.

321. The range of disturbance impact of harbour porpoise to piling within the Gescha 2 study (Rose *et al.,* 2019) was 17km (Standard Deviation (SD) 15-19km), and the duration of disturbance (i.e. the time it took for harbour porpoise to return to baseline levels) was between 28 and 48 hours, as shown by CPOD data, and the impact range was found to be between 11.4 and 19.5km based on aerial data (at least 12 hours after piling) (Rose *et al.,* 2019). These results are similar to those reported in the Gescha 1 study (with a disturbance range of 15km (SD 14-16km) and duration of disturbance of 25 to 30 hours), which showed higher piling noise levels (Rose *et al.,* 2019). This suggests that the noise level of the piling is not the only determining factor when discussing the potential for disturbance.

322. Analysis of the CPOD data collected in the Gescha 2 study (Rose *et al.,* 2019) indicated that there is no correlation between noise levels received and the range at which harbour porpoise become disturbed, for noise that is below 165dB at 750m from source. This could be due to individuals maintaining a certain distance from noisy activities, irrespective of the actual noise levels, provided that noise level is above a certain threshold for that individual (Rose *et al.,* 2019). It should be noted however that this study recorded noise levels up to 20kHz only, and therefore there may be higher frequency noise associated with piling that these results do not take into account.

323. A reduction in harbour porpoise presence was seen for all wind farms, for both the Gescha 1 and 2 studies, up to 24 hours prior to any noisy activity occurring, which could be due to the increased vessel activity at the pile location prior to piling taking place (Rose *et al.,* 2019). However, the displacement during pile driving was noted to be larger than for the period prior to piling. In Gescha 2, a decrease in detection rates was found in the three hours prior to piling activity at a distance up to 15km from the piling location, with no difference in detection rates observed at a distance of 25km (Rose *et al.,* 2019).

324. During the piling campaign at Beatrice Offshore Wind Farm in 2017, an array of underwater noise recorders were deployed to determine noise levels associated with the piling campaign, alongside a separate array of acoustic recorders to monitor the presence of harbour porpoise during piling (Graham *et al*., 2019). Piling at Beatrice comprised of four pin piles at each turbine or sub-station structure, with a 2.2m diameter and a hammer energy of 2,400kJ. The sound levels recorded were then used to determine the sound level at each of the acoustic recorders.

325. This study assumed that a change in the number of harbour porpoise present at each location was assumed based on the number of positive identifications of porpoise vocalisations (Graham *et al*., 2019). These two data sets (the harbour porpoise presence and the perceived sound level at each location) were then analysed in order to determine any disturbance impacts as a result of the piling activities and at what sound level impacts are observed. Harbour porpoise presence was measured over a period of 48 hours prior to piling being undertaken and continued following the cessation of piling to ensure that any change in porpoise detections could be observed (a total period of 96 hours was recorded for each included piling event, with a total of 17 piling events included within this analysis) (Graham *et al*., 2019).

326. The results of the study at Beatrice Offshore Wind Farm (Graham *et al*., 2019) found that at the start of the piling campaign, there was a 50% chance of a harbour porpoise responding to piling activity, within a distance of 7.4km, during the 24 hours following piling. At the middle of the piling campaign, this 50% response distance had reduced to 4.0km, and by the end of the piling had reduced further to 1.3km. The response to audiogram-weighted SEL noise levels reduced over time, with a 50% response being observed at sound levels of 54.1dB re 1 μPa^2s at the first location, during the first 24 hours following piling, increasing to 60.0dB re 1 1μPa^2s during the middle of the campaign, and to 70.9dB re 1 μPa^2s by the end of the piling activities. Similarly, the response to unweighted SEL noise levels reduced over time, with a 50% response being observed at sound levels of 144.3dB re 1 μPa^2s at the first location, during the first 24 hours following piling, increasing to 150.0dB re 1 1μPa^2s during the middle of the campaign, and to 160.4dB re 1 μPa^2s by the end of the piling activities (Graham *et al*., 2019).

327. Additional comparisons were made through this study (Graham *et al*., 2019) to assess the difference in harbour porpoise presence where ADDs were used and where they were not, as well as relating to the number of vessels present within 1km of the piling site. A significant difference was observed in the presence of harbour porpoise where ADDs were used compared to where they were not, but only in the short-term (less than 12 hours following piling), and there was no significant difference when considering a longer time period from piling. With 50% response distances for pile locations with ADD use recorded as up to 5.3km (during 12 hours after piling), and up to 0.7km with no ADD in use, in the 12 hours following piling. It should be noted however that only two locations used in the analysis had ADD use, and therefore the sample number in this analysis is small (Graham *et al*., 2019).

328. Overall, this study has shown that the response of harbour porpoise to piling activities reduces over time, suggesting a habituation effect occurred. In addition, there is some indication that the use of ADDs does reduce the presence of harbour porpoise in the short term. In addition, higher levels of vessel activity increased the potential for a response by harbour porpoise. Harbour porpoise response to piling activity was best explained by the distance from the piling location, or from the received noise levels (taking into account weighting for their hearing) (Graham *et al*., 2019).

10.6.1.2.2.3 *Disturbance / Displacement of Harbour Porpoise based on EDRs for Piling*

329. The current advice from the SNCBs is that a potential disturbance range (EDR) of 26km (potential disturbance area of up to 2,124km^2) around piling locations for monopiles without noise abatement and 15km (potential disturbance area of up to 707km^2) for pin-piles with and without noise abatement is used to assess the area that harbour porpoise may be disturbed in the SNS SAC (JNCC *et al*., 2020). SEP and DEP are located approximately 14km and 25.6km, respectively, from the SNS SAC, therefore EDR approach has been used for the EIA as well as the **RIAA** (document reference 5.4).

330. Not all harbour porpoise within these potential disturbance areas based on EDRs will be disturbed, however as worst-case scenario 100% disturbance of harbour porpoise in the areas has been assumed.

331. The estimated number of harbour porpoise and percentage of the North Sea MU reference population that could be disturbed as a result of underwater noise during piling at SEP or DEP is presented in **Table 10-48**.

332. The magnitude of the potential impact is assessed as low for 26km EDR at DEP, with 1.5% of NS MU anticipated to be affected or negligible for 26km EDR at SEP or 15km EDR at SEP or DEP, with 1% or less of NS MU anticipated to be temporarily disturbed (**Table 10-48**).

333. Further assessments in relation to the SNS SAC are provided in the **RIAA** (document reference 5.4).

Table 10-48: Maximum Number of Harbour Porpoise (and % of Reference Population) that Could be at Disturbed Dduring Piling at SEP or DEP in Isolation Based on EDRs

Species	Location	26km EDR (2,124km^2) for monopile		15km EDR (707km^2) for pin-pile	
		Maximum number of individuals (% of reference population)	Magnitude (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Harbour porpoise	SEP	1,338 (0.39% of NS MU)	**Negligible**	445 (0.13% of NS MU)	**Negligible**
	DEP	5,161 (1.49% of NS MU)	**Low**	1,718 (0.5% of NS MU)	**Negligible**

10.6.1.2.2.4 *Possible Behavioural Response in Harbour Porpoise*

334. The range of possible behavioural reactions that may occur as a result of exposure to noise include orientation or attraction to a noise source, increased alertness, modification of characteristics of their own sounds, cessation of feeding or social interaction, alteration of movement / diving behaviour, temporary or permanent habitat abandonment and, in severe cases, panic, or stranding, sometimes resulting in injury or death (Southall *et al*., 2007).

335. The sensitivity of harbour porpoise to this type of effect is considered to be medium.

336. Based on the unweighted Lucke *et al*. (2009) criteria (unweighted SEL of 145 dB re 1 µPa^{2}s), the estimated maximum range which could result in a possible behavioural response by harbour porpoise is estimated to be up to 25km and 23km for the maximum hammer energy of the monopile (5,500kJ) and pin-pile (3,000kJ), respectively (**Table 10-28:**).

337. It should be noted that a behavioural response does not mean that the individuals will avoid the area. In addition, the maximum predicted ranges for behavioural response are based on the maximum hammer energy at the worst-case location for noise propagation. In reality, the duration of any piling at maximum energy would be less (if this energy is reached at all) and noise propagation would vary considerably with location (i.e. be less than the worst-case).

338. The study of harbour porpoise at Horns Rev (Brandt *et al*., 2011), found that at closer distances (2.5 to 4.8km) there was 100% avoidance. However, this proportion decreased significantly moving away from the pile driving activity, such that at distances of 10.1 to 17.8km, avoidance occurred in 32 to 49% of the population and at 21.2km, the abundance reduced by just 2%. This suggests that an assumption of behavioural displacement of all individuals is unrealistic and that in reality not all individuals would move out of the area. To take this into account, the proportion of harbour porpoise that may show a behavioural response has been calculated by assuming 75% or 50% could respond. This approach is consistent with the response at distances of 10.1 to 17.8km indicated by the Brandt *et al*. (2011) study (**Plate 10-4**), at which approximately 50% could respond at the maximum predicted level as suggested by the dose-response curve in Thompson *et al*. (2013).

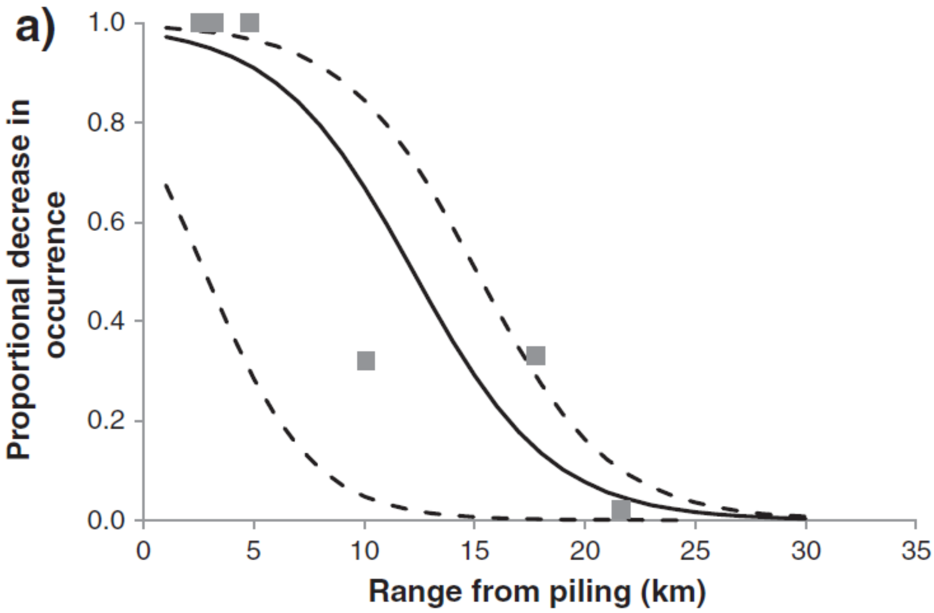

Plate 10-4: Predicted Harbour Porpoise Dose Response Curve based on the Monitoring of Piling Activity at Horns Rev II (based on Data from Brandt et al., 2011, as Presented in Thompson et al. (2013))

339. The estimated number of harbour porpoise that could exhibit a possible behavioural response, based on the modelled results of a single strike of the maximum monopile and pin-pile hammer energy (under the Lucke *et al*. (2009) unweighted criteria (unweighted SEL of 145 dB re 1 µPa^{2}s)), has been calculated for either 100%, 75%, or 50% of all individuals responding (**Table 10-49**). The magnitude of the potential effect is assessed as negligible with less than 1% of the reference population anticipated to respond.

Table 10-49: Estimated Number of Harbour Porpoise (and % of Reference Population) that Could Exhibit a Possible Behavioural Response at SEP and DEP (Based on 100%, 75% and 50% of all Individuals in Maximum Area of Impact)

Potential Impact	Location	100% of individuals		75% of individuals		50% of individuals	
		Maximum number of individuals (% of reference population)	Magnitude (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Possible behavioural response of harbour porpoise - single strike of the maximum monopile hammer energy (5,500kJ)	SEP	617 (0.18% of NS MU)	**Negligible**	463 (0.13% of NS MU)	**Negligible**	309 (0.089% of NS MU)	**Negligible**
	DEP	3,402 (0.98% of NS MU)	**Negligible**	2,552 (0.74% of NS MU)	**Negligible**	1,701 (0.49% of NS MU)	**Negligible**
Possible behavioural response of harbour porpoise - single strike of the maximum pin-pile hammer energy (3,000kJ)	SEP	529 (0.15% of NS MU)	**Negligible**	397 (0.11% of NS MU)	**Negligible**	265 (0.076% of NS MU)	**Negligible**
	DEP	2,916 (0.84% of NS MU)	**Negligible**	2,187 (0.63% of NS MU)	**Negligible**	1,458 (0.42% of NS MU)	**Negligible**

10.6.1.2.2.5 *Duration of Piling*

340. The total duration of the installation campaign for the wind turbines is expected to be a maximum of three months for each Project (**Table 10-1**). This will include transit of the foundation components in batches to the site(s) and foundation installation, including any piling.

341. Piling would not be constant during the piling phases and construction periods. There will be gaps between the installations of individual piles, and if installed in groups there could be time periods when piling is not taking place as piles are brought out to the site. There will also be potential delays for weather or other technical issues.

342. **Table 10-50** summarises the worst-case scenarios for the duration of piling at each site based on the maximum number of wind turbines, number of piles and piling duration to install each pile, including soft-start, ramp-up and ADD activation.

Table 10-50: Maximum Duration of Piling at SEP and DEP, Based on Worst-Case Scenarios, Including Soft-Start, Ramp-Up and ADD Activation

Site	Parameter	Number of piles	Maximum active piling time per pile	Total piling time	ADD activation	Total duration
SEP	Up to 23 wind turbines	Up to 23 monopiles	4 hours including soft-start and ramp-up	Up to 92 hours (4 days) for 23 monopiles	4 hours for 10 minute ADD activation (8 hours for 20 minute ADD activation)	Up to 96 hours (4 days) with 10 minute ADD activation for 23 monopiles (up to 100 hours (4.2 days) with 20 minute ADD activation)
		Up to 92 pin-piles for jackets	3 hours including soft-start and ramp-up	Up to 276 hours (11.5 days) for 92 pin-piles	4 hours for 10 minute ADD activation (8 hours of 20 minute ADD activation) prior to installation of 4 pin-piles	Up to 280 hours (12 days) with 10 minute ADD activation for 23 foundations (up to 284 hours (12 days) with 20 minute ADD activation)
	One OSP	8 pin-piles	3 hours including soft-start and ramp-up	24 hours (one day) for 8 pin-piles	20 minutes for 10 minute ADD activation (40 minutes for 20 minute ADD activation) prior to installation of 4 pin-piles	Up to 24.5 hours with 10 minute ADD activation (up to 25 hours with 20 minute ADD activation)
	Piling of up to 23 monopiles and one OSP (including soft-start, ramp-up and ADD activation) = up to 120.5 hours (5 days) with 10 minute activation (125 hours (5.2 days) with 20 minute ADD activation); or					
	Piling of up to 92 pin-piles and one OSP (including soft-start, ramp-up and ADD activation) = up to 304.5 hours (13 days) with 10 minute ADD activation (309 hours (13 days) with 20 minute ADD activation)					
DEP	Up to 30 wind turbines	Up to 30 monopiles	4 hours including soft-start and ramp-up	Up to 120 hours (5 days) for 30 monopiles	5 hours for 10 minute ADD activation (10 hours for 20	Up to 125 hours (5.2 days) with 10 minute ADD activation for 30 monopiles (up to 130 hours (up to 5.4

Site	Parameter	Number of piles	Maximum active piling time per pile	Total piling time	ADD activation	Total duration
					minutes ADD activation)	days) with 20 minute ADD activation)
		Up to 120 pin-piles for jackets	3 hours including soft-start and ramp-up	Up to 360 hours (15 days) for 120 pin-piles	5 hours for 10 minute ADD activation (up to 10 hours for 20 minute ADD activation) prior to installation of 4 pin-piles	Up to 365 hours (15.2 days) with 10 minute ADD activation for 30 foundations (up to 370 hours (15.4 days) with 20 minute ADD activation)
	One OSP	8 pin-piles	3 hours including soft-start and ramp-up	24 hours (one day) for 8 pin-piles	20 minutes for 10 minute ADD activation (40 minutes for 20 minute activation) prior to installation of 4 pin-piles	Up to 24.5 hours with 10 minute ADD activation (up to 25 hours with 20 minute ADD activation)
	Piling of up to 30 monopiles and one OSP (including soft-start, ramp-up and ADD activation) = up to 149.5 hours (6.2 days) with 10 minute activation (155 hours (6.5 days) with 20 minute ADD activation); or					
	Piling of up to 120 pin-piles and one OSP (including soft-start, ramp-up and ADD activation) = up to 389.5 hours (16.2 days) with 10 minute ADD activation (395 hours (16.5 days) with 20 minute ADD activation)					

343. The duration of piling is based on a worst-case scenario and a very precautionary approach, and as has been shown at other offshore wind farms, the duration used in the impact assessment can be overestimated. For example, for the installation of monopile foundations at DOW the impact assessment was based on an estimated piling period of 93 days, time to install each monopile was estimated to be up to 4.5 hours and the estimated duration of active piling was 301.5 hours (approximately 13 days). However, the actual total duration of active piling to install the 67 monopiles was 65 hours (approximately 3 days) with the average time for installation per monopile of 71 minutes (Dudgeon Offshore Wind Farm (DOWL), 2016). Therefore, the actual piling duration was approximately 21% of the predicated maximum piling duration. The piling duration to install the individual monopiles at DOW varied considerably for each location and the worst-case scenario of up to 4.5 hours to install a pile was an accurate assessment of the actual maximum duration (4.35 hours), however the majority of piles were installed in much shorter duration. At DOW the time intervals between the installations of individual monopiles, not including the intervals between groups of monopiles was on average approximately 23 hours. Monopiles were installed in groups of up to three, due to the capacity of the piling vessel, which meant that it could only carry three monopiles and three transition pieces before returning to port to collect the next three monopiles. The intervals between groups of monopiles being installed ranged from approximately 2.5 days to 11 days with an average of approximately four days between the 22 groups of three monopiles (DOWL, 2016).

344. Similar results were also observed for the Beatrice Offshore Wind Farm, where within the ES it was estimated that each pin-pile would require 5 hours of active piling time. However, during construction, the total duration of piling ranged from 19 minutes to 2 hours and 45 minutes, with an average duration of 1 hour and 15 minutes per pile (Beatrice Offshore Wind Farm Ltd, 2018).

345. The duration of the exclusion could last up to three days following a single piling event if the animal is close to the source. Data presented by Brandt *et al*. (2009, 2011) indicated that harbour porpoise would completely leave the area (indicated by the duration of waiting time between porpoise detections after first piling) for a median time of 16.6 hours and a maximum of 74.2 hours within 0.5-6km of the noise source. Waiting times did not return to ‘normal’ until 22.7 hours after piling. At distances of greater than approximately 9km from the noise source there was a much shorter duration of effect; with waiting times returning to ‘normal’ between one and 2.6 hours after piling ceased. However, at 18-25km there was still a marked effect. Porpoise activity (measured by the number of minutes per hour in which porpoise were detected expressed as porpoise positive minutes) was significantly lower within approximately 3km of the noise source for 40 hours after piling.

346. A study on the effects of offshore wind farm construction on harbour porpoise within the German North Sea between 2009 and 2013 (Brandt *et al*., 2016), indicated that the duration of effect after piling was about 20-31 hours within close vicinity of the construction site (up to 2km) and decreased with increasing distance. The study also observed significant decreases in porpoise detections prior to piling at distances of up to 10km, which is thought to relate to increased shipping activity during preparation works. The study concluded that although there were adverse short-term effects (1-2 days in duration) of construction on acoustic porpoise detections, there is currently no indication that harbour porpoises within the German Bight were negatively affected by wind farm construction at the population level (Brandt *et al*., 2016). It is acknowledged that some of the projects included in this study used noise mitigation techniques.

347. The duration of any potential displacement effect will differ depending on the distance of the individual from the piling activity and the noise level the animal is exposed to. Furthermore, for those individuals that are distant from the activity that do not respond, and therefore are not affected, will continue with their normal behaviour that may involve approaching the wind farm area.

348. Nabe-Nielsen *et al*. (2018) developed the DEPONS (Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea) model to simulate individual animal's movements, energetics and survival for assessing population consequences of sub-lethal behavioural effects. The model was used to assess the impact of offshore wind farm construction noise on the North Sea harbour porpoise population, based on the acoustic monitoring of harbour porpoise during construction of the Dutch Gemini offshore wind farm. Local population densities around the Gemini wind farm recovered 2–6 hours after piling, similar recovery rates were obtained in the model. The model indicated that, assuming noise influenced porpoise movements as observed at the Gemini wind farm, the North Sea harbour porpoise population was not affected by construction of 65 wind farms, as required to meet the EU renewable energy target (Nabe-Nielsen *et al*., 2018).

349. The DEPONS model determined that at the North Sea scale, population dynamics were indistinguishable from those in the noise-free baseline scenario when porpoises reacted to noise up to 8.9km from the construction sites, as at the Gemini wind farm. Underwater noise from offshore wind farm construction noise only influenced population dynamics in the North Sea when simulated animals were assumed to respond at distances exceeding 20–50km from the wind farms. Indicating that in these scenarios, the population effect of noise was more strongly related to the distance at which animals reacted to noise (Nabe-Nielsen *et al*., 2018). The duration of any potential displacement effect will differ depending on the distance of the individual from the piling activity and the noise level to which the animal is exposed.

10.6.1.2.3 Impact Significance and Residual Impact

10.6.1.2.3.1 *Impact Significance for Disturbance During Proposed ADD Activation*

350. Taking into account the medium sensitivity (**Table 10-20**) and the potential magnitude of the temporary impact (e.g. number of individuals as a percentage of the reference population), the impact significance for disturbance during ADD activation has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-51**).

351. The use of ADDs as mitigation to reduce the risk of auditory injury (PTS) to marine mammals will be developed for the MMMP prior to construction. ADD activation duration would be determined to reduce the risk of auditory injury (PTS) without causing any significant or unnecessary disturbance.

352. The assessment of impact significance takes into account the duration of ADD activation for SEP and DEP, as outlined in **Section 10.6.1.2.2.5**.

Table 10-51: Assessment of Impact Significance for Disturbance from ADD Activation

Species	Impact	Location	Sensitivity	Magnitude	Significance
Harbour porpoise	ADD activation	SEP	Medium	Negligible	**Minor adverse**
		DEP		Negligible	**Minor adverse**
Bottlenose dolphin	ADD activation	SEP	Medium	Negligible	**Minor adverse**
		DEP		Negligible	**Minor adverse**
White-beaked dolphin	ADD activation	SEP	Medium	Negligible	**Minor adverse**
		DEP		Negligible	**Minor adverse**
Minke whale	ADD activation	SEP	Medium	Negligible	**Minor adverse**
		DEP		Negligible	**Minor adverse**
Grey seal	ADD activation	SEP	Medium	Negligible	**Minor adverse**
		DEP		Negligible	**Minor adverse**
Harbour seal	ADD activation	SEP	Medium	Negligible	**Minor adverse**
		DEP		Negligible	**Minor adverse**

10.6.1.2.3.2 *Impact Significance and Residual Impact for Disturbance / Displacement of Harbour Porpoise based on EDRs for Piling*

353. Taking into account the medium sensitivity (**Table 10-20**) and the potential magnitude of the temporary impact, the impact significance for any disturbance in harbour porpoise based on the EDRs for piling has been assessed as **minor adverse (not significant)** (**Table 10-52**).

354. The assessment of impact significance takes into account the duration of active piling for SEP and DEP, as outlined in **Section 10.6.1.2.2.5**.

355. Further assessments in relation to the SNS SAC are provided in the **RIAA** (document reference 5.4).

356. A SIP for the SNS SAC will be developed (as outlined in **Section 10.3.4.2**) to set out the approach to deliver any project mitigation or management measures in relation to the disturbance of harbour porpoise.

Table 10-52: Assessment of Impact Significance for Disturbance of Harbour Porpoise during Pilling Based on EDRs

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	26km EDR for monopile	SEP	Medium	Negligible	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**
		DEP		Low	**Minor adverse**		**Minor adverse**
	15km EDR for pin-pile	SEP	Medium	Negligible	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**
		DEP		Negligible	**Minor adverse**		**Minor adverse**

10.6.1.2.3.3 *Impact Significance and Residual Impact for Possible Behavioural Response of Harbour Porpoise*

357. Taking into account the medium sensitivity and the potential magnitude of the temporary impact, the impact significance for possible behavioural response in harbour porpoise during piling based on Lucke *et al*. (2009) criteria (unweighted SEL of 145 dB re 1 µPa^{2}s) has been assessed as **minor adverse (not significant)**, based on 100%, 75% or 50% of individuals in maximum area responding (**Table 10-53**).

358. The assessment of impact significance takes into account the duration of active piling for SEP and DEP, as outlined in **Section 10.6.1.2.2.5**.

Table 10-53: Assessment of Impact Significance for Possible Behavioural Response of Harbour Porpoise during Pilling Based on Lucke et al. (2009) Criteria

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	Possible behavioural response - 25km for monopile	SEP	Medium	Negligible	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**
		DEP		Negligible	**Minor adverse**		**Minor adverse**
	Possible behavioural response – 23km for pin-pile	SEP	Medium	Negligible	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**
		DEP		Negligible	**Minor adverse**		**Minor adverse**

10.6.1.2.4 Impact Assessment for SEP and DEP

359. As outlined in **Section 10.3.3.2**, there is the potential that SEP and DEP could be constructed concurrently.

360. The closest distance between SEP and DEP is 10.7km for DEP South array area and 11km for DEP North array area.

10.6.1.2.4.1 *Disturbance During ADD Activation*

361. The assessments of the potential disturbance during any ADD activation is indicative only, as the final requirements for mitigation in the MMMP will be determined prior to construction.

362. The maximum predicted impact range during 20 minute ADD activation (based on their swim speeds) is up to 1.8km for harbour porpoise, bottlenose dolphin, white-beaked dolphin, grey seal and harbour seal, and up to 3.9km for minke whale. Therefore, there would be no overlap between the two Projects and the assessments for SEP or DEP in isolation are appropriate.

363. If the SEP and DEP are both constructed, there is the potential for impact ranges from both Projects to occur at the same time, and therefore, as a worst-case, the maximum number of marine mammals from each Project have been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently, and ADDs were activated at both sites at the same time (**Table 10-54**).

364. The magnitude of the potential impact is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, with 1% or less of the relevant reference populations anticipated to be temporarily disturbed (**Table 10-54**).

365. Maximum total ADD activation time to install all piles, based on worst-case scenarios for SEP and DEP:

- SEP and DEP:
  - 53 monopiles = up to 9 hours for 10 minute ADD activation prior to each soft-start (or up to 18 hours for 20 minute ADD activation); or
  - 212 pin-piles, however, anticipated 4 pin-piles for jacket foundation of each wind turbine to be installed in sequence, therefore ADDs only activated per foundation (53 foundations) = up to 9 hours for 10 minute ADD activation (or up to 18 hours for 20 minute ADD activation); and
  - 16 pin-piles for offshore sub-station, anticipated 4 pin-piles would be installed in sequence and ADDs activated prior to each group of 4 pin-piles = 40 minutes for 10 minute ADD activation (80 minutes for 20 minute activation).

Table 10-54: Maximum Number of Individuals (and % of Reference Population) that Could be at Disturbed During ADD Activation at SEP and DEP

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 20 minute ADD activation	
		Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Harbour porpoise	SEP & DEP	7.8 (0.0022% of NS MU)	**Negligible**	31.2 (0.009% of NS MU)	**Negligible**
Bottlenose dolphin	SEP & DEP	0.15 (0.0075% of GNS MU; 0.068% CES MU)	**Negligible (negligible)**	0.6 (0.03% of GNS MU; 0.27% CES MU)	**Negligible (negligible)**
White-beaked dolphin	SEP & DEP	0.03 (0.000069% of CGNS MU)	**Negligible**	0.12 (0.0003% of CGNS MU)	**Negligible**
Minke whale	SEP & DEP	0.24 (0.0012% of CGNS MU)	**Negligible**	0.96 (0.005% of CGNS MU)	**Negligible**
Grey seal	SEP & DEP	4.04 (0.047% of SE MU or 0.017% of wider ref pop)	**Negligible (negligible)**	16.21 (0.187% of SE MU or 0.067% of wider ref pop)	**Negligible (negligible)**
Harbour seal	SEP & DEP	0.90 (0.024% of SE MU or 0.003% of wider ref pop)	**Negligible (negligible)**	3.6 (0.10% of SE MU or 0.012% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.2.4.2 *Disturbance / Displacement of Harbour Porpoise based on EDRs for Piling*

366. SEP and DEP are located between 10.7km and 33.6km apart, and therefore there could be overlap between the maximum potential impact range based on 26km EDR for monopiles, but not for 15km EDR for pin-piles. The assessments have been based on the worst-case overlap in the impact areas, taking into account the furthest potential locations within both sites, to indicate the maximum number that could be impacted from SEP and DEP, if they are developed concurrently and piling was undertaken at both sites at the same time.

367. The estimated maximum number of harbour porpoise and percentage of the North Sea MU reference population that could be disturbed as a result of underwater noise during piling at SEP and DEP based on EDRs is presented in **Table 10-55**.

368. The magnitude of the potential impact is assessed as low for monopiles at SEP and DEP and negligible for pin-piles at SEP and DEP (**Table 10-55**).

369. Further assessments in relation to the SNS SAC are provided in the **RIAA** (document reference 5.4).

Table 10-55: Maximum Number of Harbour Porpoise (and % of Reference Population) That Could be at Disturbed during Piling Based on EDRs at SEP and DEP

Species	Location	EDR	Maximum area (taking into account overlap of locations in SEP and DEP at furthest possible points)	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Harbour porpoise	SEP & DEP	26km EDR ($2,124km^2$) for monopile	$3,739km^2$	5,459 (1.57% of NS MU)	**Low**
		15km EDR ($707km^2$) for pin-pile*	$1,414km^2$	2,163 (0.62% of NS MU)	**Negligible**

** worst-case is no overlap for 15km EDR*

10.6.1.2.4.3 *Possible Behavioural Response in Harbour Porpoise*

370. If SEP and DEP were piled at the same time, there could be overlap between the maximum potential impact ranges, with a possible behavioural response by harbour porpoise estimated to be up to 25km and 23km for the maximum hammer energy of the monopile (5,500kJ) and pin-pile (3,000kJ), respectively (**Table 10-28:**). However, the assessments have been based on the worst-case of no overlap in the impact areas and the maximum number of harbour porpoise from each Project, to indicate the maximum number that could be impacted from SEP and DEP, if they are developed concurrently and piling was undertaken at both sites at the same time[3].

[3] The impact area for both SEP and DEP being constructed at the same time do not take account of the potential overlap in areas, as the calculations are based on the impact areas provided by the underwater noise modelling, rather than an area based on the impact ranges only

371. The estimated maximum number of harbour porpoise and percentage of the North Sea MU reference population that could have a possible behavioural response, based on 100%, 75% and 50% of individuals responding in the area, as a result of underwater noise during piling at SEP and DEP based on the Lucke *et al*. (2009) criteria (unweighted SEL of 145 dB re 1 µPa^{2}s) is presented in **Table 10-56**.

372. The magnitude of the potential impact is assessed as low for 100% disturbance of harbour porpoise for monopiles at SEP and DEP and negligible for 75% or 50% of harbour porpoise for monopiles at SEP and DEP, and negligible for 100%, 75% and 50% disturbance of harbour porpoise for pin-piles at SEP and DEP (**Table 10-56**).

Table 10-56: Estimated Number of Harbour Porpoise (and % of Reference Population) that Could Exhibit a Possible Behavioural Response (Based on 100%, 75% and 50% of All Individuals in Maximum Area of Modelled Impact) at SEP and DEP

Potential Impact	Location	100% of individuals		75% of individuals		50% of individuals	
		Maximum number of individuals (% of reference population)	Magnitude (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Possible behavioural response of harbour porpoise - single strike of the maximum monopile hammer energy (5,500kJ)	SEP & DEP	4,019 (1.16% of NS MU)	**Low**	3,015 (0.87% of NS MU)	**Negligible**	2,010 (0.58% of NS MU)	**Negligible**
Possible behavioural response of harbour porpoise - single strike of the maximum pin-pile hammer energy (3,000kJ)	SEP & DEP	3,445 (0.99% of NS MU)	**Negligible**	2,584 (0.75% of NS MU)	**Negligible**	1,723 (0.5% of NS MU)	**Negligible**

10.6.1.2.4.4 *Duration of Piling*

373. Based on assessment in **Table 10-50**, if SEP and DEP were constructed sequentially the maximum duration of piling, based on worst-case scenarios, including soft-start, ramp-up and ADD activation would be:

- SEP & DEP sequentially
    - Piling of 53 monopiles and two OSPs (including soft-start, ramp-up and ADD activation) = up to 270 hours (11.25 days) with 10 minute activation (or up to 280 hours (12 days) with 20 minute ADD activation); or
    - Piling of 212 pin-piles and two OSPs (including soft-start, ramp-up and ADD activation) = up to 694 hours (29 days) with 10 minute ADD activation (or up to 704 hours (30 days) with 20 minute ADD activation).

374. However, if SEP and DEP were constructed concurrently, and assuming piling at the same time on each site the maximum duration of piling, based on worst-case scenarios, including soft-start, ramp-up and ADD activation would be the same as the assessments for DEP in isolation (e.g. 2 x 23 monopiles installed at the same time at both SEP and DEP plus additional 7 monopiles at DEP in isolation = 30 monopiles; or 2 x 92 pin-piles installed at the same time at both SEP and DEP plus additional 28 pin-piles at DEP in isolation = 120 pin-piles) plus the two OSPs:

- SEP & DEP simultaneously
    - Piling of 53 monopiles (2 x 23 monopiles concurrently installed) and two OSPs (including soft-start, ramp-up and ADD activation) = up to 174 hours (up to 7.5 days) with 10 minute activation (or 180 hours (up to 8 days) with 20 minute ADD activation); or
    - Piling of 212 pin-piles (2 x 92 concurrently installed) and two OSPs (including soft-start, ramp-up and ADD activation) = 414 hours (17.5 days) with 10 minute ADD activation (or 420 hours (up to 18 days) with 20 minute ADD activation).

10.6.1.2.4.5 *Impact Significance and Residual Impact*

Impact Significance for Disturbance During Proposed ADD Activation

375. Taking into account the medium sensitivity (**Table 10-20**) and the potential magnitude of the temporary impact (e.g. number of individuals as a percentage of the reference population), the impact significance for disturbance during ADD activation has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal if ADDs were activated at the same time at SEP and DEP (**Table 10-57**).

376. The assessment of impact significance takes into account the duration of ADD activation for both SEP and DEP.

377. The use of ADDs as mitigation to reduce the risk of auditory injury (PTS) to marine mammals will be developed for the MMMP prior to construction. ADD activation duration would be determined to reduce the risk of auditory injury (PTS) without causing any significant or unnecessary disturbance.

Table 10-57: Assessment of Impact Significance for Disturbance from ADD Activation at SEP and DEP

Species	Impact	Location	Sensitivity	Magnitude	Significance
Harbour porpoise	ADD activation	SEP & DEP	Medium	Negligible	**Minor adverse**
Bottlenose dolphin	ADD activation	SEP & DEP	Medium	Negligible	**Minor adverse**
White-beaked dolphin	ADD activation	SEP & DEP	Medium	Negligible	**Minor adverse**
Minke whale	ADD activation	SEP & DEP	Medium	Negligible	**Minor adverse**
Grey seal	ADD activation	SEP & DEP	Medium	Negligible	**Minor adverse**
Harbour seal	ADD activation	SEP & DEP	Medium	Negligible	**Minor adverse**

Impact Significance and Residual Impact for Disturbance / Displacement of Harbour Porpoise based on EDRs for Piling

378. Taking into account the medium sensitivity (**Table 10-20**) and the potential magnitude of the temporary impact, the impact significance for any disturbance in harbour porpoise based on the EDRs for piling has been assessed as **minor adverse (not significant)** (**Table 10-58**).

379. The assessment of impact significance takes into account the duration of piling for SEP and DEP, as outlined in **Section 10.6.1.2.4.4**.

380. Further assessments in relation to the SNS SAC are provided in the **RIAAA** (document reference 5.4).

381. The SIP for the SNS SAC will be developed (as outlined in **Section 10.3.4.2**) to set out the approach to deliver any project mitigation or management measures in relation to the disturbance of harbour porpoise.

Table 10-58: Assessment of Impact Significance for Disturbance of Harbour Porpoise during Pilling Based on EDRs for SEP and DEP

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	26km EDR for monopile	SEP & DEP	Medium	Low	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**
	15km EDR for pin-pile	SEP & DEP	Medium	Negligible	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**

Impact Significance and Residual Impact for Possible Behavioural Response in Harbour Porpoise

382. Taking into account the medium sensitivity and the potential magnitude of the temporary impact, the impact significance for possible behavioural response in harbour porpoise during piling based on Lucke *et al*. (2009) criteria (unweighted SEL of 145 dB re 1 µPa^{2}s) has been assessed as **minor adverse (not significant)**, based on 100%, 75% or 50% of all individuals in maximum area responding for SEP and DEP (**Table 10-59**).

383. The assessment of impact significance takes into account the duration of active piling for SEP and DEP, as outlined in **Section 10.6.1.2.4.4**.

Table 10-59: Assessment of Impact Significance for Possible Behavioural Response of Harbour Porpoise during Pilling at SEP and DEP Based on Lucke et al. (2009) Criteria

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	Possible behavioural response - 25km for monopile	SEP & DEP	Medium	Low	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**
	Possible behavioural response – 23km for pin-pile	SEP & DEP	Medium	Negligible	**Minor adverse**	SIP (**Section 10.3.4.2**)	**Minor adverse**

10.6.1.3 Impact 3: Effects from Underwater Noise Associated with Other Construction Activities

385. Potential sources of underwater noise during construction activities, other than piling, include sea bed preparation, dredging, rock placement, drilling (if piling is refused at any location), trenching and cable installation.

386. The cable installation methods that are currently being considered are:

- Ploughing;
- Trenching or cutting;
- Jetting;
- Surface laid with cable protection where burial is not possible; and
- Rock placement for protection of the cables.

387. There are no clear indications that underwater noise caused by the installation of sub-sea cables poses a high risk of harming marine fauna (OSPAR, 2009). However, behavioural responses of marine mammals to dredging, an activity emitting comparatively higher underwater noise levels, are predicted to be similar to those during cable installation (OSPAR, 2009).

388. Dredging produces continuous, broadband sound. Sound pressure levels (SPLs) can vary widely, for example, with dredger type, operational stage, or environmental conditions (e.g. sediment type, water depth, salinity and seasonal phenomena such as thermoclines; Jones and Marten, 2016). These factors will also affect the propagation of sound from dredging/cable installation activities and along with ambient sound already present, will influence the distance at which sounds can be detected.

389. Dredging/cable installation activities has the potential to generate underwater noise at sound levels and frequencies for sufficient durations to disturb marine mammals. Noise measurements indicate that the most intense sound emissions from trailing suction hopper dredgers (TSHD) are typically low frequencies, up to and including 1kHz (Robinson *et al*., 2011) and is comparable to those for a cargo ship travelling at modest speed (between 8 and 16 knots) (Theobald *et al*., 2011).

390. Reviews of published sources of underwater noise during dredging activity (e.g. Thomsen *et al*., 2006; Theobald *et al*., 2011; Todd *et al*., 2014), indicate that the sound levels that marine mammals may be exposed to during dredging activities are typically below auditory injury thresholds (PTS) exposure criteria (as defined in Southall *et al*., 2019). Therefore, the potential risk of any auditory injury in marine mammals as a result of dredging activity is highly unlikely. The thresholds for temporary loss in hearing sensitivity (TTS) could be exceeded during dredging, however, only if marine mammals remain in close proximity to the active dredger for extended periods, which is highly unlikely (Todd *et al*., 2014).

391. Underwater noise as a result of dredging activity/cable installation, also has the potential to disturb marine mammals (Pirotta *et al*., 2013). Therefore, there is the potential for short, perhaps medium-term behavioural reactions and disturbance to marine mammals in the area during dredging / cable installation activity. Marine mammals may exhibit varying behavioural reactions intensities as a result of exposure to noise (Southall *et al*., 2007).

392. The noise levels produced by dredging activity/cable installation, could overlap with the hearing sensitives and communication frequencies used by marine mammals (Todd *et al*., 2014), and therefore have the potential to impact marine mammals present in the area. However, species such as harbour porpoise have a relatively poor sensitivity below 1kHz, and are less likely to be affected by masking, although for seals there could be the potential of masking communication, especially during the breeding season (Todd *et al*., 2014).

393. In 2012, 25 harbour seal from The Wash were tagged, as well as a further 10 from the Thames (Russell, 2016b). Of those, 24 of the tags were in place for sufficient time to allow for activity budget analysis, in order to determine key foraging areas of harbour seal in the SNS. The results of this study show foraging activity of harbour seal off the coast off Norfolk, and at SEP and DEP (**Plate 10-5**: Russell, 2016b). The results of this tagging study show foraging activity (in red) within a number of offshore wind farm sites, including Sheringham Shoal, Dudgeon, with a relatively lower level of activity at Hornsea Projects One, Two, and Four, as well as Dogger Bank A. While the majority of these wind farm projects at the time of tagging had not commenced (in 2012), Sheringham Shoal was undergoing construction, with turbine installation undertaken from 2011 to 2012, and cabling works from 2010 to 2012. This indicates that harbour seal will still undertake foraging activity during wind farm construction activities.

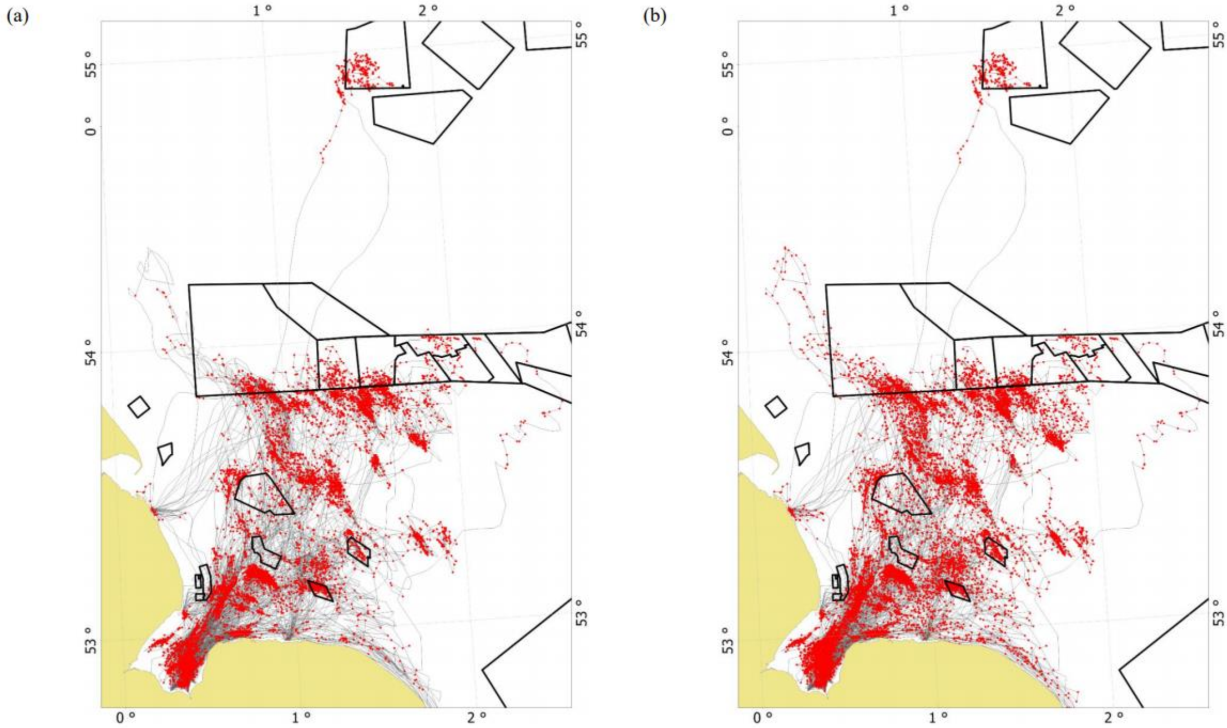

Plate 10-5: The Tracks (Grey) and Estimated Foraging Locations (Red) of Tagged Harbour Seals in Geo- (a) and Hydro- (b) Space (Russell, 2016b).

10.6.1.3.1 Sensitivity of Marine Mammals

394. The sensitivity of marine mammals to TTS and disturbance as a result of underwater noise during construction activities, other than piling, is considered to be medium in this assessment as a precautionary approach (**Table 10-20**). Marine mammals within the potential disturbance area are considered to have limited capacity to avoid such effects (**Table 10-7**), although any disturbance to marine mammals would be temporary and they would be expected to return to the area once the disturbance had ceased or they had become habituated to the sound.

10.6.1.3.2 Underwater Noise Modelling

395. Underwater noise modelling was undertaken to assess the impact ranges of construction activities, other than piling, on marine mammals, and this has been used to determine the potential impact on marine mammal species. The underwater noise propagation modelling was undertaken using a simple modelling approach for a number of offshore construction activities; using measured sound source data scaled to relevant parameters for SEP and DEP (see **Appendix 10.2 Underwater Noise Modelling Report** for further information). The activities that were assessed include:

- Cable laying: noise from the cable laying vessel and any other associated noise during the offshore cable installation (estimated sound source of 171dB re 1µPs @1m (RMS));
- Trenching: plough trenching may be required during the export cable installation (estimated sound source of 172dB re 1µPs @1m (RMS));

- Rock placement: potentially required for offshore cables (cable crossings and cable protection) and scour protection around foundation structures (estimated sound source of 172dB re 1µPs @1m (RMS));
- Drilling: may be required in the case of impact piling refusal (estimated sound source of 169dB re 1µPs @1m (RMS)); and
- Dredging: sea bed preparation, a TSHD may be required for the export, infield and interconnector cable installation (estimated sound source of 186dB re 1µPs @1m (RMS)).

396. For SEL_{cum} calculations, the duration of the noise is also considered, with all sources operating for a worst-case of 24-hours in a day for non-impulsive noise.

397. To account for the weightings required for modelling using the Southall *et al*. (2019) criteria, reductions in source level have been applied to the various noise sources (see **Appendix 10.2 Underwater Noise Modelling Report** for further information).

398. The cumulative impact ranges are to the nearest 100m, however, they are likely to be less than 100m especially for PTS impact ranges.

399. The results of the underwater noise modelling (**Table 10-60**) indicate that any marine mammal would have to be less than 100m (precautionary maximum range) from the continuous noise source for 24 hours, to be exposed to noise levels that could induce PTS or TTS, with the exception of harbour porpoise and the predicted impact ranges for TTS of 1km for rock placement and 0.2km for dredging, based on the Southall *et al*. (2019) non-impulsive thresholds and criteria for SEL_{cum}.

400. It should be noted that the predicted impact ranges are the distances which represent the 'onset' stage, which is the minimum exposure that could potentially lead to the start of an effect and may only be marginal. In most hearing groups, the noise levels are low enough that there is negligible risk.

10.6.1.3.3 Magnitude for SEP or DEP in Isolation

401. The number of marine mammals that could be impacted as a result of underwater noise during construction from activities other than piling has been assessed based on the number of animals that could be present in each of the modelled impact ranges for the construction activities (**Table 10-60**).

402. It is important to note that PTS is unlikely to occur in marine mammals, as the modelling indicates that the marine mammal would have to remain less than 100m for 24 hours for any potential risk of PTS (**Appendix 10.2 Underwater Noise Modelling Report**). Therefore, PTS as a result of construction activity, other than piling, is highly unlikely and has not been assessed further.

403. There is unlikely to be any significant risk of any TTS, as again the modelling indicates that the marine mammal would have to remain less than 100m for 24 hours in a day. With the exception of harbour porpoise which would have to remain 1km or less during dredging for 24 hours or 200m or less during rock placement for 24 hours to be at risk of TTS (**Table 10-60**). Therefore, TTS as a result of construction activity, other than piling, is highly unlikely.

404. The magnitude of the potential impact for any TTS as a result of non-piling construction noise is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale grey seal and harbour seal, with less than 1% of the reference populations exposed to any temporary impact (**Table 10-61**).

405. There is the potential that more than one of these activities could be underway at either site or the export cable corridor area at the same time. As a worst-case and unlikely scenario, an assessment for all five activities being undertaken simultaneously has also been undertaken. The magnitude of the potential impact of TTS as a result of non-piling construction noise is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale grey seal and harbour seal (**Table 10-61**).

406. The potential for TTS effects that could result from underwater noise during other construction activities, including cable laying and protection would be temporary in nature, not consistent throughout the offshore construction periods for SEP and DEP and would be limited to only part of the overall construction period and area at any one time.

407. The noise level generated by the construction activities are barely audible above the predicted vessel noise (**Section 10.6.1.4**) If the response is displacement from the area, it is predicted that marine mammals will return once the activity has been completed and therefore any impacts from underwater noise as a result of construction activities other than piling noise will be both localised and temporary. Therefore, there is unlikely to be the potential for any significant disturbance impact on marine mammals.

Table 10-60: Predicted Impact Ranges (and Areas) for TTS from Cumulative Exposure of Other Construction Activities

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Cable laying	Trenching	Rock placement	Drilling	Dredging	Total area for all activities
Harbour porpoise (VHF)	TTS	SEL_{cum} Weighted (153 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	1km (3.14km^2)	<0.1km (<0.03km^2)	0.2km (0.13km^2)	3.36km^2
Bottlenose dolphin and white-beaked dolphin (HF)	TTS	SEL_{cum} Weighted (178 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.15km^2
Minke whale (LF)	TTS	SEL_{cum} Weighted (179 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.15km^2
Grey and Harbour seal (PW)	TTS	SEL_{cum} Weighted (181 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.15km^2

Table 10-61: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of Underwater Noise Associated with Non-Piling Construction Activities Based on Underwater Noise Modelling for Each Individual Activity and for All Activities at the Same Time at SEP and DEP

Species	Potential Impact	Location	Maximum number of individuals (% of reference population) for TTS for each individual activity	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude* (temporary impact)
Harbour porpoise (VHF)	TTS from cumulative SEL, based on 24 hour exposure, for: - Cable laying - Trenching - Drilling	SEP	0.019 (0.000005% of NS MU)	**Negligible**	8.2 (0.0024% of NS MU)	**Negligible**
		DEP	0.073 (0.000021% of NS MU)	**Negligible**		
		SEP, DEP & cable export area	0.044 (0.000013% of NS MU)	**Negligible**		
	TTS from cumulative SEL, based on 12 hour exposure, for: - Rock placement	SEP	1.98 (0.00057% of NS MU)	**Negligible**		
		DEP	7.63 (0.0022% of NS MU)	**Negligible**		
		SEP, DEP & cable export area	4.58 (0.0013% of NS MU)	**Negligible**		
	TTS from cumulative SEL,	SEP	0.082 (0.000024% of NS MU)	**Negligible**		

Species	Potential Impact	Location	Maximum number of individuals (% of reference population) for TTS for each individual activity	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude* (temporary impact)
	based on 24 hour exposure, for: - Dredging	DEP	0.32 (0.00009% of NS MU)	**Negligible**		
		SEP, DEP & export cable corridor	0.19 (0.000055% of NS MU)	**Negligible**		
Bottlenose dolphin (HF)	TTS from cumulative SEL, based on 24 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging	SEP or DEP or export cable corridor	0.00089 (0.000044% of GNS MU; 0.0004% CES MU)	**Negligible (negligible)**	0.0045 (0.00022% of GNS MU; 0.0024% CES MU)	**Negligible (negligible)**
White-beaked dolphin (HF)		SEP or DEP or export cable corridor	0.00018 (0.00000041% of CGNS MU)	**Negligible**	0.0009 (0.000002% of CGNS MU)	**Negligible**
Minke whale (LF)	TTS from cumulative SEL, based on 24 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging	SEP or DEP or export cable corridor	0.0003 (0.0000015% of CGNS MU)	**Negligible**	0.0015 (0.0000075% of CGNS MU)	**Negligible**

Species	Potential Impact	Location	Maximum number of individuals (% of reference population) for TTS for each individual activity	Magnitude* (temporary impact)	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude* (temporary impact)
Grey seal (PW)	TTS from cumulative SEL, based on 24 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging	SEP	0.026 (0.0003% of SE MU or 0.00011% of wider ref pop)	**Negligible (negligible)**	0.071 (0.00081% of SE MU or 0.00029% of wider ref pop)	**Negligible (negligible)**
		DEP	0.0022 (0.00026% of SE MU or 0.000092% of wider ref pop)	**Negligible (negligible)**		
		SEP, DEP & cable export area	0.022 (0.00025% of SE MU or 0.000091% of wider ref pop)	**Negligible (negligible)**		
Harbour seal (PW)		SEP	0.0082 (0.00022% of SE MU or 0.000027% of wider ref pop)	**Negligible (negligible)**	0.036 (0.00096% of SE MU or 0.000079% of wider ref pop)	**Negligible (negligible)**
		DEP	0.0024 (0.00006% of SE MU or 0.000008% of wider ref pop)	**Negligible (negligible)**		
		SEP, DEP & cable export area	0.0057 (0.00015% of SE MU or 0.000013% of wider ref pop)	**Negligible (negligible)**		

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.3.3.1 *Duration of Other Construction Activities*

408. The maximum duration for the offshore construction period, including piling and export cable installation, is up to two years for each Project. However, construction activities would not be underway constantly throughout this period. Further details on the construction schedule is provided in **Chapter 4 Project Description**.

409. The duration of offshore export cable installation and trenching activities is expected to take approximately 50 days and 60 days for SEP and DEP export cables, respectively (**Table 10-1**).

10.6.1.3.4 Impact Significance

410. Taking into account the marine mammal sensitivity to TTS and disturbance (**Table 10-20**) and the potential magnitude of the impact, as assessed in **Table 10-61**, the impact significance for construction activities other than piling at either SEP or DEP has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-62**).

411. The underwater noise impacts from non-piling noise will be significantly less than that of impact piling and will be localised and short term. Any potential disturbance would be temporary and therefore unlikely to significantly affect marine mammal populations.

Table 10-62: Assessment of Impact Significance for Underwater Noise from Construction Activities Other than Piling

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS from cumulative SEL during other construction activities	Harbour porpoise	SEP or DEP including export cable corridor	Medium	Negligible	**Minor adverse**	No mitigation proposed	Minor adverse
	Bottlenose dolphin		Medium	Negligible	**Minor adverse**		Minor adverse
	White-beaked dolphin		Medium	Negligible	**Minor adverse**		Minor adverse
	Minke whale		Medium	Negligible	**Minor adverse**		Minor adverse
	Grey seal		Medium	Negligible	**Minor adverse**		Minor adverse
	Harbour seal		Medium	Negligible	**Minor adverse**		Minor adverse
Disturbance during other construction activities	All marine mammals	SEP or DEP including export cable corridor	Medium	Negligible	**Minor adverse**		Minor adverse

10.6.1.3.5 Mitigation

412. No mitigation is proposed for underwater noise for construction activities, other than piling, as the risk of any impacts is **negligible**.

10.6.1.3.6 Impact Assessment for SEP and DEP

413. As a worst-case, the maximum number of marine mammals from each Project has been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-63**).

414. The magnitude of the potential impact for TTS during construction activities other than piling at SEP and DEP is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-63**).

415. The noise level generated by the construction activities are barely audible above the predicted vessel noise (**Section 10.6.1.4**). The underwater noise impacts from non-piling noise will be significantly less than that of impact piling and will be localised and short term. Any potential disturbance would be temporary and therefore unlikely to significantly affect marine mammal populations.

Table 10-63: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of Underwater Noise Associated with Non-Piling Construction Activities Based on Underwater Noise Modelling for all Activities at the Same Time at SEP and DEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude* (temporary impact)
TTS from cumulative SEL, based on 12 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging	Harbour porpoise (VHF)	SEP & DEP including export cable	10.3 (0.003% of NS MU)	**Negligible**
	Bottlenose dolphin (HF)	SEP & DEP including export cable	0.009 (0.00044% of GNS MU; 0.0047% CES MU)	**Negligible (negligible)**
	White-beaked dolphin (HF)	SEP & DEP including export cable	0.002 (0.000004% of CGNS MU)	**Negligible**
	Minke whale (LF)	SEP & DEP including export cable	0.003 (0.000015% of CGNS MU)	**Negligible**
	Grey seal (PW)	SEP & DEP including export cable	0.084 (0.001% of SE MU or 0.00035% of wider ref pop)	**Negligible (negligible)**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude* (temporary impact)
	Harbour seal (PW)	SEP & DEP including export cable	0.068 (0.0018% of SE MU or 0.00015% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.3.6.1 *Duration of Other Construction Activities*

416. The maximum duration for the offshore construction period, including piling and export cable installation, is up to two years for each Project, therefore four years for SEP and DEP. However, construction activities would not be underway constantly throughout this period.

417. The duration of offshore export cable installation and trenching activities is expected to take approximately 100 days for SEP and DEP.

10.6.1.3.6.2 *Impact Significance*

418. Taking into account the medium sensitivity to TTS and disturbance (**Table 10-20**) and the potential magnitude of the impact, as assessed in **Table 10-63**, the impact significance for construction activities other than piling at SEP and DEP has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-64**).

419. Any potential disturbance would be temporary and therefore unlikely to significantly affect marine mammal populations.

Table 10-64: Assessment of Impact Significance for TTS from Construction Activities Other than Piling at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS from cumulative SEL during other construction activities	Harbour porpoise	SEP & DEP including export cable	Medium	Negligible	**Minor adverse**	No mitigation proposed	**Minor adverse**
	Bottlenose dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	White-beaked dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Minke whale		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Grey seal		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Harbour seal		Medium	Negligible	**Minor adverse**		**Minor adverse**
Disturbance during other construction activities	All marine mammals	SEP & DEP including export cable	Medium	Negligible	**Minor adverse**		**Minor adverse**

10.6.1.3.6.3 *Mitigation*

420. No mitigation is proposed for underwater noise from construction activities, other than piling, as the risk of any impact is negligible.

10.6.1.4 Impact 4: Impacts from Underwater Noise and Disturbance Associated with Construction Vessels

421. During the construction phase there will be an increase in the number of vessels; this is estimated to be up to a total of 16 vessels at SEP or DEP including the export cable corridor area at any one time (**Table 10-1**). The number, type and size of vessels will vary depending on the activities taking place at any one time.

422. Vessel movements to and from any port will be incorporated within existing vessel routes and therefore any increase in disturbance as a result of underwater noise from vessels during construction will be within the SEP and DEP offshore sites and offshore export cable corridor area.

423. The vessels will be slow moving (or stationary) and most noise emitted is likely to be of a lower frequency. Noise levels reported by Malme *et al*. (1989) and Richardson *et al*. (1995) for transiting large surface vessels indicate that physiological damage to auditory sensitive marine mammals is unlikely. A study of the noise source levels from several different vessels (Jones *et al*., 2017) shows that for a cargo vessel of 126m in length (on average), travelling at a speed of 11 knots (on average) would generate a mean sound level of 160 dB re 1 µPa @ 1m (with a maximum sound level recorded of 187 dB re 1 µPa @ 1m). The levels could be sufficient to cause local disturbance to marine mammals in the immediate vicinity of the vessel, depending on ambient noise levels.

424. Trigg *et al*. (2020) found the predicted exposure of grey seals to shipping noise did not exceed thresholds for TTS. Thomsen *et al*. (2006) reviewed the effects of ship noise on harbour porpoise and seal species and concluded that ship noise around 0.25kHz could be detected at distances of 1km; and ship noise around 2kHz could be detected at around 3km.

425. **Chapter 13 Shipping and Navigation** provides a description of the baseline conditions. The main vessel types were cargo, tankers, oil and gas and wind farm support. Aggregate dredgers, passenger and fishing and recreational vessels were also recorded.

426. Shipping and navigation data indicate 13 existing main routes within the study area, with two routes crossing the SEP wind farm site, four routes crossing the DEP wind farm site and 10 crossing the export cable corridor. The number of vessels on these main vessel routes could be up to 75 vessels per day (see **Chapter 13 Shipping and Navigation**).

427. As described within **Appendix 13.1 Navigational Risk Assessment**, there is an existing relatively high level of vessel traffic within the navigational study area (SEP and DEP plus 10km buffer), including the area close to the coastline. In summer, an average of 82 vessels were recorded per day within the study area, and in winter an average of 81 vessels were recorded.

428. During construction existing vessel traffic could be displaced due to the presence of buoyed construction areas (including 500m rolling active safety zones around fixed structures where work is being undertaken), construction vessels and partially completed or pre-commissioned structures (see **Chapter 13 Shipping and Navigation**).

10.6.1.4.1 Sensitivity of Marine Mammals

429. The sensitivity of marine mammals to temporary changes in hearing sensitivity (TTS) and disturbance is considered to be medium as a precautionary approach (see **Section 10.6.1.1.1**).

10.6.1.4.2 Underwater Noise Modelling

430. Underwater noise modelling was undertaken to assess the impact ranges for PTS and TTS from vessels on marine mammals. The underwater noise propagation modelling was undertaken using a simple modelling approach; using measured sound source data scaled to relevant parameters for SEP and DEP (see **Appendix 10.2 Underwater Noise Modelling Report** for further information). The unweighted source levels for vessels modelled were:

- Large vessel = 168dB re 1µPs @1m (RMS); and
- Medium vessel = 161dB re 1µPs @1m (RMS).

431. For SEL_{cum} calculations, the duration of the vessel noise was assumed to be 24-hours for non-impulsive noise.

432. To account for the weightings required for modelling using the Southall *et al*. (2019) criteria, reductions in source level have been applied to the various noise sources (see **Appendix 10.2 Underwater Noise Modelling Report** for further information).

433. The cumulative impact ranges are to the nearest 100m, however, they are likely to be much less than 100m especially for PTS impact ranges.

434. The results of the underwater noise modelling (**Table 10-65**) indicate that any marine mammal would have to be less than 100m (precautionary maximum range) from the vessel for 24 hours, to be exposed to noise levels that could induce PTS or TTS based on the Southall *et al*. (2019) thresholds and criteria.

Table 10-65: Predicted Impact Ranges (and Areas) for TTS from Cumulative Exposure Underwater Noise from Construction Vessels

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Large vessel	Medium vessel	Total area for up to 16 vessels
Harbour porpoise (VHF)	PTS	SEL_{cum} Weighted (173 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2
	TTS	SEL_{cum} Weighted (153 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Large vessel	Medium vessel	Total area for up to 16 vessels
Bottlenose dolphin and white-beaked dolphin (HF)	PTS	SEL_{cum} Weighted (198 dB re 1 $\mu Pa^2 s$) Non-impulsive	<<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2
	TTS	SEL_{cum} Weighted (178 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2
Minke whale (LF)	PTS	SEL_{cum} Weighted (199 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	
	TTS	SEL_{cum} Weighted (179 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2
Grey and Harbour seal (PW)	PTS	SEL_{cum} Weighted (201 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2
	TTS	SEL_{cum} Weighted (181 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	0.48km^2

10.6.1.4.3 Magnitude for SEP or DEP in Isolation

435. PTS is unlikely to occur in marine mammals, as the modelling indicates that the marine mammal would have to remain less than 100m from the source for 24 hours for any potential risk of PTS (**Table 10-65**).

436. The number of marine mammals that could be impacted from TTS as a result of underwater noise during construction from vessels has been assessed based on the maximum impact area for large and medium sized vessels (**Table 10-65**) and for up to 16 vessels at each site, including in the export cable corridor area (**Table 10-66**).

437. The magnitude of the potential impact of TTS as a result of construction vessel noise is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale grey seal and harbour seal (**Table 10-66**).

Table 10-66: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of Underwater Noise Associated with All Construction Vessels at SEP or DEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude* (temporary impact)
PTS and TTS from cumulative SEL, based on 24 hour exposure for large or medium vessels	Harbour porpoise (VHF)	SEP or DEP including export cable corridor area	1.2 (0.00034% of NS MU)	**Negligible**
	Bottlenose dolphin (HF)	SEP or DEP including export cable corridor area	0.014 (0.00071% of GNS MU; 0.0064% CES MU)	**Negligible (negligible)**
	White-beaked dolphin (HF)	SEP or DEP including export cable corridor area	0.0029 (0.0000066% of CGNS MU)	**Negligible**
	Minke whale (LF)	SEP or DEP including export cable corridor area	0.0048 (0.000024% of CGNS MU)	**Negligible**
	Grey seal (PW)	SEP or DEP including export cable corridor area	0.41 (0.0047% of SE MU or 0.0017% of wider ref. pop.)	**Negligible (negligible)**
	Harbour seal (PW)	SEP or DEP including export cable corridor area	0.13 (0.0035% of SE MU or 0.00043% of wider ref. pop.)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.4.3.1 *Disturbance from Underwater Noise and Presence of Vessels for SEP or DEP in Isolation*

438. Disturbance from vessel noise could occur where increased noise from construction vessels associated is greater than the background ambient noise.

439. As outlined in **Section 10.6.1.2**, Brandt *et al*. (2018) found that at seven German offshore wind farms in the vicinity (up to 2km) of the construction site, harbour porpoise detections declined several hours before the start of piling as a result of increased construction related activities and vessels. Similarly, studies in the Moray Firth during piling of the Beatrice Offshore Wind Farm, indicate higher vessel activity within 1km was associated with an increased probability of response in harbour porpoise (Graham *et al*., 2019).

440. Studies in the Moray Firth indicate that at a mean distance of 2km from construction vessels, harbour porpoise occurrence decreased by up to 35.2% as vessel intensity increased. Harbour porpoise responses decreased with increasing distance to vessels, out to 4km where no response was observed (Benhemma-Le Gall *et al*., 2021).

441. During the periods when piling is underway, vessel noise is unlikely to add an additional impact to those assessed for piling, as the vessels and vessel noise would be within the maximum impact areas assessed.

442. The distance at which animals may react to vessels is difficult to predict and behavioural responses can vary a great deal depending on species, location, type and size of vessel, vessel speed, noise levels and frequency, ambient noise levels and environmental conditions.

443. Modelling by Heinänen and Skov (2015) indicates that the number of ships represents a relatively important factor determining the density of harbour porpoise in the North Sea MU during both seasons, with markedly lower densities with increasing levels of traffic. A threshold level in terms of impact seems to be approximately 20,000 ships per year (approximately 80 vessels per day within a 5km^2 area).

444. Taking into account the maximum number of vessels that could be onsite during construction, the site area and the displacement of other vessels from the area, the number of vessels would not exceed the Heinänen and Skov (2015) threshold level of 80 vessels per day in a 5km^2 area for harbour porpoise.

445. For example, 16 vessels in either the SEP or DEP wind farm sites (97.0km^2 and 114.8km^2 respectively) would equate to less than 0.2 vessels per km^2 (approximately one vessel per 5km^2). In addition, due to safety and logistical considerations during piling, it is likely that the number of vessels in a small area, for example, around a pile location during pile installation would be limited to a very low number of essential vessels only.

446. Studies on bottlenose dolphin found that boat physical presence, and not just noise, can result in disturbance (Pirotta *et al*., 2015). However, disturbance and any reduction in foraging activity was short-term. The boat effect did not persist following boat passage and was limited to the time when the boat was physically present (Pirotta *et al*., 2015).

447. Jones *et al*. (2017) produced usage maps characterising densities of grey and harbour seals and ships around the British Isles, which were used to produce risk maps of seal co-occurrence with shipping traffic. The analysis indicates that rates of co-occurrence were highest within 50 km of the coast, close to seal haul-outs. When considering exposure to shipping traffic in isolation, the study found no evidence relating to declining seal population trajectories with high levels of co-occurrence between seals and vessels. For example, in areas of east England where the harbour seal population is increasing there are high intensities of vessels (Duck and Morris, 2016; Jones *et al*., 2017).

448. If the behavioural response is displacement from the area, it is predicted that marine mammals will return once the activity has been completed and therefore any impacts from underwater noise as a result of construction vessels will be both localised and temporary. Therefore, there is unlikely to be the potential for any significant impact on marine mammals. As a precautionary approach, the magnitude for the disturbance of all marine mammals as a result of underwater noise and presence of vessels has been assessed as low.

10.6.1.4.3.2 *Duration of Construction Vessels*

449. The maximum duration for the offshore construction period, including piling and export cable installation, is up to two years for each Project. Therefore, it is assumed that construction vessels could be on either SEP or DEP, including the offshore export cable corridor areas, for two years.

10.6.1.4.4 Impact Significance

450. Taking into account the marine mammal sensitivity to PTS, TTS and disturbance (**Table 10-20**) and the potential magnitude of the impact, as assessed in **Table 10-66**, the impact significance for PTS, TTS and disturbance for underwater noise from construction vessels at either SEP or DEP in isolation has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-67**).

Table 10-67: Assessment of Impact Significance for Underwater Noise and Disturbance from Construction Vessels at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
PTS and TTS from cumulative SEL for construction vessels	All marine mammal species	SEP or DEP including export cable	Medium	Negligible	**Minor adverse**	No additional mitigation proposed. It is assumed best practice measures will be applied.	**Minor adverse**
Disturbance from construction vessels	All marine mammals	SEP or DEP including export cable	Medium	Low	**Minor adverse**		**Minor adverse**

10.6.1.4.5 Mitigation

451. No mitigation is proposed for underwater noise from construction vessels, as the risk of any impact is negligible. However, vessel movements, where possible, will be incorporated into recognised vessel routes and hence to areas where marine mammals are accustomed to vessels, in order to reduce any impacts, including increased disturbance. All vessel movements will be kept to the minimum number that is required to reduce any potential impacts, including increased disturbance. Additionally, vessel operators will use good practice to reduce impacts on marine mammals (see the **Draft MMMP** (document reference 9.4)).

10.6.1.4.6 Impact Assessment for SEP and DEP

452. As a worst-case the maximum number of marine mammals from each Project has been assessed to indicate the maximum number of marine mammals that could be impacted from SEP and DEP, if they are developed concurrently (**Table 10-68**). The assessment is based on up to 25 vessels on both sites at the same time (equating to an impact area of 0.75km^2 (impact area of <0.03km^2 per vessel (**Table 10-65**) multiplied by 25 vessels)).

453. The magnitude of the potential impact for TTS for underwater noise from construction vessels at SEP and DEP is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-68**).

454. As outlined in **Section 10.6.1.4.3.1**, if the behavioural response is displacement from the area, it is predicted that marine mammals will return once the activity has been completed and therefore any impacts from underwater noise as a result of construction vessels will be both localised and temporary. Therefore, there is unlikely to be the potential for any significant impact on marine mammals. As a precautionary approach the magnitude for the disturbance of all marine mammals as a result of underwater noise and presence of vessels has been assessed as low.

Table 10-68: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of Underwater Noise Associated with All Construction Vessels at SEP and DEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude* (temporary impact)
TTS from cumulative SEL, based on 24 hour exposure, for large or medium vessels	Harbour porpoise (VHF)	SEP & DEP including export cable corridor area	1.8 (0.00053% of NS MU)	**Negligible**
	Bottlenose dolphin (HF)	SEP & DEP including	0.022 (0.0011% of GNS MU; 0.01% CES MU)	**Negligible (negligible)**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude* (temporary impact)
		export cable corridor area		
	White-beaked dolphin (HF)	SEP & DEP including export cable corridor area	0.0045 (0.00001% of CGNS MU)	**Negligible**
	Minke whale (LF)	SEP & DEP including export cable corridor area	0.0075 (0.000037% of CGNS MU)	**Negligible**
	Grey seal (PW)	SEP & DEP including export cable corridor area	0.64 (0.0074% of SE MU or 0.0027% of wider ref pop)	**Negligible (negligible)**
	Harbour seal (PW)	SEP & DEP including export cable corridor area	0.06 (0.0016% of SE MU or 0.0002% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.4.6.1 *Duration of Construction Vessel Activity*

455. The maximum duration for the offshore construction period, including piling and export cable installation, is up to two years for concurrent construction. Therefore, it is assumed that construction vessels could be on either SEP or DEP, including export cable corridor areas, for two years.

10.6.1.4.6.2 *Impact Significance*

456. Taking into account the medium sensitivity to TTS and disturbance (**Table 10-20**) and the potential magnitude of the impact, as assessed in **Table 10-68**, the impact significance for underwater noise and disturbance from construction vessels at SEP and DEP has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-69**).

Table 10-69: Assessment of Impact Significance for Underwater Noise and Disturbance from Construction Vessels at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS from cumulative SEL for construction vessels	Harbour porpoise	SEP & DEP including export cable corridor area	Medium	Negligible	**Minor adverse**	No additional mitigation proposed. It is assumed best practice measures will be applied.	**Minor adverse**
	Bottlenose dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	White-beaked dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Minke whale		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Grey seal		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Harbour seal		Medium	Negligible	**Minor adverse**		**Minor adverse**
Disturbance from construction vessels	All marine mammals	SEP & DEP including export cable corridor area	Medium	Low	**Minor adverse**		**Minor adverse**

10.6.1.4.6.3 *Mitigation*

457. No mitigation is proposed for underwater noise from construction vessels, as the risk of any impact is not significant.

458. However, vessel movements, where possible, will be incorporated into recognised vessel routes and hence to areas where marine mammals are accustomed to vessels, in order to reduce any impacts, including increased disturbance. All vessel movements will be kept to the minimum number that is required to reduce any potential impacts, including increased disturbance. Additionally, vessel operators will use good practice to reduce impacts on marine mammals (see the **Draft MMMP** (document reference 9.4)).

10.6.1.5 Impact 5: Barrier Effects from Underwater Noise during Construction

459. Underwater noise during construction could have the potential to create a barrier effect, preventing movement or migration of marine mammals between important feeding and / or breeding areas, or potentially increasing swimming distances if marine mammals avoid the site and go around it. However, SEP and DEP, including the export cable corridor are not located on any known migration routes for marine mammals.

460. Telemetry studies (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**) and the relatively low seal at sea usage (Carter *et al.,* 2020; see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**) in and around SEP and DEP do not indicate any regular seal foraging routes through the sites. **Plate 10-5** indicates that harbour seal will still undertake foraging activity during wind farm construction activities, based on a study by Russell (2016b).

461. SEP and DEP are located 15.8km and 26.5km from the coast, respectively. The nearest main seal haul-out site at Blakeney Point is approximately 12km from the export cable corridor at its closest point (**Section 10.5.5** and **10.5.6**).

10.6.1.5.1.1 *Duration of Barrier Effects from Underwater Noise during Construction*

462. Based on assessment in **Table 10-50**, if SEP and DEP were constructed sequentially the maximum duration of piling, based on worst-case scenarios, including soft-start, ramp-up and ADD activation would be:

- SEP & DEP sequentially
  - Piling of 53 monopiles and two OSPs (including soft-start, ramp-up and ADD activation) = up to 270 hours (11.25 days) with 10 minute activation (or up to 280 hours (12 days) with 20 minute ADD activation); or
  - Piling of 212 pin-piles and two OSPs (including soft-start, ramp-up and ADD activation) = up to 694 hours (29 days) with 10 minute ADD activation (or up to 704 hours (30 days) with 20 minute ADD activation).

463. However, if SEP and DEP were constructed concurrently, and assuming piling at the same time on each site, the maximum duration of piling, based on worst-case scenarios, including soft-start, ramp-up and ADD activation would be the same as the assessments for DEP in isolation (e.g. 2 x 23 monopiles installed at the same time at both SEP and DEP plus additional 7 monopiles at DEP in isolation = 30 monopiles; or 2 x 92 pin-piles installed at the same time at both SEP and DEP plus additional 28 pin-piles at DEP in isolation = 120 pin-piles) plus the two OSPs:

- SEP and DEP simultaneously
    - Piling of 53 monopiles (2 x 23 monopiles concurrently installed) and two OSPs (including soft-start, ramp-up and ADD activation) = up to 174 hours (up to 7.5 days) with 10 minute activation (or 180 hours (up to 8 days) with 20 minute ADD activation); or
    - Piling of 212 pin-piles (2 x 92 concurrently installed) and two OSPs (including soft-start, ramp-up and ADD activation) = 414 hours (17.5 days) with 10 minute ADD activation (or 420 hours (up to 18 days) with 20 minute ADD activation).

10.6.1.5.2 Impact Assessment for SEP or DEP In Isolation

464. The greatest potential barrier effect for marine mammals could be from underwater noise during piling (**Section 10.6.1.2**). As outlined in **Section 10.6.1.2.2.5**, piling would not be constant during the piling phases and construction periods. There will be gaps between the installations of individual piles, and if installed in groups there could be time periods when piling is not taking place as piles are brought out to the site. There will also be potential delays for weather or other technical issues.

465. The maximum duration of any barrier effects would be for the maximum piling duration at SEP and DEP, based on worst-case scenarios, including soft-start, ramp-up and ADD activation, as assessed in **Table 10-50**.

466. There is unlikely to be the potential for any barrier effects from underwater noise for other construction activities (**Section 10.6.1.3**) and vessels (**Section 10.6.1.4**), as it is predicted that marine mammals will return once the activity has been completed and therefore any impacts from underwater noise as a result of construction activities other than piling noise will be both localised and temporary. Therefore, there is unlikely to be the potential for any barrier effects that could significantly restrict the movements of marine mammals.

467. Marine mammals are wide ranging. For example, grey seals travel over 100km between haul-out sites and with foraging trips lasting up to 30 days (SCOS, 2020). Data from The Wash (from 2003- 2005) suggest that harbour seal in this area travel and forage between 75km and 120km offshore (Sharples *et al.,* 2008). Therefore, if there are any potential barrier effects from underwater noise, marine mammals would be able to compensate by travelling to other foraging areas within their range.

468. There is unlikely to be any significant long-term impacts from any barrier effects, as any areas affected would be relatively small in comparison to the range of marine mammals and would not be continuous throughout the offshore construction period. The magnitude of impact for any potential temporary barrier effects, based on worst-case, is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-70**).

469. Taking into account the medium marine mammal sensitivity and the potential magnitude of the impact, the impact significance for any potential barrier effects at either SEP or DEP as a result of underwater noise during construction has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-70**).

Table 10-70: Assessment of Impact Significance for Any Potential Barrier Effects from Underwater Noise during Construction at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Barrier effects from underwater noise	Harbour porpoise	SEP or DEP including export cable	Medium	Negligible	**Minor adverse**	No mitigation proposed. However, while not proposed mitigation for this effect, the measures in SIP will reduce potential barrier effects of harbour porpoise (and other marine mammals)	**Minor adverse**
	Bottlenose dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	White-beaked dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Minke whale		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Grey seal		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Harbour seal		Medium	Negligible	**Minor adverse**		**Minor adverse**

10.6.1.5.3 Mitigation

470. A SIP for the SNS SAC will be developed (as outlined in **Section 10.3.4.2**) to set out the approach to deliver any project mitigation or management measures in relation to the barrier effects of harbour porpoise.

471. Any measures to reduce the potential significant disturbance of harbour porpoise would also reduce the potential for any significant disturbance, including barrier effects, in other marine mammal species.

10.6.1.5.4 Impact Assessment for SEP and DEP

472. Based on the qualitative assessment for SEP or DEP in isolation and the shorter duration of piling during SEP and DEP, the magnitude of impact for any potential temporary barrier effects for SEP and DEP is also assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-70**).

473. Taking into account the marine mammal sensitivity and the potential magnitude of the impact, as assessed for SEP or DEP in isolation the impact significance for any potential barrier effects as a result of underwater noise during concurrent construction at SEP and DEP has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-71**).

474. Mitigation would be the same as outlined in **Section 10.6.1.5.3** for SEP or DEP in isolation.

Table 10-71: Assessment of Impact Significance for Any Potential Barrier Effects from Underwater Noise during Construction at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Barrier effects from underwater noise	Harbour porpoise	SEP & DEP including export cable	Medium	Negligible	**Minor adverse**	No mitigation proposed. However, measures in SIP will reduce potential significant disturbance of harbour porpoise (and other marine mammals)	**Minor adverse**
	Bottlenose dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	White-beaked dolphin		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Minke whale		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Grey seal		Medium	Negligible	**Minor adverse**		**Minor adverse**
	Harbour seal		Medium	Negligible	**Minor adverse**		**Minor adverse**

10.6.1.6 Impact 6: Increased Risk of Collision with Vessels during Construction

475. During the offshore construction phase of SEP and DEP there will be an increase in vessel traffic within the wind farm sites and offshore cable corridors. However, it is anticipated that vessels would follow an established shipping route to the relevant ports in order to minimise vessel traffic in the wider area. The **Draft MMMP** (document reference 9.4) provides a protocol for minimising collision risk of marine mammals with vessels.

10.6.1.6.1 Sensitivity of Marine Mammals

476. Marine mammals in and around SEP and DEP and in the wider SNS area would typically be habituated to the presence of vessels (given the existing levels of marine traffic, see **Chapter 13 Shipping and Navigation**) and would be able to detect and avoid vessels. However, as a precautionary approach the sensitivity of marine mammals to collision risk with vessels during construction is considered to be high.

10.6.1.6.2 Magnitude for SEP or DEP in Isolation

477. The approximate number of vessels on site at any one time during construction is estimated to be 16 vessels at SEP or DEP, with an average of approximately 25 trips per month, resulting in a daily average of approximately 0.83 vessel movements, based on 603 vessel trips over two year construction period (**Table 10-1**).

478. As outlined in **Chapter 13 Shipping and Navigation**, the baseline conditions indicate an already relatively high level of shipping activity in and around SEP, DEP and the offshore export cable corridor. Shipping and navigation data indicate 13 existing main routes within the study area, with two routes crossing the SEP wind farm site, four routes crossing the DEP wind farm site and 10 crossing the cable corridor. The number of vessels on these main vessel routes could be up to 75 vessels per day.

479. As described within **Appendix 13.1 Navigational Risk Assessment**, there is an existing relatively high level of vessel traffic within the navigational study area (SEP and DEP plus 10km buffer), including area close to the coastline. In summer, an average of 82 vessels were recorded per day within the study area, and in winter an average of 81 vessels were recorded.

480. In total, for the construction of either SEP or DEP, the daily construction vessel trips represent a very small increase of 1% compared to average daily vessels currently within the SEP and DEP shipping and navigation study area, during summer and winter.

481. Marine mammals are able to detect and avoid vessels. However, vessel strikes are known to occur, possibly due to distraction whilst foraging and socially interacting, or due to the marine mammals’ inquisitive nature (Wilson *et al*., 2007). Therefore, increased vessel movements, especially those outwith recognised vessel routes, can pose an increased risk of vessel collision to marine mammals.

482. Studies have shown that larger vessels are more likely to cause the most severe or lethal injuries, with vessels over 80m in length causing the most damage to marine mammals (Laist *et al*., 2001). Vessels travelling at high speeds are considered to be more likely to collide with marine mammals, and those travelling at speeds below 10 knots would rarely cause any serious injury (Laist *et al*., 2001).

483. Harbour porpoise are small and highly mobile and given their responses to vessel noise (e.g. Thomsen *et al*., 2006; Polacheck and Thorpe, 1990), are expected to largely avoid vessel collisions. The Heinänen and Skov (2015) report indicates a negative relationship between the number of ships and the distribution of harbour porpoise in the North Sea, suggesting that the species could exhibit avoidance behaviour which reduces the risk of strikes.

484. Between 2005 and 2015, the UK Cetacean Strandings Investigation Programme (CSIP) conducted 849 post-mortem examinations of the 3,598 reported harbour porpoise strandings. A cause of death was established in 815 examined individuals, of these, 45 had died from physical trauma of unknown cause and 17 (2%) died as a result of physical trauma following probable impact from a ship or boat (CSIP, 2011-2016; **Table 10-72**).

485. Between 2005 and 2015 one bottlenose dolphin and one white-beaked dolphin died as a result of physical trauma of unknown cause and two minke whale had died as a result of physical trauma following probable impact from a ship or boat (CSIP, 2011-2016; **Table 10-72**).

486. Approximately 4% of all harbour porpoise post mortem examinations from the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS area) are thought to have evidence of interaction with vessels (Evans *et al*., 2011).

Table 10-72: Summary of UK Cetacean Strandings (2005-2015) and Causes of Death from Physical Trauma of Unknown Cause and Physical Trauma Following Probable Impact from a Ship or Boat

Species	Number of strandings	Number of post-mortems	Number of post-mortems where cause of death established	Cause of death: physical trauma of unknown cause	Cause of death: physical trauma following probable impact from a ship or boat
Harbour porpoise	3,598	849	815	45	17
Bottlenose dolphin	102	36	27	1	0
White-beaked dolphin	149	56	52	1	0
Minke whale	162	27	25	0	2

487. There is currently limited information on the collision risk of marine mammals in the SNS area.

488. The CSIP data (**Table 10-72**) shows that mortality of cetaceans from vessel collisions can occur, although it accounts for a relatively small number of the strandings where cause of death was established. It is also important to note that the strandings data are biased to those carcasses that wash ashore for collection and therefore may not be representative.

489. In 2016, SMRU conducted a study to determine the likelihood of harbour seal injury occurring due to co-presence with large vessels within the Moray Firth (Onoufriou *et al*., 2016). This study used telemetry data of harbour seal within the Moray Firth, alongside vessel AIS data. The data indicated vessel and seal co-occurrence was high (defined as over 2,500 co-occurrence minutes per year) in very localised areas. However, there appeared to be no relationship between areas in high co-occurrence and incidences of injury (Onoufriou *et al*., 2016).

490. 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).

491. Although the risk of collision is likely to be low, as a precautionary worst-case scenario, the number of marine mammals that could be at increased collision risk with vessels during construction has been assessed based on 5% of the number of animals that could be present in the SEP, DEP and offshore export cable corridor potentially being at increased collision risk (**Table 10-73**).

492. This is a highly precautionary assumption, as it is unlikely that marine mammals present in the SEP, DEP and export cable corridor areas would be at increased collision risk with vessels during construction, considering the minimal number of vessel movements compared to the existing number of vessel movements in the area and that vessels within the wind farm sites and cable corridor areas would be stationary or very slow moving. In addition, based on the assumption that marine mammals would be disturbed as a result of the vessel noise and presence (**Table 10-73**), there should be no potential for increased collision risk with construction vessels.

493. The magnitude for potential increased collision risk with construction vessels based on a precautionary worst-case scenario has been assessed as low for harbour porpoise, low (medium) for bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, medium (medium) for grey seal and medium (low) for harbour seal (**Table 10-73**). However, as previously outlined, taking into account the disturbance from vessels, the actual risk is likely to be very low or negligible.

Table 10-73: Estimated Number of Individuals (and % of Reference Population) that Could be at Increased Collision Risk with Construction Vessels, based on 5% of Individuals Present in SEP or DEP and Offshore Export Cable Corridors

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise	SEP and export cable corridor (160.8km^2)	5.1 (0.0015% of NS MU)	Low

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
	DEP and export cable corridor (211.6km^2)	25.7 (0.0074% of NS MU)	Low
Bottlenose dolphin	SEP and export cable corridor (160.8km^2)	0.24 (0.01% of GNS MU; 0.11% CES MU)	Low (medium)
	DEP and export cable corridor (211.6km^2)	0.32 (0.02% of GNS MU; 0.14% CES MU)	Low (medium)
White-beaked dolphin	SEP and export cable corridor (160.8km^2)	0.05 (0.0001% of CGNS MU)	Negligible
	DEP and export cable corridor (211.6km^2)	0.06 (0.0001% of CGNS MU)	Negligible
Minke whale	SEP and export cable corridor (160.8km^2)	0.08 (0.0004% of CGNS MU)	Negligible
	DEP and export cable corridor (211.6km^2)	0.11 (0.0005% of CGNS MU)	Negligible
Grey seal	SEP and export cable corridor (160.8km^2)	6.9 (0.08% of SE MU or 0.03% of wider ref pop)	Medium (medium)
	DEP and export cable corridor (211.6km^2)	7.8 (0.09% of SE MU or 0.03% of wider ref pop)	Medium (medium)
Harbour seal	SEP and export cable corridor (160.8km^2)	2.2 (0.06% of SE MU or 0.007% of wider ref pop)	Medium (low)
	DEP and export cable corridor (211.6km^2)	0.9 (0.02% of SE MU or 0.003% of wider ref pop)	Medium (low)

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.6.3 Impact Significance

494. Taking into account the high marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 10-73**, the impact significance for any potential increased collision risk as a result of vessels during construction at either SEP or DEP including the offshore export cable corridor has been assessed as moderate for harbour porpoise, moderate (major) for bottlenose dolphin, minor for white-beaked dolphin and minke whale, major (major) for grey and major (moderate) harbour seal at SEP or DEP (**Table 10-74**).

10.6.1.6.4 Mitigation

495. As outlined in the **Draft MMMP** (document reference 9.4) and the **Outline Project Environmental Management Plan (PEMP)** (document reference 9.10) submitted with the DCO application), vessel movements, where possible, will be incorporated into recognised vessel routes (including those already used for the existing SOW and DOW) and hence to areas where marine mammals are accustomed to vessels, in order to reduce any increased collision risk. All vessel movements will be kept to the minimum number that is required to reduce any potential for collision risk. Additionally, vessel operators will use good practice to reduce any risk of collisions with marine mammals.

496. *Residual Impact*

497. The residual impact, taking into account good practice to reduce any risk of collisions with marine mammals, would be **minor adverse (not significant)** at either SEP or DEP including the offshore export cable corridor for all marine mammals. There have been no known reported incidents of marine mammal collisions with offshore wind farm vessels.

Table 10-74: Assessment of Impact Significance for Any Increased Collision Risk with Vessels during Construction at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Increased collision risk	Harbour porpoise	SEP including export cable	High	Low	Moderate	Recommended good practice **Draft MMMP** (document reference 9.4).	**Minor adverse**
		DEP including export cable		Low	Moderate		**Minor adverse**
	Bottlenose dolphin	SEP including export cable	High	Low (medium)	Moderate (major)		**Minor adverse**
		DEP including export cable		Low (medium)	Moderate (major)		**Minor adverse**
	White-beaked dolphin	SEP including export cable	High	Negligible	Minor		**Minor adverse**
		DEP including export cable		Negligible	Minor		**Minor adverse**
	Minke whale	SEP including export cable	High	Negligible	Minor		**Minor adverse**
		DEP including export cable		Negligible	Minor		**Minor adverse**
	Grey seal	SEP including export cable	High	Medium (medium)	Major (major)		**Minor adverse**
		DEP including export cable		Medium (medium)	Moderate (moderate)		**Minor adverse**
	Harbour seal	SEP including export cable	High	Medium (low)	Major (moderate)		**Minor adverse**

Potential Impact	Species	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
		DEP including export cable		Medium (low)	Major (moderate)		**Minor adverse**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.6.5 Impact Assessment for SEP and DEP

498. As a precautionary worst-case the number of marine mammals that could be at increased risk of collision with construction vessels, if SEP and DEP are constructed concurrently has been based on the estimated maximum number for SEP or DEP in isolation (**Table 10-75**).

499. The magnitude for potential increased collision risk with construction vessels based on a precautionary worst-case scenario has been assessed as low for harbour porpoise, medium (medium) for bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, medium (medium) for grey seal and medium (medium) for harbour seal (**Table 10-75**).

500. The magnitude of the potential impact is assessed as medium for bottlenose dolphin, however, as previously outlined, the assessments for bottlenose dolphin have been based on a very precautionary approach, as there is currently no density estimate for the area in and around SEP and DEP. In addition, bottlenose dolphin are more likely to be present close to shore, rather than the offshore areas. Therefore, the risk of any increased collision of bottlenose dolphin is likely to be a lot less than in the worst-case assessment.

501. In addition, as previously outlined, taking into account the disturbance from vessels, the actual risk is likely to be very low or negligible.

Table 10-75: Estimated Number of Individuals (and % of Reference Population) that Could be at Increased Collision Risk with Construction Vessels, based on 5% of Individuals Present in SEP and DEP Wind Farm Sites and Export Cable Corridor

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	Magnitude* (permanent impact)
Harbour porpoise	SEP & DEP and export cable corridor areas (372.4km^2)	27.9 (0.008% of NS MU)	**Low**
Bottlenose dolphin	SEP & DEP and export cable corridor areas (372.4km^2)	0.55 (0.027% of GNS MU; 0.25% CES MU)	**Medium (medium)**
White-beaked dolphin	SEP & DEP and export cable corridor areas (372.4km^2)	0.11 (0.0003% of CGNS MU)	**Negligible**
Minke whale	SEP & DEP and export cable corridor areas (372.4km^2)	0.19 (0.0009% of CGNS MU)	**Negligible**
Grey seal	SEP & DEP and export cable corridor areas (372.4km^2)	14.7 (0.17% of SE MU or 0.06% of wider ref pop)	**Medium (medium)**
Harbour seal	SEP & DEP and export cable corridor areas (372.4km^2)	3.1 (0.08% of SE MU or 0.01% of wider ref pop)	**Medium (medium)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.6.5.1 *Impact Significance*

502. Taking into account the high marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 10-75**, the impact significance for any potential increased collision risk as a result of vessels during construction of SEP and DEP has been assessed as moderate for harbour porpoise, major (major) for bottlenose dolphin, minor for white-beaked dolphin, minor for minke whale, major (major) for grey seal and major (major) for harbour seal (**Table 10-76**).

10.6.1.6.5.2 *Mitigation*

503. As outlined in **Section 10.6.1.6.4**.

10.6.1.6.6 Residual Impact

504. The residual impact, taking into account good practice to reduce any risk of collisions with marine mammals, would be **minor adverse (not significant)** for all marine mammals.

Table 10-76: Assessment of Impact Significance for any Increased Collision Risk with Vessels during Construction at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Increased collision risk	Harbour porpoise	SEP & DEP including export cable	High	Low	Moderate	Recommended good practice as **Draft MMMP** (document reference 9.4).	**Negligible to Minor adverse**
	Bottlenose dolphin	SEP & DEP including export cable	High	Medium (medium)	Major (major)		**Negligible to Minor adverse**
	White-beaked dolphin	SEP & DEP including export cable	High	Negligible	Minor		**Negligible to Minor adverse**
	Minke whale	SEP & DEP including export cable	High	Negligible	Minor		**Negligible to Minor adverse**
	Grey seal	SEP & DEP including export cable	High	Medium (medium)	Major (major)		**Negligible to Minor adverse**
	Harbour seal	SEP & DEP including export cable	High	Medium (medium)	Major (major)		**Negligible to Minor adverse**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.7 Impact 7: Disturbance at Seal Haul-Out Sites

505. Increased activity around landfall, including an increase in vessel and human activity, has the potential to disturb seals at haul-out sites, particularly during sensitive periods, such as the breeding season and moult period. The grey seal moult period is between December and April, and their pupping occurs mainly between early November and mid-December (see **Section 10.5.5**). For harbour seal, the pupping season is between June and July (see **Section 10.5.6**).

506. Disturbance from vessel transits to and from SEP and DEP also has the potential to disturb seals at haul-out sites, depending on the route and proximity to the haul-out sites.

507. The Blakeney Point haul-out site is located closest to SEP and DEP at approximately 12km from the offshore export cable corridor). As outlined in **Sections 10.5.5** and **10.5.6**, the Blakeney Point haul-out site has a significant number of both grey seal and harbour seal. Other haul-out sites further from SEP and DEP are at Horsey (44km at closest point), Scroby Sands (58km at closest point), The Wash (57km at closest point) and Donna Nook (66km at closest point). Given the distances between the SEP and DEP and the nearest known seal haul-out sites; there is very little potential for any direct disturbance as a result of construction activities. Moreover, given that the likely construction port will be at Great Yarmouth, vessels transiting to and from SEP and DEP would not pass within the vicinity of the Blakeney Point haul-out site.

508. Whilst the construction port(s) to be used for SEP and DEP is not yet confirmed, it is likely to be Great Yarmouth which is currently used for SOW and DOW operation and maintenance activities. Vessel movements to and from any port will be incorporated within existing vessel routes. Taking into account the proximity of shipping channels to and from existing ports, it is likely that seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels.

509. There is an existing relatively high level of vessel traffic within the navigational study area (SEP and DEP plus 10km buffer), including close to the coastline. In summer, an average of 82 vessels were recorded per day within the study area, and in winter an average of 81 vessels were recorded (**Appendix 13.1 Navigational Risk Assessment**). High density navigation routes[4] show an average of up to 16 vessels per day (per $4km^2$) travelling along an existing vessel route within 7km of Blakeney Point in 2015, and up to 111 vessels per day (per $4km^2$) passing along a vessel route within 6km of Donna Nook.

10.6.1.7.1 Sensitivity of Seals

510. Both grey seal and harbour seal may become disturbed from haul-out sites due to the presence of vessels, which, if occurring in the breeding season, can result in the abandonment of pups. Due to this, both grey seal and harbour seals are considered to be sensitive to vessel disturbance at haul-out sites, particularly if that occurs within the breeding season.

[redacted] [accessed 24/02/2021]

511. The response of seals to disturbance at haul-out sites can range from increased alertness to moving into the water (Wilson, 2014). The potential impact on pupping groups can include temporary or permanent pup separation, disruption of suckling, energetic costs and energetic deficit to pups, physiological stress and sometimes enforced move to distant or suboptimal habitat. Potential impacts on moulting groups can include energy loss and stress, while impacts on other haul-out groups can cause loss of resting and digestion time and stress (Wilson, 2014). The potential impacts will be determined by the response of the seals, the duration and proximity of the disturbance to the seals.

512. Studies on the distance of disturbance, on land or in the water, for hauled-out harbour seals have found that the closer the disturbance, the more likely seals are to move into the water. The estimated distance at which most seal movements into the water occurred varies from study site and type of disturbance but has been estimated at typically less than 100m (Wilson, 2014).

513. For grey seal, mothers responded by moving into the water more due to boat speed than as a result of the distance, although movement into the water was generally observed to occur at distances of between 20 and 70m, with no detectable disturbance at 150m (Wilson, 2014; Strong and Morris, 2010). However, grey and harbour seals have also been reported to move into the water when vessels are at a distance of approximately 200m to 300m (Wilson, 2014).

514. A study was carried out by SMRU (Paterson *et al.,* 2015) using a series of controlled disturbance tests at harbour seal haul-out sites, consisted of regular (every three days) disturbance through direct approaches by vessel and effectively 'chasing' the seals into the water. The seal behaviour was recorded via GPS tags, and found that even intense levels of disturbance did not cause seals to abandon their haul-out sites more than would be considered normal (for example seals travelling between sites) and the seals were found to haul-out at nearby sites or to undertake a foraging trip in response to the disturbance (but would later return).

515. Further studies on the effects of vessel disturbance on harbour seals when they are hauled out, suggest that even with repeated disturbance events that are severe enough to cause individuals to flee into the water, the likelihood of harbour seals moving to a different haul-out site would not increase. Furthermore, this appeared to have little effect on their movements and foraging behaviour (Paterson *et al.,* 2019).

516. A study of the reactions of harbour seal from cruise ships found that, if a cruise ship was less than 100m from a harbour seal haul-out site, individuals were 25 times more likely to flee into the water than if the cruise ship was at a distance of 500m from the haul-out site (Jansen *et al.,* 2010). At distances of less than 100m, 89% of individuals would flee into the water, at 300m this would fall to 44% of individuals, and at 500m, only 6% of individuals would flee into the water (Jansen *et al.,* 2010). Beyond 600m, there was no discernible effect on the behaviour of harbour seal.

517. Therefore, it is considered that, for grey seal, vessels travelling within 300m of a haul-out site, a grey seal may flee into water, but significant disturbance would be expected at a distance of less than 150m. For harbour seal, if a vessel travels within 600m of a haul-out site, there is the potential for a flee response, and if a vessel is within 300m, a significant number of harbour seal would flee.

518. The sensitivity of both seal species to disturbance from seal haul-out sites is therefore low, and as a very precautionary approach, it is proposed that sensitivity during the breeding season and annual moult could be slightly higher and has therefore been considered as medium in this assessment.

10.6.1.7.2 Magnitude for SEP or DEP in Isolation

519. SEP and DEP are located 12km at closest point to any seal haul-out site (**Sections 10.5.5** and **10.5.6**), there is therefore no potential for any direct disturbance as a result of construction activities within either SEP or DEP (including landfall and the export cable corridor).

520. Therefore, the potential for any increase in disturbance to seal haul-out sites as a result of construction activities at the offshore wind farm sites, activities along the cable route and at landfall site, or vessels in these areas during construction will be negligible.

521. Vessel movements to SEP and DEP from the chosen construction port(s) (anticipated to be Great Yarmouth) would use direct established routes and are unlikely to be close to the shore, or within the distance required to cause a disturbance impact, based on the distance thresholds as noted above (of 300m for grey seal and 600m for harbour seal), except when near the port to avoid the risk of collision and grounding.

522. In addition, taking into account the proximity of shipping channels to and from existing ports, it is likely that any seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels.

523. In total, for the construction of either SEP or DEP, up to 16 construction vessels may be on the site at any one time, representing an increase of 20% compared to average daily vessels (n=82, in summer) currently within the SEP and DEP vessel and navigation study area, or an increase of 18% compared to the average daily vessels present in winter (n=81). This represents a relatively significant increase in the current number of vessels in the area.

524. However, taking into account the proximity of shipping channels to and from existing ports, it is likely that seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels. Therefore, the magnitude of impact of grey and harbour seals at haul-out sites to disturbance from vessels moving to and from the port(s) during construction is likely to be negligible.

10.6.1.7.2.1 *Impact Significance*

525. Taking into account the low to medium sensitivity, and the potential magnitude of negligible for the temporary impact, the impact significance for disturbance at seal haul-out sites during construction of SEP or DEP has been assessed as **negligible to minor adverse (not significant)** for both grey seal and harbour seal (**Table 10-77**).

Table 10-77: Assessment of Impact Significance for Disturbance at Seal Haul-Out Sites During Construction

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Disturbance at seal haul-out sites	Grey seal	SEP	Low to Medium	Negligible	**Negligible to minor adverse**	Recommended good practice as outlined in the **Draft MMMP** (document reference 9.4).	**Negligible to Minor adverse**
		DEP		Negligible	**Negligible to minor adverse**		**Negligible to Minor adverse**
	Harbour seal	SEP	Low to Medium	Negligible	**Negligible to minor adverse**		**Negligible to Minor adverse**
		DEP		Negligible	**Negligible to minor adverse**		**Negligible to Minor adverse**

10.6.1.7.2.2 *Mitigation*

526. No mitigation is required for the disturbance of seals at haul-out sites. However, as outlined in the **Outline PEMP** (document reference 9.10), where possible and safe to do so, transiting vessels would maintain distances of 600m or more off the coast, particularly in areas near known seal haul-out sites during sensitive periods. All vessel movements will be kept to the minimum number that is required to reduce any potential for disturbance.

10.6.1.7.3 Impact Assessment for SEP and DEP

527. The impacts for SEP and DEP would be the same as those assessed for SEP or DEP in isolation. Whilst the number of construction vessel trips would be double the SEP or DEP in isolation scenario, the number on each site at any one time would be the same, as would the vessel transit routes. Trips would be spread over a longer time period, however, given the good practice mitigation maintaining distances from seal-haul out sites (see the **Outline PEMP** (document reference 9.10)), there would be no change of the magnitude or overall impact significance conclusions under a SEP and DEP scenario in comparison to the either SEP or DEP in isolation scenarios.

10.6.1.8 Impact 8: Changes to Prey Availability

528. As outlined in **Chapter 9 Fish and Shellfish Ecology**, the potential impacts on fish species during construction can result from:

- Physical disturbance and temporary loss of sea bed habitat;
- Increased SSCs and sediment re-deposition;
- Re-mobilisation of contaminated sediment; and
- Underwater noise.

529. Any impacts on prey species has the potential to affect marine mammals.

10.6.1.8.1 Sensitivity of Marine Mammals

530. As outlined in **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**, the diet of harbour porpoise consists of a wide variety of prey species and varies geographically and seasonally, reflecting changes in available food resources. Harbour porpoise have relatively high daily energy demands and need to capture enough prey to meet daily energy requirements. It has been estimated that, depending on the conditions, harbour porpoise can rely on stored energy (primarily blubber) for three to five days, depending on body condition (Kastelein *et al*., 1997). Harbour porpoise are therefore considered to have low to medium sensitivity to changes in prey resources.

531. Bottlenose dolphin and white-beaked dolphin are opportunistic feeders, feeding on wide range of prey species and have large foraging ranges (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**) and are therefore considered to have low sensitivity to changes in prey resources.

532. Minke whale feed on a variety of prey species, but in some areas, they have been found to prey upon specific species at the population level (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). Therefore, minke whale are considered to have a low to medium sensitivity to changes in prey resource.

533. Grey and harbour seal feed on a variety of prey species, both are considered to be opportunistic feeders, feeding on wide range of prey species and they are able to forage in other areas and have relatively large foraging ranges (see **Appendix 10.1 Marine Mammal Consultation Responses, Information and Survey Data**). Grey seal and harbour seal are therefore considered to have low sensitivity to changes in prey resources.

10.6.1.8.2 Magnitude for SEP or DEP in Isolation

10.6.1.8.2.1 *Physical Disturbance and Temporary Habitat Loss*

534. During construction, activities such as foundation installation (for wind turbines and OSPs), sea bed preparation (including sandwave levelling, boulder removal and UXO clearance), the trenching and burial of interlink cables, infield cables and offshore export cables, cable protection, vessel moorings and jack-up vessel legs all have the potential to cause physical disturbance or temporary loss of sea bed habitat (see **Chapter 8 Benthic Ecology** and **Chapter 9 Fish and Shellfish Ecology**).

535. During construction, the maximum total area of sea bed habitat that could be disturbed is (**Table 10-1**):

- SEP in isolation = up to 2.12km^2 (approximately 1.32% of the SEP wind farm site and offshore export cable corridor)
- DEP in isolation = up to 5.12km^2 (approximately 2.42% of the DEP wind farm site and offshore export cable corridor)

536. The disturbance would be temporary during the approximate two years (24 months) of construction activity at each site with the majority of disturbance occurring during installation of foundations and cables. Some elements of disturbance, such as that caused by jack-up vessel legs, will be highly localised and only occur over a short period.

537. The magnitude of effect of physical disturbance to sea bed habitat during construction has been assessed as low for SEP and DEP in **Chapter 8 Benthic Ecology**. In **Chapter 9 Fish and Shellfish Ecology** the magnitude of physical disturbance during construction activities for either SEP or DEP is considered to be negligible for all species, based on the availability of similar suitable habitat both in the offshore development areas and in the wider context of the SNS together with the intermittent and reversible nature of the effect. The impact significance for fish species is assessed as negligible to minor adverse.

538. Therefore, any potential changes to prey availability as a result of physical disturbance and temporary habitat loss is assessed as negligible for marine mammals.

539. Temporary habitat loss during construction has not been assessed as a direct impact on marine mammals, as any impacts of habitat loss would only cause an indirect effect in terms of changes in prey availability.

10.6.1.8.2.2 *Increased Suspended Sediments and Sediment Deposition*

540. Construction activities such as sea bed preparation, foundation installation, drilling operations and cable installation may lead to the potential for increased SSC in the water column and subsequent sediment re-deposition. Activities such as sea bed disturbances from jack-up vessels and placement of cable protection are not expected to increase the SSCs to the extent to which it would cause an impact to benthic or fish receptors.

541. Increases in suspended sediment are expected to cause localised and short-term increases in SSC at the point of discharge. Released sediment may then be transported by tidal currents in suspension in the water column. Due to the small quantities of fine-sediment released, the fine-sediment is likely to be widely and rapidly dispersed. This would result in only low SSCs and low changes in sea bed level when the sediments are deposited. In **Chapter 8 Benthic Ecology**, the impact magnitude is considered to be negligible at SEP and DEP. The magnitude of effect in **Chapter 9 Fish and Shellfish Ecology** is assessed as low for all species at SEP and DEP. The impact significance for fish species is assessed as minor adverse.

542. Therefore, any potential changes to prey availability as a result of increased SSCs and sediment deposition is assessed as negligible for marine mammals.

10.6.1.8.2.3 *Re-mobilisation of Contaminated Sediment*

543. The data and analysis in **Chapter 7 Marine Water and Sediment Quality** indicates that levels of contaminants at SEP and DEP are very low and do not contain elevated levels to cause concern, therefore the magnitude of the effect is negligible.

544. Therefore, any potential changes to prey availability as a result of re-mobilisation of contaminated sediments is assessed as being of negligible significance for marine mammals.

10.6.1.8.2.4 *Underwater noise*

545. Potential sources of underwater noise and vibration during construction include UXO clearance, piling, increased vessel traffic, sea bed preparation, rock placement and cable installation. Of these, UXO clearance and piling are considered to produce the highest levels of underwater noise and therefore has the greatest potential to result in adverse impacts on fish.

546. High levels of underwater noise can cause physiological (mortality, permanent injury or temporary injury), behavioural (startled movements, swimming away from noise source, change migratory patterns or cease reproductive activities) and environmental (changes to prey species or feeding behaviours) impacts on fish species.

547. Underwater noise modelling (**Appendix 10.2 Underwater Noise Modelling Report**), assessed the following fish groups (based on Popper *et al*., 2014):

- No swim bladder (e.g. sole, plaice, lemon sole, mackerel and sandeels);
- Swim bladder not involved in hearing (e.g. sea bass, salmon and sea trout); and

- Swim bladder which is involved in hearing (e.g. cod, whiting, sprat and herring).

548. The underwater noise modelling results (**Appendix 10.2 Underwater Noise Modelling Report**) indicates that fish species in which the swim bladder is involved in hearing are the most sensitive to the impact of underwater noise, therefore the worst-case scenario assessment uses these species as an indicator of overall effects.

Piling

549. **Table 10-78** summarises some of the maximum impact ranges and areas for fish species during piling, further details are provided in **Appendix 10.2 Underwater Noise Modelling Report** and **Chapter 9 Fish and Shellfish Ecology**.

550. The maximum predicted cumulative impact range for TTS of 19km for fish species based on stationary model (**Appendix 10.2 Underwater Noise Modelling Report**), is the same as TTS SEL_{cum} range for harbour porpoise, less than the TTS SEL_{cum} range of 25km for minke whale, but greater than the TTS SEL_{cum} range of 0.4km for bottlenose dolphin and white-beaked dolphin, and 9.7km for grey and harbour seal (**Table 10-25**). However, it is important to note that the SEL_{cum} modelling is based on a stationary model. This is considered to be a highly precautionary approach, as it is unlikely that an individual would remain within the vicinity of the high noise levels.

551. Therefore, modelling assuming a fleeing animal in response to noise, especially fish with a swim bladder involved in hearing, is more realistic and has been used to assess the potential impact on marine mammals. As for marine mammals, the TTS impact range is assumed to be the same as a behavioural fleeing response in fish species (and the TTS impact ranges are used as a proxy for disturbance impacts on fish species).

552. The maximum predicted cumulative impact range for TTS of 12km for fish species based on the fleeing response model (**Table 10-78**), is less than the TTS SEL_{cum} range of 19km for harbour porpoise and 25km for minke whale, but greater than the TTS SEL_{cum} range of 0.4km for bottlenose dolphin and white-beaked dolphin; and 9.7km for grey and harbour seal (**Table 10-25**).

553. Piling duration would be the same as assessed from marine mammals in **Table 10-50**.

Table 10-78: Predicted Maximum Impact Ranges (and Areas) for Monopile and Pin-Pile Maximum Hammer Energies for Fish Species with a Swim Bladder Involved in Hearing

Species	Potential Impact	Criteria and threshold (Popper *et al.*, 2014)	Location	Monopile (maximum hammer energy 5,500kJ)	Pin-pile (maximum hammer energy 3,000kJ)
Fish: swim bladder involving in hearing	Mortality and potential mortal injury	207 dB SPL_{peak}	SEP	0.25km ($0.19km^2$)	0.22km ($0.14km^2$)
			DEP	0.27km ($0.23km^2$)	0.24km ($0.17km^2$)
		207 dB SEL_{cum}	SEP	0.2km (<$0.1km^2$)	<0.1km (<$0.1km^2$)

Species	Potential Impact	Criteria and threshold (Popper *et al*., 2014)	Location	Monopile (maximum hammer energy 5,500kJ)	Pin-pile (maximum hammer energy 3,000kJ)
		Fleeing model	DEP	0.3km (0.16km^2)	<0.1km (<0.1km^2)
	Recoverable injury	203 dB SEL_{cum} Fleeing model	SEP	0.6km (1.1km^2)	0.1km (<0.1km^2)
			DEP	0.9km (1.9km^2)	0.13km (<0.1km^2)
	TTS	186 dB SEL_{cum} Fleeing model	SEP	**9.6km (210km^2)**	5.8km (78km^2)
			DEP	**12km (330km^2)**	7.9km (130km^2)

554. As a precautionary approach, the number of marine mammals that could be impacted as a result of any changes in prey availability has been assessed based on the worst-case for TTS SEL_{cum} for fish species with a swim bladder involved in hearing, using the more realistic fleeing response model (210km^2 at SEP and 330km^2 at DEP). However, it is highly unlikely that there would be significant changes to prey over the entire area. It is more likely that effects would be restricted to an area around the working sites.

555. The magnitude of any changes in prey availability as a result of underwater noise during piling has been assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin and minke whale, low (low) for grey seal and low (negligible) for harbour seal (**Table 10-79**).

556. It is also important to note that there is unlikely to be any additional displacement of marine mammals as a result of any changes in prey availability during piling as marine mammals would also be disturbed from the area.

Table 10-79: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of Changes in Prey Availability during Piling at SEP or DEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Changes in prey availability	Harbour porpoise	SEP	132.3 (0.04% of NS MU)	**Negligible**
		DEP	802 (0.23% of NS MU)	**Negligible**
	Bottlenose dolphin	SEP	6.3 (0.31% of GNS MU; 2.79% of CES MU)	**Negligible (low)**
		DEP	9.8 (0.49% of GNS MU; 4.4% of CES MU)	**Negligible (low)**
		SEP	1.26 (0.0029% of CGNS MU)	**Negligible**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
	White-beaked dolphin	DEP	1.98 (0.0045% of CGNS MU)	**Negligible**
	Minke whale	SEP	2.1 (0.010% of CGNS MU)	**Negligible**
		DEP	3.3 (0.016% of CGNS MU)	**Negligible**
	Grey seal	SEP	179.1 (2.07% of SE MU or 0.74% of wider ref pop)	**Low (negligible)**
		DEP	243.9 (2.81% of SE MU or 1.01% of wider ref pop)	**Low (Low)**
	Harbour seal	SEP	57.5 (1.53% of SE MU or 0.19% of wider ref pop)	**Low (negligible)**
		DEP	26.4 (0.70% of SE MU or 0.09% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

557. For assessing response in prey during piling Hawkins *et al*. (2014) gives unweighted SPL_{peak}, $SPL_{peak\text{-}to\text{-}peak}$, and SEL_{ss} levels where a 50% response level was recorded in sprat and mackerel for an impulsive noise source, simulating pile driving. In the absence of reliable numerical criteria for behavioural disturbance in fish, observed levels from Hawkins *et al*. (2014) have been used, even though the authors of the paper themselves do not recommend use of the values as criteria for EIA. It should be noted that the study was conducted under conditions in quiet inland waters which are unlikely to be equivalent to those around the SEP and DEP offshore sites.

558. Consideration of potential behavioural response impact ranges and areas (up to 2,000km^2 at SEP and 2,700km^2 at DEP) in reference to Hawkins *et al*. (2014) are provided **Appendix 10.2 Underwater Noise Modelling Report** and **Chapter 9 Fish and Shellfish Ecology**.

559. As a precautionary approach, taking into account 50% response in fish, 50% of marine mammals in the maximum potential impact area has been estimated to assess the potential for any temporary changes in prey availability (**Table 10-80**).

560. The duration of active piling at SEP (12.5 days) and DEP (16 days) has been taken into account in the overall assessments provided below. Additionally, the wide foraging ranges of marine mammals and the availability of prey in nearby areas has been taken into account and therefore the magnitude of any impact from the potential response of fish during piling is assessed as negligible for all marine mammal species (**Table 10-80**).

561. As previously outlined, the assessments for bottlenose dolphin have been based on a very precautionary approach, as there is currently no density estimate for the area in and around SEP and DEP. In addition, bottlenose dolphin are more likely to be present close to shore, rather than the offshore areas. Therefore, any impact to bottlenose dolphin is likely to be a lot less than in the worst-case assessment.

562. Grey seals will typically forage in the open sea and return regularly to land to haul-out, although they may frequently travel up to 100km between haul-out sites. Foraging trips generally occur within 100km of their haul-out sites, although grey seal can travel up to several hundred kilometres offshore to forage (SCOS, 2020). The assessments for grey seal have been based on a very precautionary approach, it is highly unlikely that there would be significant changes to prey over the entire area. It is more likely that effects would be restricted to an area around the working sites and that any temporary changes in prey availability would be of a short duration.

Table 10-80: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of 50% Response in Prey during Piling at SEP or DEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Duration of active piling	Magnitude
Changes in prey availability	Harbour porpoise	SEP	630 (0.18% of NS MU)	**Negligible**	12.5 days	**Negligible**
		DEP	3,280.5 (0.95% of NS MU)	**Negligible**	16 days	**Negligible**
	Bottlenose dolphin	SEP	29.8 (1.47% of GNS MU; 13.3% of CES MU)	**Low (high)**	12.5 days	**Negligible**
		DEP	40.2 (1.99% of GNS MU; 17.96% of CES MU)	**Low (high)**	16 days	**Negligible**
	White-beaked dolphin	SEP	6 (0.01% of CGNS MU)	**Negligible**	12.5 days	**Negligible**
		DEP	8 (0.02% of CGNS MU)	**Negligible**	16 days	**Negligible**
	Minke whale	SEP	10 (0.05% of CGNS MU)	**Negligible**	12.5 days	**Negligible**
		DEP	13.5 (0.07% of CGNS MU)	**Negligible**	16 days	**Negligible**
	Grey seal	SEP	853 (9.8% of SE MU or 3.54% of wider ref pop)	**Medium (low)**	12.5 days	**Negligible**
		DEP	997.7 (11.51% of SE MU or 4.14% of wider ref pop)	**High (low)**	16 days	**Negligible**
	Harbour seal	SEP	274 (7.3% of SE MU or 0.9% of wider ref pop)	**Medium (negligible)**	12.5 days	**Negligible**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)	Duration of active piling	Magnitude
		DEP	108 (2.88% of SE MU or 0.35% of wider ref pop)	**Low (negligible)**	16 days	**Negligible**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

Other Construction Activities and Vessels

563. The potential impact ranges modelled for fish species as a result of underwater noise during cable laying, trenching, rock placement, drilling, dredging and for vessels is less than 50m (**Appendix 10.2 Underwater Noise Modelling Report**), which is less than the precited impact ranges for marine mammals (**Table 10-60**).

564. Therefore, any potential changes to prey availability as a result of other construction activities and vessels is assessed as negligible for marine mammals.

10.6.1.8.3 Impact Significance

565. Taking into account the marine mammal sensitivity and the potential magnitude of the impact, the impact significance for any potential changes in prey availability as a result of underwater noise during piling at SEP or DEP has been assessed as **negligible or minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-81**).

Table 10-81: Assessment of Impact Significance for Any Potential Changes in Prey Availability During Construction at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Change in prey availability during piling	Harbour porpoise	SEP	Medium to low	Negligible	**Minor adverse to Negligible**	No mitigation proposed for prey. However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	**Minor adverse to Negligible**
		DEP		Negligible	**Minor adverse to Negligible**		**Minor adverse to Negligible**
	Bottlenose dolphin	SEP	Low	Negligible (low)	**Negligible (minor)**		**Negligible (minor)**
		DEP		Negligible (low)	**Negligible (minor)**		**Negligible (minor)**
	White-beaked dolphin	SEP	Low	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Minke whale	SEP	Medium to low	Negligible	**Minor adverse to Negligible**		**Minor adverse to Negligible**
		DEP		Negligible	**Minor adverse to Negligible**		**Minor adverse to Negligible**
	Grey seal	SEP	Low	Low (negligible)	**Minor adverse (negligible)**		**Minor adverse (negligible)**
		DEP		Low (low)	**Negligible (negligible)**		**Negligible (negligible)**
	Harbour seal	SEP	Low	Low (negligible)	**Minor adverse (negligible)**		**Minor adverse (negligible)**
		DEP		Negligible (negligible)	**Minor adverse (negligible)**		**Minor adverse (negligible)**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.8.4 Mitigation

566. Mitigation in the MMMP and SIP to reduce the potential impacts of underwater noise for marine mammals would also reduce the potential impacts on prey species. No further mitigation is required or proposed in relation to any changes in prey availability.

10.6.1.8.5 Impact Assessment for SEP and DEP

567. As a worst-case, the maximum number of marine mammals potentially present within the SEP and DEP offshore sites has been assessed to indicate the maximum number of marine mammals that could be impacted as a result of potential changes in prey availability. The assessment for potential impacts on prey from underwater noise is based on TTS impact ranges during piling if SEP and DEP are developed concurrently (**Table 10-82**).

568. The magnitude of impact for any potential temporary changes in prey availability, based on worst-case for TTS, at SEP and DEP is assessed as negligible for harbour porpoise, negligible (medium) for bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, low(low) for grey seal and low (negligible) for harbour seal (**Table 10-82**).

Table 10-82: Maximum Number of Individuals (and % of Reference Population) that Could be Impacted as a Result of Changes in Prey Availability during Construction at SEP and DEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude* (temporary impact)
Changes in prey availability	Harbour porpoise	SEP & DEP	934.2 (0.27% of NS MU)	**Negligible**
	Bottlenose dolphin	SEP & DEP	16.1 (0.80% of GNS MU; 7.18% of CES MU)	**Negligible (medium)**
	White-beaked dolphin	SEP & DEP	3.24 (0.0074% of CGNS MU)	**Negligible**
	Minke whale	SEP & DEP	5.4 (0.027% of CGNS MU)	**Negligible**
	Grey seal	SEP & DEP	423.0 (4.88% of SE MU or 1.75% of wider ref pop)	**Low (low)**
	Harbour seal	SEP & DEP	83.9 (2.24% of SE MU or 0.27% of wider ref pop)	**Low (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.8.5.1 *Impact Significance*

569. Taking into account the marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 10-82**, the impact significance for any potential changes in prey availability as a result of underwater noise during concurrent piling at SEP and DEP has been assessed as **negligible or minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-83**).

Table 10-83: Assessment of Impact Significance for Any Potential Changes in Prey Availability during Construction at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Change in prey availability during piling	Harbour porpoise	SEP & DEP	Medium to low	Negligible	**Minor adverse to Negligible**	No mitigation proposed for prey. However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	**Minor adverse to Negligible**
	Bottlenose dolphin	SEP & DEP	Low	Negligible (medium)	**Negligible (minor)**		**Negligible (minor adverse)**
	White-beaked dolphin	SEP & DEP	Low	Negligible	**Negligible**		**Negligible**
	Minke whale	SEP & DEP	Medium to low	Negligible	**Minor adverse to Negligible**		**Minor adverse to Negligible**
	Grey seal	SEP & DEP	Low	Low (low)	**Minor adverse (minor)**		**Minor adverse (negligible)**
	Harbour seal	SEP & DEP	Low	Low (negligible)	**Minor adverse (negligible)**		**Minor adverse (negligible)**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.1.8.5.2 *Mitigation*

570. As for SEP or DEP in isolation, mitigation in the MMMP and SIP to reduce the potential impacts of underwater noise for marine mammals would also reduce the potential impacts on prey species. No further mitigation is required or proposed in relation to any changes in prey availability.

10.6.1.9 Impact 9: Changes to Water Quality

571. As outlined in **Chapter 7 Marine Water and Sediment Quality** potential changes in water quality during construction could occur through:

- Deterioration in water quality due to an increase in suspended sediment through sea bed preparation for foundations;
- Deterioration in water quality due to an increase in suspended sediment associated with drill arisings for foundation installation of piled foundations;
- Deterioration in water quality due to an increase in suspended sediment during export cable installation;
- Deterioration in water quality due to an increase in suspended sediment during offshore cable installation (infield and interlink cables); and
- Deterioration in water quality due to the release of contaminated sediment.

10.6.1.9.1 Sensitivity of Marine Mammals

572. Marine mammals often inhabit turbid environments and cetaceans utilise sonar to sense the environment around them and there is little evidence that turbidity affects cetaceans directly (Todd *et al*., 2014). Pinnipeds are not known to produce sonar for prey detection purposes; however, it is likely that other senses are used instead of, or in combination with, vision. Studies have shown that vision is not essential to seal survival, or ability to forage (Todd *et al*., 2014).

573. Increased turbidity is unlikely to have a substantial direct impact on marine mammals that often inhabit naturally turbid or dark environments. This is likely because other senses are utilised, and vision is not relied upon solely. Therefore, harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal have negligible sensitivity to increases in suspended sediments during construction.

574. Any direct impacts to marine mammals as a result of any contaminated sediment during construction activities are unlikely as any exposure is more likely to be through potential indirect impacts via prey species, as assessed in **Section 10.6.1.8.2.3**. Therefore, marine mammals are considered to have negligible sensitivity to any direct impacts from contaminated sediment during construction activities.

10.6.1.9.2 Magnitude for SEP or DEP in Isolation

575. The magnitude for the potential changes in water quality has been based on the assessments in **Chapter 7 Marine Water and Sediment Quality** (**Table 10-84**).

*Table 10-84: Magnitude of Potential Changes in Water Quality during Construction at SEP or DEP, Based on Assessments in **Chapter 7 Marine Water and Sediment Quality***

Potential Impact	Location	Magnitude (temporary impact)
Deterioration in water quality due to an increase in suspended sediment through sea bed preparation	SEP or DEP	**Negligible**
Deterioration in water quality due to an increase in suspended sediment associated with drill arisings for foundation installation of piled foundations	SEP or DEP	**Negligible**
Deterioration in water quality due to an increase in suspended sediment during export cable installation	SEP or DEP	**Negligible**
Deterioration in water quality due to an increase in suspended sediment during offshore cable installation (infield and interlink cables)	SEP or DEP	**Negligible**
Deterioration in water quality due to the release of contaminated sediment	SEP or DEP	**Negligible**

10.6.1.9.3 Impact Significance

576. Taking into account the negligible marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 10-84**, the impact significance for any potential changes in water quality during construction at SEP or DEP has been assessed as **negligible** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-74**).

Table 10-85: Assessment of Impact Significance for any Changes in Water Quality during Construction at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Changes in water quality	Harbour porpoise	SEP	Negligible	Negligible	**Negligible**	No further mitigation proposed other than embedded mitigation.	**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Bottlenose dolphin	SEP	Negligible	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	White-beaked dolphin	SEP	Negligible	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Minke whale	SEP	Negligible	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Grey seal	SEP	Negligible	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Harbour seal	SEP	Negligible	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**

10.6.1.9.4 Mitigation

577. No mitigation is required or proposed, other than the embedded mitigation for water quality outlined in **Table 10-2**.

10.6.1.9.5 Impact Assessment for SEP and DEP

578. The impacts for SEP and DEP would be the same as those assessed for SEP or DEP in isolation due to the limited range of the potential changes in water quality, with a **negligible** magnitude, impact and residual significance.

10.6.1.10 Overall Impacts During Construction

10.6.1.10.1 Potential Overall Effects During Pilling

579. The assessment of potential impacts during piling (**Sections 10.6.1.1** and **10.6.1.2** represents the worst-case scenario for underwater noise, based on the maximum potential area for piling. Any potential impacts from other construction activities and vessels at SEP, DEP and the export cable corridor are likely to be within the worst-case impact area assessed for piling. However, as a precautionary approach, the spatial worst-case for the maximum area over which potential disturbance could occur at any one time has been determined.

580. For harbour porpoise the maximum area for potential disturbance is the 26km EDR for a single monopile installation at SEP or DEP as assessed in **Section 10.6.1.2.2.3**. SEP and DEP are located 15.8km and 26.5km from the coast, respectively, therefore any other construction activities, including vessels, in the export cable corridor would be within the 26km EDR.

581. SEP has an area of 97.0km^2, with an offshore export cable corridor area of approximately 63.8km^2. DEP has an area of 114.8km^2, with an export cable corridor area of up to approximately 96.8km^2. Therefore, the 2,124km^2 area for the 26km EDR at SEP would cover the SEP wind farm site plus export cable corridor and the 2,124km^2 area for the 26km EDR at DEP would cover the DEP wind farm site plus export cable corridor.

582. As a result, there would be no additional disturbance of harbour porpoise from construction or vessel noise sources at SEP or DEP in addition to the 26km EDR. This would include ADD activation which would also be within the 26km EDR.

583. There would be no further additional impacts as any potential changes in prey availability would be within the maximum impact area assessed for harbour porpoise.

584. For the other marine mammal species, for which there are no EDRs and it is not applicable to use the 26km EDR, the overall potential effects have been based on the maximum potential disturbance during piling at the same time as other potential construction activities, including vessels, in the offshore export cable corridor.

585. For bottlenose dolphin and white-beaked dolphin the maximum potential overall impact area is encompassed by the maximum predicted impact area for TTS SEL_{cum} in prey species as assessed in **Section 10.6.1.8**. With a maximum impact area of 210km^2 at SEP and 330km^2 at DEP, this is greater than the maximum TTS SEL_{cum} impact area for piling (0.33km^2 for SEP and 0.44km^2 for DEP), plus all other construction activities (0.15km^2 at SEP or DEP) and all vessels (0.48km^2 for SEP or DEP), with total areas of up to 0.96km^2 for SEP and 1.07km^2 for DEP. However, the total areas are likely to be a lot less, as most of these areas would overlap and would not be additive.

586. For minke whale, the maximum potential area for overall effects from underwater noise during construction is encompassed by the maximum TTS SEL_{cum} area for piling (25km with an area of 720km^2 at SEP and 1,100km^2 at DEP), as assessed in **Section 10.6.1.1**. As outlined above for harbour porpoise and the 26km EDR, this range and area would include the SEP or DEP wind farm sites plus offshore export cable corridors and therefore all activities and noise sources within the area, including ADD activation and other construction activities, including vessels. For minke whale, there would be no further additional impacts as any potential changes in prey availability would be within the maximum impact area assessed.

587. For grey seal and harbour seal the maximum potential overall impact area is the maximum predicted impact area for TTS SEL_{cum} in prey species as assessed in **Section 10.6.1.8**. With a maximum impact area of 210km^2 at SEP and 330km^2 at DEP, this is greater than the maximum impact area TTS SEL_{cum} areas for piling (140km^2 for SEP and 220km^2 for DEP), plus all other construction activities (0.15km^2 at SEP or DEP) and all vessels (0.48km^2 for SEP or DEP), with total areas of up to 140.63km^2 for SEP and 220.63km^2 for DEP. However, the total areas are likely to be a lot less, as most of these areas would overlap and would not be additive.

588. There would be no further additional impacts as the maximum impact area during construction has been assessed for all species.

10.6.1.10.2 Potential Overall Effects During Other Construction Activities

589. There would be no further overall effects during construction other than those assessed above, as the potential disturbance from underwater noise during other construction activities has been based on the maximum potential impact area, which would include any potential disturbance from vessels associated with these activities, any changes in prey availability and water quality.

10.6.2 Potential Impacts during Operation

590. The potential impacts during operation and maintenance that have been assessed for marine mammals are:

- Behavioural impacts resulting from the underwater noise associated with operational turbines;
- Behavioural impacts resulting from the underwater noise associated with maintenance activities, such as any additional rock placement and cable re-burial;
- Barrier effects as a result of underwater noise;
- Impacts resulting from the deployment of maintenance vessels:
  - Underwater noise and disturbance from vessels;
  - Vessel interaction (collision risk);
  - Disturbance at seal haul-out sites;
- Changes to prey resource; and
- Changes to water quality.

10.6.2.1 Impact 1: Impacts from Underwater Noise Associated with Operational Wind Turbines

591. The operational turbines will operate nearly continuously, except for occasional shutdowns for maintenance or severe weather. The SEP and DEP design life is 40 years. Therefore, there is concern that underwater noise from operational turbines could contribute a consistent, long duration of sound to the marine environment. However, the underwater noise levels emitted during the operation of the turbines are low and not expected to cause physiological injury to marine mammals, but could cause behavioural reactions if the animals are in the immediate vicinity of the wind turbine (Tougaard *et al*., 2009a; Sigray and Andersson, 2011).

592. The main sources of sound generated during the operation of wind turbines are aerodynamic and mechanical. The mechanical noise is from the nacelle at the top of the wind turbine tower. As the wind turbine blades rotate, vibrations are generated that travel down the turbine tower into the foundation and radiate into the surrounding water column and sea bed (Tougaard *et al*., 2009a; 2020; Nedwell *et al*., 2003). The resulting sound is described as continuous and non-impulsive and is characterized by one or more tonal components that are typically at frequencies below 1kHz. The frequency content of the tonal signals is determined by the mechanical properties of the wind turbine and does not change with wind speed (Madsen *et al*., 2006). Noise levels generated above the water surface are low enough that no significant airborne sound will pass from the air to the water (e.g. Godin, 2008).

593. Measurements made at three different wind turbines in Denmark and Sweden at ranges between 14m and 40m from the turbine foundations found that the sound generated due to turbine operation was only detectable over underwater ambient noise at frequencies below 500Hz (Tougaard *et al*., 2009a).

594. Tougaard *et al*. (2020) reviewed the available measurements of underwater noise from different wind turbines during operation and found that source levels were at least 10–20 dB lower than ship noise in the same frequency range. A simple multi-turbine model indicated that cumulative noise levels could be elevated up to a few kilometres from a wind farm under very low ambient noise conditions. However, the noise levels were well below ambient levels unless very close to the individual turbines in locations with high ambient noise from shipping or high wind speeds (Tougaard *et al*., 2020).

595. There is the potential for larger operational wind turbines to have greater noise levels compared to smaller wind turbines currently in operation (Stöber and Thomsen, 2021). This increase in size of operational wind turbines at SEP and DEP has been taken into account in the underwater noise modelling (see **Appendix 10.2 Underwater Noise Modelling Report**). However, the shift from using gear boxes to direct drive technology is expected to reduce the sound level by 10 dB (Stöber and Thomsen, 2021).

596. As outlined in **Appendix 10.2 Underwater Noise Modelling Report**, noise measurements made at operational wind farms have demonstrated that the operational noise produced was at such a low level that it was difficult to measure relative to background noise at distances of a few hundred metres.

10.6.2.1.1 Sensitivity of Marine Mammals

597. Currently available data indicates that there is no lasting disturbance or exclusion of harbour porpoise or seals around wind farm sites during operation (Diederichs *et al*., 2008; Lindeboom *et al*., 2011; Marine Scotland, 2012; McConnell *et al*., 2012; Russell *et al*., 2014; Scheidat *et al*., 2011; Teilmann *et al*., 2006; Tougaard *et al*., 2005, 2009a, 2009b). Data collected suggests that any behavioural responses for harbour porpoise and seal may only occur up to a few hundred metres away (Touggard *et al*., 2009b; McConnell *et al*., 2012).

598. Monitoring was carried out at the Horns Rev and Nysted wind farms in Denmark during the operation between 1999 and 2006 (Diederichs *et al*., 2008). Numbers of harbour porpoise within Horns Rev were slightly reduced compared to the wider area during the first two years of operation, however, it was not possible to conclude that the wind farm was solely responsible for this change in abundance without analysing other dynamic environmental variables (Tougaard *et al*., 2009a). Later studies by Diederichs *et al*. (2008) recorded no noticeable effect on the abundances of harbour porpoise at varying wind velocities at both of the offshore wind farms studied, following two years of operation.

599. Monitoring studies at Nysted and Rødsand have also indicated that operational activities have had no impact on regional seal populations (Teilmann *et al*., 2006; McConnell *et al*., 2012). Tagged harbour seals have been recorded within two operational wind farm sites (Alpha Ventus in Germany and Sheringham Shoal in UK) with the movement of several of the seals suggesting foraging behaviour around wind turbine structures (Russell *et al*., 2014).

600. Both harbour porpoise and seals have been shown to forage within operational wind farm sites (e.g. Lindeboom *et al*., 2011; Russell *et al*., 2014), indicating no restriction to movements in operational offshore wind farm sites.

601. There is currently limited information for other marine mammal species, however, bottlenose dolphin are frequently observed in and around the Aberdeen Offshore Wind Farm (European Offshore Wind Deployment Centre).

602. Modelling of noise effects of operational offshore wind turbines suggest that harbour seals, grey seals and bottlenose dolphins are not considered to be at risk of displacement by the operational wind farms (Marmo *et al*., 2013).

603. As a precautionary approach, harbour porpoise, bottlenose dolphin, white-beaked dolphin, grey seal and harbour seal are likely to have low sensitivity (rather than negligible) to disturbance from underwater noise as a result of operational wind turbines.

604. Taking into account that minke whales are more sensitive to low frequency noise, it is probable that they could be more sensitive to operational wind turbine noise (Marmo *et al*., 2013). Therefore, as a precautionary approach minke whale are classed as having medium sensitivity.

605. The sensitivity of marine mammals to TTS is considered to be medium.

10.6.2.1.2 Underwater Noise Modelling

606. Underwater noise modelling was undertaken to assess the potential impact ranges for operational wind turbines (see **Appendix 10.2 Underwater Noise Modelling Report**). The cumulative impact ranges are to the nearest 100m, however, they are likely to be less than 100m especially for PTS impact ranges.

607. The results of the underwater noise modelling (**Table 10-86**) indicate that any marine mammal would have to be less than 100m (precautionary maximum range) for 24 hours in a 24 hour period, to be exposed to noise levels that could induce PTS or TTS based on the Southall *et al*. (2019) non-impulsive thresholds and criteria for SEL_{cum}.

Table 10-86: Predicted Impact Ranges (and Areas) for PTS and TTS from Cumulative Exposure of Operational Turbines

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Operational wind turbines (18+ MW)
Harbour porpoise (VHF)	PTS	SEL_{cum} Weighted (173 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)
	TTS	SEL_{cum} Weighted (153 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)
Bottlenose dolphin and white-beaked dolphin (HF)	PTS	SEL_{cum} Weighted (198 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)
	TTS	SEL_{cum} Weighted (178 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Operational wind turbines (18+ MW)
Minke whale (LF)	PTS	SEL_{cum} Weighted (199 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)
	TTS	SEL_{cum} Weighted (179 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)
Grey and Harbour seal (PW)	PTS	SEL_{cum} Weighted (201 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)
	TTS	SEL_{cum} Weighted (181 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)

10.6.2.1.3 Magnitude for SEP or DEP in Isolation

608. It is important to note that PTS is unlikely to occur in marine mammals, as the modelling indicates that the marine mammal would have to remain less than 100m for 24 hours in any given 24-hour period for any potential risk of PTS (**Table 10-86**). Therefore, PTS as a result of operational wind turbine noise, is highly unlikely and has not been assessed further.

609. Similarly, there is unlikely to be any significant risk of TTS, as again the modelling indicates that the marine mammal would have to remain less than 100m for 24 hours in any given 24-hour period (**Table 10-86**). Therefore, TTS as a result of operational wind turbine noise, is also highly unlikely.

610. For marine mammals a fleeing response is assumed to occur at the same noise levels as TTS. Therefore, the potential range and areas for TTS presented in **Table 10-86**, with the estimated number and percentage of reference populations in **Table 10-87** providing an indication of possible fleeing response / displacement.

611. The magnitude of the potential impact for TTS / fleeing response as a result of underwater noise from all operational wind turbines at each site (23 wind turbines at SEP (23 x 0.03km^2 = 0.69km^2) and 30 at DEP (30 x 0.03km^2 = 0.90km^2)) is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale grey seal and harbour seal (**Table 10-87**), with less than 0.01% of the reference populations exposed to any long term impact (see **Table 10-9**).

612. The indicative separation distance between turbines (inter-row) and between turbines in rows (in-row) would be a minimum of 1.05km (maximum of 3.3km) therefore there would be no overlap in the potential impact range of less than 100m (<0.1km) around each turbine.

Table 10-87: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS / Fleeing Response from Cumulative Exposure for all Operational Turbines at SEP or DEP

Species	Location	Operational Turbines	
		Maximum number of individuals (% of reference population)	Magnitude* (long-term impact)
Harbour porpoise	SEP (up to 23 wind turbines)	0.43 (0.00013% of NS MU)	**Negligible**
	DEP (up to 30 wind turbines)	2.19 (0.00063% of NS MU)	**Negligible**
Bottlenose dolphin	SEP (up to 23 wind turbines)	0.021 (0.0010% of GNS MU; 0.009% of CES MU)	**Negligible (low)**
	DEP (up to 30 wind turbines)	0.027 (0.0013% of GNS MU; 0.012% of CES MU)	**Negligible (low)**
White-beaked dolphin	SEP (up to 23 wind turbines)	0.0041 (0.000009% of CGNS MU)	**Negligible**
	DEP (up to 30 wind turbines)	0.0054 (0.000012% of CGNS MU)	**Negligible**
Minke whale	SEP (up to 23 wind turbines)	0.0069 (0.000034% of CGNS MU)	**Negligible**
	DEP (up to 30 wind turbines)	0.0090 (0.000045% of CGNS MU)	**Negligible**
Grey seal	SEP (up to 23 wind turbines)	0.59 (0.0068% of SE MU or 0.0013% of wider ref pop)	**Negligible (negligible)**
	DEP (up to 30 wind turbines)	0.67 (0.0077% of SE MU or 0.0028% of wider ref pop)	**Negligible (negligible)**
Harbour seal	SEP (up to 23 wind turbines)	0.19 (0.005% of SE MU or 0.0003% of wider ref pop)	**Negligible (negligible)**
	DEP (up to 30 wind turbines)	0.07 (0.0019% of SE MU or 0.0002% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.2.1.4 Impact Significance

613. Taking into account low sensitivity and the potential magnitude of the potential long-term impact (**Table 10-87**), the impact significance for any displacement as a result of underwater noise from operational turbines has been assessed as **negligible (not significant)** for harbour porpoise, white-beaked dolphin, grey seal and harbour seal. Impact significance for bottlenose dolphin has been assessed as **negligible** to **minor adverse (not significant)** (**Table 10-88**). As a precautionary approach taking into account medium sensitivity the impact significance for any displacement as a result of underwater noise from operational turbines has been assessed as **minor adverse (not significant)** for minke whale.

Table 10-88 Assessment of Impact Significance for Underwater Noise from Operational Turbines at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude*	Significance*	Mitigation	Residual Impact
Underwater noise from operational turbines	Harbour porpoise	SEP	Low	Negligible	**Negligible**	No mitigation proposed	**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Bottlenose dolphin	SEP	Low	Negligible (low)	**Negligible (minor adverse)**		**Negligible to Minor adverse**
		DEP		Negligible (low)	**Negligible (minor adverse)**		**Negligible to Minor adverse**
	White-beaked dolphin	SEP	Low	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Minke whale	SEP	Medium	Negligible	**Minor adverse**		**Minor adverse**
		DEP		Negligible	**Minor adverse**		**Minor adverse**
	Grey seal	SEP	Low	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**
	Harbour seal	SEP	Low	Negligible	**Negligible**		**Negligible**
		DEP		Negligible	**Negligible**		**Negligible**

* Magnitudes and significance given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.2.1.5 Mitigation

614. No mitigation is required or proposed.

10.6.2.1.6 Impact Assessment for SEP and DEP

615. The magnitude of the potential impact for TTS / fleeing response as a result of underwater noise from all operational wind turbines at SEP (23 wind turbines) and DEP (30 wind turbines) is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-89**).

Table 10-89: Maximum Number of Individuals (and % of Reference Population) that Could be at Risk of TTS / Fleeing Response from Cumulative Exposure for all Operational Turbines at SEP and DEP

Species	Location	Operational Turbines	
		Maximum number of individuals (% of reference population)	Magnitude (long-term impact)
Harbour porpoise	SEP & DEP (up to 53 wind turbines)	2.62 (0.00076% of NS MU)	**Negligible**
Bottlenose dolphin	SEP & DEP (up to 53 wind turbines)	0.047 (0.0023% of GNS MU; 0.021% of CES MU)	**Negligible (low)**
White-beaked dolphin	SEP & DEP (up to 53 wind turbines)	0.0095 (0.000022% of CGNS MU)	**Negligible**
Minke whale	SEP & DEP (up to 53 wind turbines)	0.016 (0.000079% of CGNS MU)	**Negligible**
Grey seal	SEP & DEP (up to 53 wind turbines)	1.25 (0.0145% of SE MU or 0.0052% of wider ref pop)	**Negligible (negligible)**
Harbour seal	SEP & DEP (up to 53 wind turbines)	0.26 (0.007% of SE MU or 0.0009% of wider ref pop)	**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.2.1.6.1 *Impact Significance*

616. Taking into account low to medium sensitivity and the potential magnitude of the potential long-term impact (**Table 10-89**), the impact significance for any displacement as a result of underwater noise from operational turbines at SEP and DEP has been assessed as **negligible (not significant)** for harbour porpoise, white beaked dolphin, grey seal and harbour seal; **negligible to minor adverse (not significant)** for bottlenose dolphin; and **minor adverse (not significant)** and for minke whale **to minor adverse** (**Table 10-90**).

Table 10-90: Assessment of Impact Significance for Underwater Noise from Operational Turbines at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude*	Significance	Mitigation	Residual Impact
Underwater noise from operational turbines	Harbour porpoise	SEP & DEP	Low	Negligible	**Negligible**	No mitigation proposed	**Negligible**
	Bottlenose dolphin	SEP & DEP	Low	Negligible (low)	**Negligible**		**Negligible (minor adverse)**
	White-beaked dolphin	SEP & DEP	Low	Negligible	**Negligible**		**Negligible**
	Minke whale	SEP & DEP	Medium	Negligible	**Minor adverse**		**Minor adverse**
	Grey seal	SEP & DEP	Low	Negligible (negligible)	**Negligible**		**Negligible (negligible)**
	Harbour seal	SEP & DEP	Low	Negligible (negligible)	**Negligible**		**Negligible (negligible)**

* Magnitudes given in brackets are for the secondary MU assessed for bottlenose dolphin (CES) and for the wider population for seal species

10.6.2.1.6.2 *Mitigation*

617. No mitigation is required or proposed.

10.6.2.2 Impact 2: Impacts from Underwater Noise Associated with Operation and Maintenance Activities

10.6.2.2.1 Sensitivity of Marine Mammals

618. As outlined in **Section 10.6.1.3.1**, the sensitivity of marine mammals to disturbance as a result of underwater noise during activities such as cable laying, trenching or rock placement, is considered to be medium in this assessment as a precautionary approach.

10.6.2.2.2 Magnitude for SEP or DEP in Isolation

619. The requirements for any potential maintenance work, such as additional rock placement or cable re-burial, are currently unknown, however the work required, and associated impacts would be less than those during construction. **Table 10-1** provides estimates (as outlined in **Chapter 4 Project Description**) for potential cable repairs and reburial.

620. As outlined in **Section 10.6.1.3**, the potential for PTS or TTS is only likely in very close proximity to cable laying or rock placement activities and if the marine mammal remains within close proximity for 24 hours. Therefore, the only potential impact from underwater noise during maintenance activities is disturbance.

621. The impacts from additional cable laying and protection are temporary in nature and will be limited to relatively short periods during the operation and maintenance phase. Disturbance responses are likely to occur at significantly shorter ranges than construction noise. Any disturbance is likely to be limited to the area in and around where the actual activity is taking place.

622. Therefore, the underwater noise from maintenance activities are considered to be the same or less than those assessed for underwater noise from other construction activities (including rock placement, trenching and cable laying) (**Section 10.6.1.3**).

623. The magnitude for all marine mammal species is assessed as negligible based on maximum impact areas for all activities (**Table 10-61**).

10.6.2.2.3 Impact Significance

624. Taking into account medium sensitivity and the potential magnitude of the temporary impact, the impact significance for any disturbance of harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal has been assessed as **minor adverse (not significant)** (**Table 10-91**).

Table 10-91: Assessment of Impact Significance for Underwater Noise from Maintenance Activities

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Disturbance during maintenance activities	All marine mammals	SEP or DEP including export cable corridor	Medium	Negligible	**Minor adverse**	No mitigation proposed	**Minor adverse**

10.6.2.2.4 Mitigation

625. No mitigation is required or proposed for underwater noise for maintenance activities, such as rock placement, trenching and cable laying, as the effects are negligible and not significant.

10.6.2.2.5 Impact Assessment for SEP and DEP

626. The potential impacts for underwater noise during maintenance activities at SEP and DEP would be the same or less than the assessment of the construction activities, other than piling, assessed in **Section 10.6.1.3.6**. Therefore, the impact significance has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-92**).

Table 10-92: Assessment of Impact Significance for Underwater Noise from Maintenance Activities at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Disturbance during maintenance activities	All marine mammals	SEP & DEP including export cable	Medium	Negligible	**Minor adverse**	No mitigation proposed	**Minor adverse**

10.6.2.3 Impact 3: Impacts from Underwater Noise and Disturbance Associated with Operation and Maintenance Vessels

10.6.2.3.1 Sensitivity of Marine Mammals

627. As outlined in **Section 10.6.1.4.1**, the sensitivity of marine mammals to vessel noise and presence is assessed as a precautionary medium.

10.6.2.3.2 Magnitude for SEP or DEP in Isolation

628. As outlined in **Section 10.6.1.4.1**, the potential for PTS or TTS is only likely in very close proximity to vessels and if the marine mammal remains within close proximity for 24 hours in a 24 hour period. Therefore, the only potential impact from underwater noise from vessels is disturbance.

629. The requirements for any potential maintenance work are currently unknown, however the work required, and impacts associated with underwater noise and disturbance from vessels during operation and maintenance would be less than those during construction.

630. It is estimated that the maximum number of vessels that could be required on site at any one-time during operation and maintenance could be seven, which is considerably less than the 16 vessels that could be on each site during construction. However, as a precautionary approach the assessment for construction has been used for the operation and maintenance assessment, as a worst-case scenario.

631. For the operation of either SEP or DEP, there could be up to 604 vessel trips per year (approximately 1.67 trips per day), representing an increase of up to 2% compared to average daily vessels currently within the SEP and DEP vessel and navigation study area during summer and winter.

632. The magnitude for all marine mammal species is assessed as negligible based on maximum impact areas for all vessels (**Table 10-66**).

10.6.2.3.3 Impact Significance

633. Taking into account medium sensitivity and the potential magnitude of the temporary impact, the impact significance for disturbance from underwater noise from operation and maintenance vessels is assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour (**Table 10-93**).

Table 10-93: Assessment of Impact Significance for Underwater Noise and Disturbance from Operation and Maintenance Vessels

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Underwater noise and disturbance from operation and maintenance vessels	All marine mammals	SEP or DEP including export cable corridor	Medium	Negligible	**Minor adverse**	No mitigation proposed	**Minor adverse**

10.6.2.3.4 Mitigation

634. No mitigation is required or proposed for underwater noise or disturbance from operation and maintenance vessels, as the risk of any impact is negligible.

10.6.2.3.5 Impact Assessment for SEP and DEP

635. The potential impacts for underwater noise and disturbance from operation and maintenance vessels at SEP and DEP would be less than the assessment for construction vessels in **Table 10-67**. However, the assessment for construction vessels has been used for the assessment for operation and maintenance vessels as a precautionary and worst-case scenario. Therefore, the impact significance has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-94**).

Table 10-94: Assessment of Impact Significance for Underwater Noise and Disturbance from Operation and Maintenance Vessels at SEP and DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Underwater noise and disturbance from operation and maintenance vessels	All marine mammals	SEP & DEP including export cable corridor	Medium	Negligible	**Minor adverse**	No mitigation proposed	**Minor adverse**

10.6.2.4 Impact 4: Barrier Effects from Underwater Noise during Operation and Maintenance

636. No barrier effects as a result of underwater noise during operation and maintenance are anticipated.

637. As assessed in **Section 10.6.2.1**, the magnitude for displacement (based on TTS / fleeing response) as a result of underwater noise from operational turbines has been assessed as negligible for harbour porpoise, white-beaked dolphin, minke whale, grey seal and harbour seal and low for bottlenose dolphin. With an impact significance of **negligible** to **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal for SEP or DEP in isolation and SEP and DEP.

638. As outlined in **Section 10.6.2.1**, the indicative separation distance between turbines (inter-row) and between turbines in rows (in-row) would be a minimum of 1.05km (maximum of 3.3km) therefore there would be no overlap in the potential impact range of less than 100m (<0.1km) around each turbine and there would be adequate room for marine mammals to move through the wind farm arrays at SEP and DEP.

639. As assessed in **Section 10.6.2.2**, the magnitude for disturbance as a result of barrier effects from underwater noise from operation and maintenance activities is assessed as negligible for all marine mammal species based on maximum impact areas for all activities, with a **minor adverse** impact significance.

640. Therefore, any potential barrier effects as a result of underwater noise during operation and maintenance has not been assessed further.

10.6.2.5 Impact 5: Increased Risk of Collision with Vessels during Operation

10.6.2.5.1 Sensitivity of Marine Mammals

641. As outlined in **Section 10.6.1.6.1**, marine mammals are considered to have a low sensitivity to the risk of a vessel strike.

10.6.2.5.2 Magnitude for SEP or DEP in Isolation

642. It is estimated that the maximum number of vessels that could be required on site at any one-time during operation and maintenance could be seven at SEP or DEP, which is less than the 16 vessels that could be on site during construction (**Table 10-1**). However, as a precautionary approach the assessment for construction has been used for the operation and maintenance assessment, as a worst-case scenario.

643. The potential for increased collision risk with construction or operation and maintenance vessels based on a precautionary worst-case scenario has been assessed as low for harbour porpoise, low (medium) for bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, medium to low for grey seal and harbour seal (**Table 10-73**).

10.6.2.5.3 Impact Significance

644. Taking into account the low marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 10-73**, the impact significance for any potential increased collision risk as a result of vessels during construction has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, grey seal and harbour seal and negligible for white-beaked dolphin and minke whale (**Table 10-74**). However, the residual impact, taking into account good practice to reduce any risk of collisions with marine mammals, would be negligible for all marine mammals.

10.6.2.5.4 Mitigation

645. As previously outlined, the PEMP (in accordance with the **Outline PEMP** (document reference 9.10)) will ensure vessel movements, where possible, are incorporated into recognised vessel routes and hence to areas where marine mammals are accustomed to vessels, in order to reduce any increased collision risk. All vessel movements will be kept to the minimum number that is required to reduce any potential collision risk. Additionally, vessel operators will use good practice to reduce any risk of collisions with marine mammals.

10.6.2.5.5 Impact Assessment for SEP and DEP

646. As a precautionary approach, it is estimated that the maximum number of vessels that could be required on site at any one-time during operation and maintenance could be a total of 14 for SEP and DEP, which is less than the 16 vessels that could be on site during construction. The assessment for the potential increased collision risk with operation and maintenance vessels at SEP and DEP is the same as the assessment for the potential increased collision risk with construction vessels at SEP or DEP in isolation **Section 10.6.1.6.5**.

647. The impact significance for any potential increased collision risk as a result of vessels during construction or operation and maintenance has been assessed as **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, grey seal and harbour seal and negligible for white-beaked dolphin and minke whale (**Table 10-76**).

10.6.2.6 Impact 6: Disturbance at Seal Haul-Out Sites

10.6.2.6.1 Sensitivity of Seals

648. The sensitivity of disturbance to both grey seal and harbour seal at haul-out sites would be the same for the operational period as for the construction period (**Section 10.6.1.7.1**). Therefore, the sensitivity is low for both species, and is increased to medium during the pupping and moult periods of both species, to account for their increased sensitivity during that period.

10.6.2.6.2 Magnitude for SEP or DEP in Isolation

649. The potential for any increase in disturbance to seal haul-out sites as a result of operation activities at the offshore wind farm sites, activities along the offshore export cable corridor and at the landfall site, or from vessel movements during operation will be negligible. Taking into account the proximity of shipping channels to and from existing ports, it is likely that seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels. Therefore, the magnitude of impact of grey and harbour seals at haul-out sites to disturbance from vessels during operation is assessed as negligible.

650. As noted in **Chapter 4 Project Description**, the operation and maintenance port will be at Great Yarmouth and therefore the vessel routes could pass seal haul-out sites at Horsey and Scroby Sands (see **Section 10.5.5**). However, as outlined in **Section 10.6.2.6.2.2**, vessels would use established vessel routes to the port and, where possible, transiting vessels would maintain distances of 600m or more off the coast, particularly in areas near known seal haul-out sites during sensitive periods.

10.6.2.6.2.1 *Impact Significance*

651. Taking into account the low to medium sensitivity and negligible magnitude of the temporary impact, the impact significance for disturbance at seal haul-out sites has been assessed as **negligible to minor adverse (not significant)** for both grey seal and harbour seal (**Table 10-95**).

Table 10-95: Assessment of Impact Significance for Disturbance at Seal Haul-Out Sites during Operation and Maintenance

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Disturbance at seal haul-out sites	Grey seal	SEP including export cable	Low to Medium	Negligible	**Negligible to Minor adverse**	No mitigation proposed	**Negligible to Minor adverse**
		DEP including export cable		Negligible	**Negligible to Minor adverse**		**Negligible to Minor adverse**
	Harbour seal	SEP including export cable	Low to Medium	Negligible	**Negligible to Minor adverse**		**Negligible to Minor adverse**
		DEP including export cable		Negligible	**Negligible to Minor adverse**		**Negligible to Minor adverse**

10.6.2.6.2.2 *Mitigation*

652. No mitigation is required for the disturbance of seals at haul-out sites. However, where possible and safe to do so, transiting vessels would maintain distances of 600m or more off the coast, particularly in areas near known seal haul-out sites during sensitive periods.

10.6.2.6.3 Impact Assessment for SEP and DEP

653. The impacts for SEP and DEP would be similar to that presented for SEP or DEP in isolation. While the number of vessel transits in a SEP and DEP scenario will be an increase in comparison to the SEP or DEP in isolation scenario (with an estimated 3.3 vessels transits per day compared to 1.6 transits for the SEP or DEP in isolation scenario), the majority will be small vessels, and are unlikely to cause any disturbance to seals at haul-out sites. In addition, this is a small increase in terms of vessel transits per day above baseline levels. Measures that the Applicant will implement to reduce disturbance and risk of vessel collision risk are provided in the **Draft MMMP** (document reference 9.4).

654. Therefore, the impact assessment as presented in **Table 10-95** for SEP or DEP in isolation, with an impact significance of **negligible to minor adverse (not significant)** for both grey seal and harbour seal, applies for the scenario of SEP and DEP.

10.6.2.7 Impact 7: Changes to Prey Availability

655. As outlined in **Chapter 9 Fish and Shellfish Ecology**, the potential impacts on fish species during operation and maintenance can result from:

- Temporary habitat loss / disturbance;
- Permanent loss;
- Long term habitat loss;
- Introduction of wind turbine foundations, scour protection and hard substrate;
- Increased suspended sediments and sediment re-deposition;
- Re-mobilisation of contaminated sediments;
- Underwater noise; and
- EMF.

656. Any impacts on prey species has the potential to affect marine mammals.

10.6.2.7.1 Sensitivity of Marine Mammals

657. As outlined in **Section 10.6.1.8.1**, harbour porpoise are considered to have low to medium sensitivity to changes in prey resources, bottlenose dolphin and white-beaked dolphin have low sensitivity, minke whale have low to medium sensitivity, grey seal and harbour seal have low sensitivity.

10.6.2.7.2 *Magnitude for SEP or DEP in Isolation*

10.6.2.7.2.1 *Temporary Habitat Loss / Disturbance*

658. Certain activities during operation will result in the temporary disturbance of the sea bed and consequent impacts on prey species. This includes any requirement for use of jack-up vessels or anchoring, as well as cable reburial and/or repairs.

659. Temporary habitat loss has not been assessed as a direct impact on marine mammals, as any impacts of habitat loss would only cause an indirect effect in terms of changes in prey availability.

660. Impacts on prey will be on a considerably smaller scale and at a much lower frequency than those assessed in relation to construction, the potential magnitude of negligible to low magnitude s has been identified, depending on the prey species. The impact significance for fish species is assessed as negligible to minor adverse.

661. Due to the considerably smaller scale to any potential changes to prey availability as a result of physical disturbance in comparison to the construction phase and temporary habitat loss is assessed as negligible for marine mammals.

10.6.2.7.2.2 *Permanent Habitat Loss*

662. Habitat loss will occur during the lifetime of SEP and DEP as a result of structures, scour and external cable protection installed on the sea bed. The introduction of hard substrate, such as wind turbine towers, foundations and associated scour protection and cable protection would increase habitat heterogeneity through the introduction of hard structures in an area predominantly characterised by sediment habitats.

663. Permanent habitat loss has not been assessed as a direct impact on marine mammals, as any impacts of habitat loss would only cause an indirect effect in terms of changes in prey availability.

664. As outlined in **Table 10-1**, at SEP, total permanent habitat loss would be up to 0.50km^2 and up to 0.67km^2 at DEP. In **Chapter 9 Fish and Shellfish Ecology** this is considered not significant in the context of the amount of similar available habitat in the wider area. Overall, due to the presence of comparable habitats identified throughout the SEP and DEP offshore sites and the wider region, and the localised spatial extent of impacts, the magnitude of effect of permanent habitat loss is considered to be low. Based on the low sensitivity of prey species and a low magnitude of effect in relation to permanent habitat loss during the operational phase of SEP or DEP, the impact significance is assessed as **minor adverse** for prey species. Therefore, the magnitude is negligible for marine mammals.

10.6.2.7.2.3 *Long Term Habitat Loss*

665. A distinction is made between permanent habitat loss where infrastructure is expected or assumed to be decommissioned *in situ* and long term habitat loss that will result from the installation of infrastructure where the Applicant has made a commitment to removal on decommissioning (i.e. that within the Cromer Shoal Chalk Beds MCZ).

666. The worst-case footprint of export cable protection (including at the HDD exit point) that could result in long term habitat loss is 900m^2 for SEP or DEP in isolation, or 1,800m^2 for SEP and DEP. With the commitment to remove this infrastructure at decommissioning, it is expected that habitat loss will last for the duration of the SEP and/or DEP operational phases (40 years). Therefore, the impact will be throughout the Projects' duration, but will be very limited in extent, therefore the magnitude of effect is assessed as low for prey species. Based on the low sensitivity of prey species and a low magnitude of effect in relation to long term habitat loss during the operational phase, the impact significance is assessed as **minor adverse** for prey species. Therefore, the magnitude is negligible for marine mammals.

10.6.2.7.2.4 *Introduction of Wind Turbine Foundations, Scour Protection and Hard Substrate*

667. The introduction of various man-made structures such as foundations and scour protection in soft sediment areas increases and changes habitat availability and type, resulting in locally altered biodiversity as species are able to establish and thrive in previously hostile environments (Birchenough and Degraer, 2020). The colonisation of such species may cause indirect effects on fish and shellfish populations if the structures act as artificial reefs, as well as direct impacts due to the potential of foundations acting as fish aggregation devices (FAD).

668. The introduction of new hard substrate in areas that are predominantly sandy or soft sediments may cause positive effects through potential habitat enhancement (Roach and Cohen, 2020).

669. Studies show that the effect of a FAD results in an increase of the biomass of fish species around foundations compared to areas where there was no FAD present. Fish are attracted and aggregate from the surrounding areas as they are attracted to the new habitat by increased feeding opportunities.

670. The potential effects of increased the biomass of fish species through introduction of various man-made structures are likely to be beneficial to marine mammals, although have been assessed as **negligible** as a precautionary approach.

10.6.2.7.2.5 *Increased SSCs and Sediment Deposition*

671. Increases in SSC within the water column and subsequent deposition onto the sea bed may occur as a result of operation and maintenance activities. Disturbance caused by jack up vessel legs or anchors, as well as cable reburial and/or repair may result in small volumes of sediment being re-suspended. However, the volumes of sediment disturbed from such activities, as well as the overall duration of the disturbance, would be significantly less compared to construction.

672. Increases in SSCs are expected to cause localised and short-term increases at the point of discharge. Released sediment may then be transported in suspension in the water column by tidal currents. It is assumed that there could be up to 10 jack-up movements per year for each of SEP and DEP (i.e. 20 in total). Cable repairs or replacements will only be carried out infrequently, for example, one export and interlink cable repair every 10 years and two infield cable repairs every 10 years. Similarly, for reburial, there may be up to 0.2km per export cable affected every 10 years, and 1% of each of the total interlink and infield cabling every 10 years.

673. Increased SSCs and levels of sediment re-deposition will be localised and short term. Therefore, the effect of SSC and re-deposition during the operational phase is considered to be **negligible** for prey species and marine mammals.

10.6.2.7.2.6 *Re-Mobilisation of Contaminated Sediments*

674. Contaminants in the area have not been reported at significantly elevated levels that would be a cause for concern. Any effects from the remobilisation of contaminated sediments and sediment redeposition are likely to be less than during the construction of SEP and DEP, either in isolation or together (**Chapter 7 Marine Water and Sediment Quality**).

675. The impact arising from remobilisation of contaminated sediments is considered to be **negligible** for both SEP or DEP in isolation for prey species and marine mammals.

10.6.2.7.2.7 *Underwater Noise during Operation and Maintenance*

676. Sources of underwater noise during operation and maintenance include operational wind turbines, maintenance activities, such as cable repairs, replacement and protection, and vessels.

677. Underwater noise modelling (**Appendix 10.2 Underwater Noise Modelling Report**) has been conducted to predict the potential impacts of these noise sources and activities on different types of fish groups (based on Popper *et al*., 2014).

678. The underwater noise modelling results indicate that the maximum predicted impact ranges for operational turbines, cable laying, trenching, rock placement and vessels is less than 0.05km for all fish species (**Table 10-96**).

679. The impact range for fish species (**Table 10-96**) are less than the predicted impact range for marine mammal species for operational turbines (**Table 10-87**), maintenance activities such as cable laying, trenching and rock placement (**Table 10-60**) and vessels (**Table 10-65**). In **Chapter 9 Fish and Shellfish Ecology** it is expected that during operation there will be only a slight and localised increase above background noise levels, therefore the magnitude of effect for fish species at either SEP or DEP is considered to be low. Therefore, there would be no additional impact on marine mammals as a result of any impacts on fish species from underwater noise during operation and maintenance. The magnitude of any potential impact would be negligible for marine mammals.

Table 10-96: Predicted Maximum Underwater Noise Impact Ranges for Fish Species during Operation and Maintenance

Species	Potential Impact	Criteria and threshold (Popper *et al*., 2014)	Operational wind turbines	Cable laying	Trenching	Rock placement	Vessels (large or medium)
All fish species	Recoverable injury	170 dB (48 hours) Unweighted SPL_{RMS}	<0.05km	<0.05km	<0.05km	<0.05km	<0.05km
	TTS	158 dB (12 hours) Unweighted SPL_{RMS}	<0.05km	<0.05km	<0.05km	<0.05km	<0.05km

10.6.2.7.2.8 *Electromagnetic Fields (EMF)*

680. OWFs transmit the energy produced along a network of cables. As energy is transmitted, the cables emit low-energy EMF. The electrical and magnetic fields generated increase proportionally to the amount of electricity transmitted.

681. As outlined in the scoping report (Royal HaskoningDHV, 2019) and scoping opinion (Planning Inspectorate, 2019b) any direct impacts on marine mammals are highly unlikely, however there is the potential for EMF to affect fish species.

682. SEP and DEP will involve installing offshore export cable circuits using HVAC technology. Fish and shellfish species are less likely to exhibit responses to HVAC cables when compared to High Voltage Direct Current (HVDC) transmission cables due to the higher strength EMFs emitted by HVDC (Normandeau *et al*., 2011).

683. As outlined in **Chapter 9 Fish and Shellfish Ecology**, the predicted magnetic fields for SEP and DEP based on Tripp (2021) are greatest on the sea bed and reduce rapidly with vertical and horizontal distance from the circuits. The magnetic fields from all scenarios reduced to very low levels within a few metres from the circuits and it is important to note that these levels do not take account of shielding factors of the cable sheath which would further reduce the fields.

684. The principal fish species groups potentially affected by EMF emitted by the interlink, infield and export cables during the operational phase of SEP and DEP are elasmobranchs; diadromous migratory species; other fish species; and shellfish species. The overall magnitude of effect of EMF for either SEP or DEP on fish and shellfish receptors is considered to be low in **Chapter 9 Fish and Shellfish Ecology**. EMF effects on prey species, taking into consideration their sensitivities, are assessed to result in an overall impact significance of **minor adverse** during the operation of SEP or DEP in isolation and together.

685. The areas potentially affected by EMF generated by the worst-case scenario for offshore cables are expected to be small and restricted to the immediate vicinity of the cables (i.e. within metres). EMFs are expected to attenuate rapidly in both horizontal and vertical plains with distance from the source. The magnitude of the effect on marine mammals as a result of any changes to prey is assessed as **negligible**.

10.6.2.7.3 Impact Significance

686. Taking into account the marine mammal sensitivity (low to medium, **Section 10.6.2.7.1**) and the potential magnitude of the impact (negligible), the impact significance for any potential changes in prey availability during operation and maintenance at SEP or DEP has been assessed as **negligible** or **minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 10-97**).

10.6.2.7.4 Mitigation

687. No mitigation is required or proposed for any potential impacts on prey species during the operation and maintenance phase.

Table 10-97: Assessment of Impact Significance for Any Potential Changes in Prey Availability during Operation and Maintenance at SEP or DEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Change in prey availability during operation and maintenance	Harbour porpoise	SEP & / or DEP including export cable	Low to Medium	Negligible	**Negligible to Minor adverse**	No mitigation proposed for prey.	**Negligible to Minor adverse**
	Bottlenose dolphin		Low	Negligible	**Negligible**		**Negligible**
	White-beaked dolphin		Low	Negligible	**Negligible**		**Negligible to Minor adverse**
	Minke whale		Low to Medium	Negligible	**Negligible to Minor adverse**		**Negligible to Minor adverse**
	Grey seal		Low	Negligible	**Negligible**		**Negligible**
	Harbour seal		Low	Negligible	**Negligible**		**Negligible**

10.6.2.7.5 Impact Assessment for SEP and DEP

688. The impacts for any potential changes in prey availability during operation and maintenance on marine mammals at SEP and DEP would be the same as the assessments for SEP or DEP in isolation.

689. As assessed in **Chapter 9 Fish and Shellfish Ecology** any potential impacts to fish species at SEP and DEP during operation and maintenance would be negligible to low.

690. The impact significance for any potential changes in prey availability on marine mammals during operation and maintenance at SEP and DEP has been assessed as **negligible or minor adverse (not significant)** for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal.

10.6.2.8 Impact 8: Changes to Water Quality

691. As outlined in **Chapter 7 Marine Water and Sediment Quality** potential changes in water quality during operation and maintenance are:

- Deterioration in water quality through an increase in suspended sediment due to cable repairs / reburial; and
- Deterioration in water quality through an increase in suspended sediment due to maintenance activities.

10.6.2.8.1 Sensitivity of Marine Mammals

692. As outlined in **Section 10.6.1.9.1**, marine mammals are considered to have negligible sensitivity to any changes in water quality.

10.6.2.8.2 Magnitude for SEP or DEP in Isolation

693. As assessed in **Chapter 7 Marine Water and Sediment Quality** any potential changes in water quality at SEP or DEP during operation and maintenance would be negligible.

10.6.2.8.3 Impact Significance

694. Taking into account the negligible sensitivity of marine mammals and negligible magnitude the impact significance for any changes in water quality during operation and maintenance at SEP or DEP has been assessed as **negligible**.

10.6.2.8.4 Mitigation

695. No mitigation is required or proposed.

10.6.2.8.5 Impact Assessment for SEP and DEP

696. As assessed in **Chapter 7 Marine Water and Sediment Quality** any potential changes in water quality at SEP and DEP during operation and maintenance would be negligible.

697. Taking into account the negligible sensitivity of marine mammals and negligible magnitude the impact significance for any changes in water quality during operation and maintenance at SEP and DEP has been assessed as **negligible**.

10.6.2.9 Overall Impacts during Operation and Maintenance

698. There would be no further overall effects during operation and maintenance, as the assessment for any potential disturbance as a result of underwater noise represents the worst-case.

699. Any potential impacts during operation and maintenance from underwater noise, changes in prey availability or water quality would be localised, temporary and negligible.

10.6.3 Potential Impacts during Decommissioning

700. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in **Chapter 4 Project Description** and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all the turbine elements, part of the foundations (those above sea bed level), removal of some or all of the infield cables, interlink cables, and export cables. Scour and cable protection would likely be left in situ, other than in the Cromer Shoal Chalk Beds MCZ where it may be removed

701. The potential impacts during decommissioning that will be assessed for marine mammals include:

- Impact 1: Physical injury, auditory injury and behavioural impacts resulting from the noise associated with foundation removal (e.g. cutting);
- Impact 2: Underwater noise and disturbance from other decommissioning activities;
- Impact 3: Underwater noise and disturbance from vessels;
- Impact 4: Barrier effects as a result of underwater noise;
- Impact 5: Increased collision risk with vessels;
- Impact 6: Disturbance at seal haul-out sites;
- Impact 7: Changes to prey resource; and
- Impact 8: Changes to water quality.

702. Potential impacts on marine mammals associated with decommissioning have not been assessed in detail, as further assessments will be carried out ahead of any decommissioning works to be undertaken taking account of known information at that time, including relevant guidelines and requirements. A detailed decommissioning programme will be provided to and approved by the Secretary of State for Business, Energy and Industrial Strategy (BEIS) prior to construction that will give details of the techniques to be employed and any relevant mitigation measures required.

703. It is not possible to provide details of the methods that will be used during decommissioning at this time. However, is it expected that the activity levels will be comparable to construction (with the exception of pile driving noise which would not occur).

704. The potential impacts on marine mammals during decommissioning would be expected to be the same or less than those assessed for construction in **Section 10.6.1**.

10.7 Cumulative Impacts

705. The CIA considers plans, projects and activities where their predicted impacts have the potential to interact with the potential impacts during construction of SEP and DEP.

706. The plans and projects screened into the CIA are located in the relevant marine mammal reference population areas. Full information on the CIA screening is provided in **Appendix 10.3 Marine Mammal CIA Screening**.

707. The CIA screening identified that there is the potential for cumulative impacts on marine mammals as a result of disturbance from underwater noise during piling and other construction activities, including vessels at SEP and DEP. Other potential impacts, including PTS from underwater noise, TTS from underwater noise, changes to prey resources and increased collision risk with vessels, were screened out of the CIA (see **Appendix 10.3 Marine Mammal CIA Screening**). All operational impacts have also been screened out of assessment.

708. The potential sources of cumulative underwater noise which could disturb marine mammals and which are screened into the CIA are:

- piling at OWFs, including SEP and DEP;
- other construction activities at OWFs including at SEP and DEP (vessels, cable installation works, dredging, sea bed preparation and rock placement);
- geophysical surveys for OWFs (other than for SEP and DEP);
- aggregate extraction and dredging;
- oil and gas seismic surveys;
- subsea cable and pipelines; and
- UXO clearance (other than for SEP and DEP).

709. The approach to the assessment for cumulative disturbance from underwater noise for harbour porpoise has been based on the approach for the assessment of disturbance in **Section 10.6.1.2**, including the current advice from the SNCBs (JNCC *et al*., 2020) on the assessment of impacts on the SNS SAC.

710. The potential disturbance from underwater noise during piling for other marine mammal species has been assessed based on the worst-case maximum area modelled for SEP and DEP for each species, using TTS / fleeing response as a proxy for disturbance, where no further information of potential disturbance impact ranges are available.

711. The potential disturbance from offshore wind farms during non-piling construction activities, such as vessel noise, sea bed preparation, rock placement and cable installation, has been based on the worst-case maximum area modelled for SEP and DEP for all five activities and up to 16 vessels (see **Section 10.6.1.3**). This is a precautionary approach, as it is highly unlikely that all non-piling construction activities and all vessels would be on each site at any one time.

712. Where a quantitative assessment has been possible, the potential magnitude of disturbance has been based on the number of harbour porpoise, bottlenose dolphin, white-beaked dolphin and minke whale in the potential impact areas using the latest SCANS-III density estimates (Hammond et al., 2021). For any project located within survey block O, the bottlenose dolphin density estimate for survey block R has been used (see **Section 10.5** for more information).

713. The number of grey and harbour seal in the potential impact areas has been estimated based on the seal at sea usage maps (Russell *et al.*, 2017).

714. It is intended that this approach to assessing the potential cumulative impacts of disturbance from underwater noise will reduce some of the uncertainties and complications in using the different assessments from EIAs, based on different noise models, thresholds and criteria, as well as different approaches to density estimates.

10.7.1 Assessment of Cumulative Impacts

715. It should be noted that a large amount of uncertainty is inherent in the CIA. At the project level, uncertainty in the assessment process has been expressed as a level of the confidence in the data used in the assessment. This relates to confidence in both the understanding of the consequences of the potential impacts on marine mammals, but also the information used to inform the predicted magnitude and significance of project impacts on marine mammals. As outlined in the tier approach, there is more information and certainty for lower tiers, compared to higher tiers (JNCC and Natural England, 2013).

716. In the CIA, the potential for impacts over wider spatial and temporal scales means that the uncertainty arising from the consideration of a large number of plans or projects leads to a lower confidence in the information used in the assessment, but also the conclusions of the assessment itself. To take this uncertainty into account, where possible, a precautionary approach has been taken at multiple stages of the assessment process.

717. The approach to dealing with uncertainty has led to a highly precautionary assessment of the cumulative impacts, especially for pile driving as the CIA is based on the worst-case scenarios for all projects included. It should therefore be noted that building precaution on precaution can lead to unrealistic worst-case scenarios within the assessment.

718. Therefore, the assessment is based on the most realistic worst-case scenario to reduce any uncertainty and avoid presentation of highly unrealistic worst-case scenarios, while still providing a conservative assessment. Careful consideration has been given to determine the most realistic worst-case scenario for the CIA.

719. The level of uncertainty in completing a CIA further supports the need for a more strategic level assessment rather than developer led assessment. Population models, such as DEPONS and the interim Population Consequences of Disturbance (iPCoD) used at a strategic level would allow consideration of the biological fitness consequences of disturbance from underwater noise, and the conclusions of a quantitative assessment to be put into a population level context (e.g. Nabe-Nielsen *et al*., 2018).

720. The DEPONS model indicated the North Sea harbour porpoise population was not affected by the construction of 65 wind farms, as required to meet the EU renewable energy target (Nabe-Nielsen *et al.,* 2018). However, wind farm construction schedules and the length of the breaks between individual piling events influenced the population effects of noise. In addition, when areas in the western North Sea were continuously exposed to noise for several years, the effect of noise was larger and more persistent than when wind farms were constructed in random order. Similarly, when wind farm construction involved near continuous pile driving, the population effects were larger than when local densities had more time to recover between consecutive pilings (Nabe-Nielsen *et al.,* 2018). This therefore demonstrates how the modelling framework can be used for spatial planning to help mitigate population effects of disturbances.

10.7.1.1 Cumulative Impact 1: Underwater Noise Impacts during Construction from Offshore Wind Farm Piling

721. One of the greatest potential noise sources during offshore wind farm construction is from pile driving. The CIA considers the potential disturbance of marine mammals during piling for SEP and DEP, with the piling at other offshore wind farm projects screened into the CIA, where there is the potential for simultaneous piling.

722. The CIA screening (see **Appendix 10.3 Marine Mammal CIA Screening**) identified nine UK OWFs with the potential for piling to be at the same time as piling at SEP and / or DEP, taking into account the relevant spatial areas for each species. The worst-case scenario would be if the following OWFs were constructed concurrently with simultaneous piling in 2028:

- SEP and / or DEP (all species)
- Berwick Bank (not for grey and harbour seal)
- Dogger Bank South (all species)
- East Anglia ONE North (all species)
- East Anglia TWO (all species)
- Five Estuaries (all species)
- Hornsea Project Four (all species)
- North Falls (all species)
- Outer Dowsing (all species)
- Rampion Extension (harbour porpoise only)

723. The potential piling period for SEP and DEP has been based on the widest likely range of offshore construction and piling dates, dependent on the construction scenario, as a precautionary approach. It should be noted that while the projects included within the CIA have the potential for piling to overlap with SEP and DEP, there is a lot of uncertainty on when OWFs could be piling. This assessment is therefore considered the worst-case.

724. Where possible, the CIA screening included consideration of the realistic potential for cumulative impacts during construction at SEP and DEP. For example, it is assumed that where offshore wind farm developers have more than one offshore wind farm, they are unlikely to develop more than one site at a time. Unless further information is available (for example, in the case of the East Anglia Hub where two sites could be developed at the same time).

10.7.1.1.1 Potential for Disturbance during Offshore Wind Farm Piling

725. The commitment to the mitigation measures agreed through the MMMP for piling as outlined above (**Table 10-3**) would reduce the risk of physical injury or permanent auditory injury (PTS) for all marine mammals. As such, SEP and DEP would not contribute to any cumulative impacts for physical injury or permanent auditory injury (PTS) from piling activities, and therefore the following assessment only considers potential disturbance effects to marine mammals.

10.7.1.1.1.1 *Sensitivity to Disturbance*

726. As outlined in **Section 10.6.1.1.1**, harbour porpoise, white-beaked dolphin, minke whale, bottlenose dolphin, grey seal and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources.

10.7.1.1.1.2 *Magnitude of Potential Disturbance*

727. The magnitude of the potential disturbance from piling activities has been estimated for each individual project screened in for assessment based on the following disturbance ranges for each marine mammal species:

- Harbour porpoise
  - The potential impact area during single pile installation, based on EDR of 26km from each piling location (2,123.7km^2 per project)
- Bottlenose dolphin and white-beaked dolphin
  - The potential impact area during single pile installation, based on maximum impact range and area for the worst-case modelled at SEP and DEP for TTS / fleeing response (weighted SEL_{cum}) of 0.4km from each piling location (0.44km^2 per project)
- Minke whale
  - The potential impact area during single pile installation, based on maximum impact range and area for the worst-case modelled at SEP and DEP for TTS / fleeing response (weighted SEL_{cum}) of 25km from each piling location (1,100km^2 per project)
- Grey seal and harbour seal
  - The potential impact area during single pile installation, based on maximum impact range and area for the worst-case modelled at SEP and DEP for TTS / fleeing response (weighted SEL_{cum}) of 9.7km from each piling location (220km^2 per project)

728. It should be noted that the potential areas of disturbance assume that there is no overlap in the areas of disturbance between different projects and are therefore highly conservative.

729. Piling at both SEP and DEP has been included in the CIA as a worst-case scenario.

730. The approach to the CIA for piling at OWFs is based on the potential for single piling at each wind farm at the same time as single piling at SEP and DEP. This approach allows for some of the offshore wind farms not to be piling at the same time, while others could be simultaneously piling (further information is available in **Appendix 10.3 Marine Mammal CIA Screening**). This is considered to be the most realistic worst-case scenario, as it is highly unlikely that all other wind farms would be simultaneously piling at exactly the same time as piling at SEP and DEP.

731. It is important to note the actual duration for active piling time which could disturb marine mammals is only a very small proportion of the potential construction period, of up to approximately 30 days for SEP and DEP, based on the estimated maximum duration to install individual piles (**Table 10-1**).

732. For harbour porpoise, the potential worst-case scenario (2,123.7km^2 at each wind farm), the estimated maximum area of potential disturbance is 23,360.7km^2, without any overlap in the potential areas of disturbance at each offshore wind farm. The maximum number of harbour porpoise that could potentially be temporarily disturbed is 16,310 individuals, which represents approximately 4.71% of the North Sea MU reference population (**Table 10-98**). Therefore, the potential magnitude of the temporary effect is assessed as low (**Table 10-9**). However, this is very precautionary, as it is unlikely that all projects could be simultaneously piling at exactly the same time as piling at SEP or DEP and other offshore wind farm projects.

733. In practice, the potential temporary effects would be less than those predicted in this assessment as there is likely to be a great deal of variation in timing, duration, and hammer energies used throughout the various offshore wind farm project construction periods. In addition, not all individuals would be displaced over the entire potential disturbance range (26km) used within the assessments. For example, the study of harbour porpoise at Horns Rev (Brandt et al., 2011), indicated that at closer distances (2.5 to 4.8km) there was 100% avoidance, however, this proportion decreased significantly moving away from the pile driving activity and at distances of 10km to 18km avoidance was 32% to 49% and at 21km the abundance was reduced by just 2%.

Table 10-98: Quantified CIA for the Potential Disturbance of Harbour Porpoise during Single Piling at the Offshore Wind Farm Projects which Could be Simultaneously Piling at the Same Time as SEP and DEP

Name of Project	SCANS-III Block	Harbour porpoise density	Impact area (26km EDR)	Maximum number of individuals potentially disturbed during single piling
SEP	O	0.888	2123.7	1,886
DEP	O	0.888	2123.7	1,886
Berwick Bank	R	0.599	2123.7	1,272

Name of Project	SCANS-III Block	Harbour porpoise density	Impact area (26km EDR)	Maximum number of individuals potentially disturbed during single piling
Dogger Bank South	O	0.888	2123.7	1,886
East Anglia ONE North	L	0.607	2123.7	1,289
East Anglia TWO	L	0.607	2123.7	1,289
Five Estuaries	L	0.607	2123.7	1,289
Hornsea Project Four	O	0.888	2123.7	1,886
North Falls	L	0.607	2123.7	1,289
Outer Dowsing	O	0.888	2123.7	1,886
Rampion Extension	C	0.213	2123.7	452
Total number of harbour porpoise (without SEP & DEP)				**16,310 (12,538)**
Percentage of NS MU (346,601 harbour porpoise) (without SEP & DEP)				**4.71% (3.62%)**
Magnitude (without SEP & DEP)				**Low (low)**

734. For bottlenose dolphin, based on a single pile installation (0.44km^2) at each of the offshore wind farms including SEP and DEP, the estimated maximum area of potential disturbance is 4.84km^2. The maximum number of bottlenose dolphin that could potentially be disturbed is 0.079 (0.0039% of the GNS MU; **Table 10-99**). The potential magnitude for the cumulative impacts of piling is assessed as negligible for bottlenose dolphin, with less than 1% of the reference population that could be temporarily disturbed.

Table 10-99: Quantified CIA for the Potential Disturbance of Bottlenose Dolphin during Single Piling at Offshore Wind Farm Projects which Could be Simultaneously Piling at the Same Time as SEP and DEP

Name of Project	SCANS-III Block	Bottlenose dolphin density	Impact area	Maximum number of individuals potentially disturbed during single piling
SEP	R	0.0298	0.44	0.013
DEP	R	0.0298	0.44	0.013
Berwick Bank	R	0.0298	0.44	0.013
Dogger Bank South	R	0.0298	0.44	0.013
East Anglia ONE North	L	0	0.44	0
East Anglia TWO	L	0	0.44	0

Name of Project	SCANS-III Block	Bottlenose dolphin density	Impact area	Maximum number of individuals potentially disturbed during single piling
Five Estuaries	L	0	0.44	0
Hornsea Project Four	R	0.0298	0.44	0.013
North Falls	L	0	0.44	0
Outer Dowsing	R	0.0298	0.44	0.013
Rampion Extension	C	0	0.44	0
Total number of bottlenose dolphin (without SEP & DEP)				**0.079 (0.052)**
Percentage of GNS MU (2,022 bottlenose dolphin) (without SEP & DEP)				**0.0039% (0.0026%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**

735. For white-beaked dolphin, based on a single pile installation (0.44km^2) at each of the offshore wind farms including SEP and DEP, the maximum number of white-beaked dolphin that could potentially be disturbed is 0.11 (0.0003% of the reference population; **Table 10-100**). The potential magnitude for the cumulative impacts of piling is assessed as negligible for white-beaked dolphin, with less than 1% of the reference population that could be temporarily disturbed.

Table 10-100: Quantified CIA for the Potential Disturbance of White-Beaked Dolphin during Single Piling at Offshore Wind Farm Projects which Could be Simultaneously Piling at the Same Time as SEP and DEP

Name of Project	SCANS-III Block	White beaked dolphin density	Impact area	Maximum number of individuals potentially disturbed during single piling
SEP	O	0.002	0.44	0.001
DEP	O	0.002	0.44	0.001
Berwick Bank	R	0.243	0.44	0.11
Dogger Bank South	O	0.002	0.44	0.001
East Anglia ONE North	L	0	0.44	0
East Anglia TWO	L	0	0.44	0
Five Estuaries	L	0	0.44	0
Hornsea Project Four	O	0.002	0.44	0.001
North Falls	L	0	0.44	0
Outer Dowsing	O	0.002	0.44	0.001

Name of Project	SCANS-III Block	White beaked dolphin density	Impact area	Maximum number of individuals potentially disturbed during single piling
Rampion Extension	C	0	0.44	0
Total number of white-beaked dolphin (without SEP & DEP)				**0.11 (0.11)**
Percentage of CGNS MU (43,951 white-beaked dolphin) (without SEP & DEP)				**0.0003% (0.0002%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**

736. For minke whales, based on a single pile installation (1,100km^2) at each of the offshore wind farms including SEP and DEP, the estimated maximum area of potential disturbance for minke whale is 12,100km^2. The maximum number of minke whale that could be potentially temporarily disturbed is 481 individuals, which represents approximately 2.39% of the reference population (**Table 10-101**). Therefore, the potential magnitude of the temporary effect is assessed as low, with between 1% and 5% of the reference population likely to be exposed to the effect.

Table 10-101: Quantified CIA for the Potential Disturbance of Minke Whale during Single Piling at Offshore Wind Farm Projects which Could be Simultaneously Piling at the Same Time as SEP and DEP

Name of Project	SCANS-III Block	Minke whale density	Impact area	Maximum number of individuals potentially disturbed during single piling
SEP	O	0.01	1,100	11
DEP	O	0.01	1,100	11
Berwick Bank	R	0.387	1,100	426
Dogger Bank South	O	0.01	1,100	11
East Anglia ONE North	L	0	1,100	0
East Anglia TWO	L	0	1,100	0
Five Estuaries	L	0	1,100	0
Hornsea Project Four	O	0.01	1,100	11
North Falls	L	0	1,100	0
Outer Dowsing	O	0.01	1,100	11
Rampion Extension	C	0	1,100	0
Total number of minke whale (without SEP & DEP)				**481 (459)**

Name of Project	SCANS-III Block	Minke whale density	Impact area	Maximum number of individuals potentially disturbed during single piling
Percentage of CGNS MU (20,118 minke whale) (without SEP & DEP)				**2.4% (2.28%)**
Magnitude (without SEP & DEP)				**Low (low)**

737. For grey and harbour seal, based on a single pile installation (220km^2) at each of the offshore wind farms including SEP and DEP, the estimated maximum area of potential disturbance for both grey seal and harbour seal is 1,980km^2. The maximum number of grey seal and harbour seal that could potentially be disturbed is 421 (1.75% of the reference population) and 130 (0.43% of the reference population), respectively (**Table 10-102**). The potential magnitude for the cumulative impacts of simultaneous piling is assessed as low for grey with between 1% and 5% of the reference population likely to be exposed to the effect and negligible for harbour seal with less than 1% of the reference population with the potential to be impacted.

Table 10-102: Quantified CIA for the Potential Disturbance of Grey and Harbour Seal during Single Piling at Offshore Wind Farm Projects Which Could be Simultaneously Piling at the Same Time as SEP and DEP

Name of Project	Grey seal density	Harbour seal density	Impact area	Maximum number of grey seals potentially disturbed during single piling	Maximum number of harbour seals potentially disturbed during single piling
SEP	0.853	0.274	220	188	60
DEP	0.739	0.08	220	163	18
Dogger Bank South	0.112	0.004	220	25	0.9
East Anglia ONE North	0.0009	0.0004	220	0.2	0.09
East Anglia TWO	0.005	0.0004	220	1.1	0.09
Five Estuaries	0.01	0.0007	220	2	0.15
Hornsea Project Four	0.14	0.04	220	31	9
North Falls	0.016	0.002	220	4	0.44
Outer Dowsing	0.038	0.191	220	8	42
Total number of grey seal or harbour seal (without SEP & DEP)				**421 (71)**	**130 (52)**
Percentage of wider reference population (24,116 grey seal; 30,590 harbour seal) (without SEP & DEP)				**1.75% (0.29%)**	**0.43% (0.17%)**
Magnitude (without SEP & DEP)				**Low (negligible)**	**Negligible (negligible)**

10.7.1.1.1.3 Mitigation

738. Through the implementation of the management measures within the SNS SAC SIPs, potential impacts will be managed and reduced. Any mitigation measures to reduce the disturbance of harbour porpoise would also reduce the potential disturbance of bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal.

10.7.1.1.1.4 *Impact Significance of Potential Disturbance during Offshore Wind Farm Piling*

739. If all included offshore wind farms were single piling at the same time as SEP and DEP, there is the potential for a low to negligible magnitude of impact (dependent on species), however, as outlined above, it is highly unlikely that all offshore wind farms could be simultaneously piling at exactly the same time.

740. Therefore, taking into account the medium receptor sensitivity for all marine mammal species, the overall cumulative impact assessment for disturbance to marine mammals from piling at offshore wind farms including SEP and DEP is and minor adverse for all species. This is deemed to be a conservative assessment based on the worst-case scenario for offshore wind farms single piling at the same time as SEP and DEP (**Table 10-103**).

741. The project specific SIPs for the SNS SAC would manage and reduce the potential for significant disturbance of harbour porpoise from cumulative underwater noise during offshore wind farm piling. Therefore, the residual impact for all marine mammal species is assessed as **minor adverse (not significant)**.

742. The confidence in this impact assessment is relatively high as it is deemed precautionary enough to comfortably encompass the likely uncertainty and variability. Throughout the assessment it has been made clear where multiple and compounding precautionary assumptions have been made. Additionally, where possible, the uncertainty in the data typically used to inform CIAs and the quantification of impacts when based on published ESs has been removed by using a standard impact range for disturbance and the SCANS-III and seal-at sea density estimates for all offshore wind farm sites.

Table 10-103: Cumulative Impact Significance for Disturbance to Marine Mammals from Offshore Wind Farms Including SEP and DEP

Potential Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigations	Residual Impact
Cumulative impact of disturbance during single piling including SEP and DEP	Harbour porpoise	Medium	Low	**Moderate adverse**	Project specific SIPs for the SNS SAC would manage and reduce potential for significant disturbance from cumulative offshore wind farm piling	**Minor adverse**
	Bottlenose dolphin		Negligible	**Minor adverse**		**Minor adverse**
	White-beaked dolphin		Negligible	**Minor adverse**		**Minor adverse**
	Minke whale		Low	**Minor adverse**		**Minor adverse**
	Grey seal		Low	**Minor adverse**		**Minor adverse**
	Harbour seal		Negligible	**Minor adverse**		**Minor adverse**

10.7.1.2 Cumulative Impact 2: Underwater Noise Impacts from all other Noise Sources

743. During the construction period for SEP and DEP, the other potential noise sources in addition to piling that could also disturb marine mammals are:

- Offshore wind farm construction activities (other than piling, including vessels, cable installation works, dredging, sea bed preparation and rock placement)
- Geophysical surveys for offshore wind farms
- Aggregate extraction and dredging for harbour porpoise
- Oil and gas seismic surveys
- Subsea cable and pipelines for harbour porpoise
- UXO clearance

744. Further information on the CIA screening is provided in **Appendix 10.3 Marine Mammal CIA Screening**.

10.7.1.2.1 Potential for Disturbance from other Offshore Wind Farm Construction Activities

10.7.1.2.1.1 *Sensitivity to Disturbance*

745. As outlined in **Section 10.6.1.1.1**, harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources.

10.7.1.2.1.2 *Magnitude of Potential Disturbance*

746. During the construction of SEP and DEP, there is the potential for overlap with impacts from the non-piling construction activities at other offshore wind farms. Noise sources which could cause potential disturbance impacts during offshore wind farm construction activities, other than pile driving, can include vessels, sea bed preparation, cable installation works and rock placement.

747. The CIA includes all projects that could have non-piling construction activities during the SEP and DEP construction period. The approach to the CIA is the same as for piling.

748. The potential disturbance from offshore wind farms during non-piling construction activities, such as vessel noise, sea bed preparation, rock placement and cable installation, has been based on the worst-case maximum area modelled for SEP and DEP for all five activities and up to 16 vessels (see **Section 10.6.1.3**):

- Harbour porpoise
  - The potential impact area, based on all five activities ($3.36km^2$) and 16 vessels ($0.48km^2$) is $3.84km^2$ per project
- Bottlenose dolphin, white-beaked dolphin, minke whale, grey and harbour seal
  - The potential impact area, based on all five activities ($0.15km^2$) and 16 vessels ($0.48km^2$) is $0.63km^2$ per project

749. This is a very precautionary approach, as it is highly unlikely that all non-piling construction activities and all vessels would be on site at any one time. Any disturbance is likely to be limited to the area in and around where the activity is actually taking place.

750. Construction at both SEP and DEP has been included in the CIA as a worst-case scenario.

751. For harbour porpoise, based on the worst-case scenario, for all offshore wind farms that could be constructing at the same time as SEP and DEP, the maximum area of potential disturbance is 57.6km^2. The maximum number of harbour porpoise that could potentially be temporarily disturbed is approximately 41 i.e. 0.0121% of the North Sea MU reference population (**Table 10-104**). Therefore, the potential magnitude of the temporary effect is assessed as negligible.

Table 10-104: Quantified CIA for the Potential Disturbance of Harbour Porpoise during the Construction (Other than Piling) at Offshore Wind Farm Projects at the Same Time as Construction at SEP and DEP

Name of Project	Area (km^2)	SCANS-III Block	Harbour porpoise density	Maximum number of individuals potentially disturbed
SEP	3.84	O	0.888	3
DEP	3.84	O	0.888	3
Norfolk Boreas	3.84	O	0.888	3
East Anglia ONE North	3.84	L	0.607	2
East Anglia TWO	3.84	L	0.607	2
Hornsea Project Four	3.84	O	0.888	3
Norfolk Vanguard	3.84	O	0.888	3
Berwick Bank	3.84	R	0.599	2
Dogger Bank South	3.84	O	0.888	3
Dolphyn Project	3.84	T	0.402	2
Five Estuaries	3.84	L	0.607	2
North Falls	3.84	O	0.888	3
Outer Dowsing	3.84	O	0.888	3
Rampion Extension	3.84	C	0.213	1
Salamander	3.84	R	0.599	2
Total number of harbour porpoise (without SEP & DEP)				**41 (34)**
Percentage of NS MU (346,601 harbour porpoise) (without SEP & DEP)				**0.012% (0.01%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**

752. Based on all offshore wind farms with the potential for overlapping construction periods with SEP and DEP, the maximum number of bottlenose dolphin that could potentially be disturbed is 0.19 (0.0094% of the reference population) (**Table 10-105**). Therefore, the potential magnitude of the temporary effect is assessed as negligible (less than 1% of the reference population).

Table 10-105: Quantified CIA for the Potential Disturbance of Bottlenose Dolphin during the Construction (Other than Piling) at Offshore Wind Farm Projects at the Same Time as Construction at SEP and DEP

Name of Project	Area (km^2)	SCANS-III Block	Bottlenose dolphin density	Maximum number of individuals potentially disturbed
SEP	0.63	R	0.0298	0.019
DEP	0.63	R	0.0298	0.019
Norfolk Boreas	0.63	R	0.0298	0.019
East Anglia ONE North	0.63	L	0	0
East Anglia TWO	0.63	L	0	0
Hornsea Project Four	0.63	R	0.0298	0.019
Norfolk Vanguard	0.63	R	0.0298	0.019
Berwick Bank	0.63	R	0.0298	0.019
Dogger Bank South	0.63	R	0.0298	0.019
Dolphyn Project	0.63	S	0.0037	0.002
Five Estuaries	0.63	L	0	0
North Falls	0.63	R	0.0298	0.019
Outer Dowsing	0.63	R	0.0298	0.019
Rampion Extension	0.63	C	0	0
Salamander	0.63	R	0.0298	0.019
Total number of bottlenose dolphin (without SEP & DEP)				**0.19 (0.15)**
Percentage of GNS MU (2,022 bottlenose dolphin) (without SEP & DEP)				**0.0094% (0.0075%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**

753. Based on all offshore wind farms with the potential for overlapping construction periods with SEP and DEP, the maximum number of white-beaked dolphin that could potentially be disturbed is 0.34 (0.0008% of the reference population) (**Table 10-106**). Therefore, the potential magnitude of the temporary effect is assessed as negligible (less than 1% of the reference population).

Table 10-106: Quantified CIA for the Potential Disturbance of White-Beaked Dolphin during Construction (Other than Piling) at Offshore Wind Farm Projects at the Same Time as Construction at SEP and DEP

Name of Project	Area (km^2)	SCANS-III Block	White-beaked dolphin density	Maximum number of individuals potentially disturbed
SEP	0.63	O	0.002	0.0013
DEP	0.63	O	0.002	0.0013
Norfolk Boreas	0.63	O	0.002	0.0013
East Anglia ONE North	0.63	L	0	0
East Anglia TWO	0.63	L	0	0
Hornsea Project Four	0.63	O	0.002	0.0013
Norfolk Vanguard	0.63	O	0.002	0.0013
Berwick Bank	0.63	R	0.243	0.15
Dogger Bank South	0.63	O	0.002	0.0013
Dolphyn Project	0.63	T	0.037	0.023
Five Estuaries	0.63	L	0	0
North Falls	0.63	O	0.002	0.0013
Outer Dowsing	0.63	O	0.002	0.0013
Rampion Extension	0.63	C	0	0
Salamander	0.63	R	0.243	0.15
Total number of white-beaked dolphin (without SEP & DEP)				**0.34 (0.34)**
Percentage of CGNS MU (43,951 white-beaked dolphin) (without SEP & DEP)				**0.0008% (0.0008%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**

754. Based on the offshore wind farms that could be undergoing construction at the same time as SEP and DEP, the maximum number of minke whale that could be potentially temporarily disturbed is 0.56, approximately 0.003% of the reference population (**Table 10-107**). Therefore, the potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

Table 10-107: Quantified CIA for the Potential Disturbance of Minke Whale during the Construction (Other than Piling) at Offshore Wind Farm Projects at the Same Time as Construction at SEP and DEP

Name of Project	Area (km^2)	SCANS-III Block	Minke whale density	Maximum number of individuals potentially disturbed
SEP	0.63	O	0.01	0.006
DEP	0.63	O	0.01	0.006

Name of Project	Area (km^2)	SCANS-III Block	Minke whale density	Maximum number of individuals potentially disturbed
Norfolk Boreas	0.63	O	0.01	0.006
East Anglia ONE North	0.63	L	0	0
East Anglia TWO	0.63	L	0	0
Hornsea Project Four	0.63	O	0.01	0.006
Norfolk Vanguard	0.63	O	0.01	0.006
Berwick Bank	0.63	R	0.387	0.24
Dogger Bank South	0.63	O	0.01	0.006
Dolphyn Project	0.63	T	0.0316	0.02
Five Estuaries	0.63	L	0	0
North Falls	0.63	O	0.01	0.006
Outer Dowsing	0.63	O	0.01	0.006
Rampion Extension	0.63	C	0	0
Salamander	0.63	R	0.387	0.24
Total number of minke whale (without SEP & DEP)				**0.56 (0.55)**
Percentage of CGNS MU (20,118 minke whale) (without SEP & DEP)				**0.003% (0.003%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**

755. Based on the projects that could have construction overlapping with SEP and DEP, the maximum number of grey seal and harbour seal that could potentially be disturbed is 0.002% and 0.001% of the reference populations, respectively (**Table 10-108**). The potential magnitude for the cumulative impacts is assessed as negligible for both grey seal and harbour seal, with less than 1% of the reference population that could be temporarily disturbed.

Table 10-108: Quantified CIA for the Potential Disturbance of Grey Seal and Harbour Seal during the Construction (Other than Piling) at Offshore Wind Farm Projects at the Same Time as Construction at SEP and DEP

Name of Project	Area (km^2)	Grey seal density	Harbour seal density	Maximum number of grey seal potentially disturbed	Maximum number of harbour seal potentially disturbed
SEP	0.63	0.853	0.274	0.54	0.173
DEP	0.63	0.739	0.08	0.466	0.050
Norfolk Boreas	0.63	0.0006	0.00006	0.0004	0.00004
East Anglia ONE North	0.63	0.0009	0.0004	0.0006	0.00025
East Anglia TWO	0.63	0.005	0.0004	0.003	0.00025

Name of Project	Area (km^2)	Grey seal density	Harbour seal density	Maximum number of grey seal potentially disturbed	Maximum number of harbour seal potentially disturbed
Hornsea Project Four	0.63	0.14	0.04	0.088	0.025
Norfolk Vanguard	0.63	0.001	0.00008	0.001	0.00005
Dogger Bank South	0.63	0.112	0.004	0.071	0.00025
Five Estuaries	0.63	0.01	0.0007	0.006	0.0004
North Falls	0.63	0.016	0.002	0.01	0.001
Outer Dowsing	0.63	0.038	0.191	0.02	0.12
Total number of grey and harbour seal (without SEP & DEP)				**1.21 (0.20)**	**0.37 (0.27)**
Percentage of wider reference population (24,116 grey seal; 30,590 harbour seal) (without SEP & DEP)				**0.005% (0.001%)**	**0.0012% (0.0003%)**
Magnitude (without SEP & DEP)				**Negligible (negligible)**	**Negligible (negligible)**

756. For the potential temporary effects during construction, including vessels, there is likely to be a great deal of variation in timing and durations, as well as different construction methods, used throughout the various offshore wind farm project construction periods. Therefore, this assessment is considered to be a precautionary worst-case.

10.7.1.2.2 Potential for Disturbance from Offshore Wind Farm Geophysical Surveys

10.7.1.2.2.1 *Sensitivity to Disturbance*

757. As outlined in **Section 10.6.1.1.1**, harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources.

10.7.1.2.2.2 *Magnitude of Potential Disturbance*

758. It is currently not possible to estimate the number of potential offshore wind farm geophysical surveys that could be undertaken at the same time as construction and potential piling activity at SEP and DEP.

759. As outlined in **Appendix 10.3 Marine Mammal CIA Screening**, offshore wind farm geophysical surveys using Sub-Bottom Profilers (SBP) and Ultra-Short Baseline (USBL) systems have the potential to disturb marine mammals and have therefore been screened into the CIA, as a precautionary approach.

760. Assessments for the Review of Consents (RoC) HRA for the SNS SAC (BEIS, 2020a), modelled the potential for disturbance due to the use of a SBP and results indicated that there is the potential for a possible behavioural response in harbour porpoise at up to 3.77km (44.65km^2) from the source. The current guidance for assessing the significance of noise disturbance for harbour porpoise SACs (JNCC *et al*., 2020) recommends the use of an EDR of 5km (78.54km^2) for geophysical surveys.

761. As a worst-case, it has been assumed that all marine mammals within 5km of the survey source, a total area of 78.54km^2, could be disturbed.

762. For geophysical surveys with sub-bottom profilers, it is realistic and appropriate to base the assessments on the potential impact area around the vessel, as the potential for disturbance would be around the vessel at any one time. Marine mammals would not be at risk throughout the entire area surveyed in a day, as animals would return once the vessel had passed, and the disturbance had ceased.

763. However, as a precautionary approach, the assessment of the potential disturbance of harbour porpoise in the SNS SAC in the **RIAA** (document reference 5.4) will also include the possible disturbance from the survey area as assessed in, *Record of the Habitats Regulations Assessment undertaken under Regulation 65 of the Conservation of Habitats and Species 2017, and Regulation 33 of the Conservation of Offshore Marine Habitats and Species Regulations 2017. Review of Consented Offshore Wind Farms in the Southern North Sea Harbour Porpoise SAC* (BEIS, 2020a).

764. It is currently not possible to estimate the location or number of potential OWF geophysical surveys that could be undertaken at the same time as construction and potential piling activity at SEP and DEP. It is therefore assumed, as a worst-case scenario, that there could potentially be up to two geophysical surveys (157.08km^2) at OWFs in the North Sea at any one time, during construction of SEP and DEP.

765. Geophysical surveys for SEP and DEP will be assessed separately, prior to the surveys being undertaken, based on the type of survey required, equipment used, area covered, time of year and duration, including cumulative impacts during geophysical surveys at SEP and DEP. Therefore, geophysical surveys for SEP and DEP are not included in this CIA.

766. Without knowing the actual location for offshore wind farm geophysical surveys, the following density estimates have been used to estimate the potential number of individuals that could potentially be disturbed:

- For harbour porpoise, the SCANS-III density estimate for the North Sea MU of 0.52/km^2
- For bottlenose dolphin, the SCANS-III density estimate for survey block O of 0.0298/km^2
- For white-beaked dolphin, the SCANS-III density estimate for survey block R of 0.002/km^2
- For minke whale, the SCANS-III density estimate for survey block R of 0.010/km^2

- For grey and harbour seal, densities were calculated for the entire area of the English North Sea, approximately covering the SE England and NE England MUs, based on the grid cells that overlap with the area, and using the most recent grey and harbour seal population estimates to convert the Carter et al. (2020) relative densities to absolute densities. This is 0.301 grey seal per km^2 and 0.044 harbour seal per km^2.

767. **Table 10-109** presents the assessment for two offshore wind farm geophysical surveys occurring at the same time as piling at SEP and DEP.

Table 10-109: Quantified CIA for the Potential Disturbance of Marine Mammals for Offshore Wind Farm Geophysical Surveys at the Same Time as Piling at SEP and DEP

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Harbour porpoise	Piling at SEP	2,123.7km^2	0.888/km^2	1,886
	Piling at DEP	2,123.7km^2	0.888/km^2	1,886
	Disturbance from two geophysical surveys in the North Sea area	157.08km^2	0.52/km^2	82 (0.02%)
	Cumulative assessment for harbour porpoise			**3,853 (1.11%) Low**
Bottlenose dolphin	Piling at SEP	0.44km^2	0.0298/km^2	0.013
	Piling at DEP	0.44km^2	0.0298/km^2	0.013
	Disturbance from two geophysical surveys in the North Sea area	157.08km^2	0.0298/km^2	5 (0.23%)
	Cumulative assessment for bottlenose dolphin			**5 (0.23%) Negligible**
White-beaked dolphin	Piling at SEP	0.44km^2	0.002/km^2	0.001
	Piling at DEP	0.44km^2	0.002/km^2	0.001

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
	Disturbance from two geophysical surveys in the North Sea area	157.08km^2	0.002/km^2	0.31 (0.0007%)
	Cumulative assessment for white-beaked dolphin			**0.32 (0.0007%) Negligible**
Minke whale	Piling at SEP	1,100km^2	0.010/km^2	11
	Piling at DEP	1,100km^2	0.010/km^2	11
	Disturbance from two geophysical surveys in the North Sea area	157.08km^2	0.010/km^2	1.57 (0.008%)
	Cumulative assessment for minke whale			**23.57 (0.12%) Negligible**
Grey seal	Piling at SEP	220km^2	0.47/km^2	188
	Piling at DEP	220km^2	0.009/km^2	163
	Disturbance from two geophysical surveys in the North Sea area	157.08km^2	0.301/km^2	47.3 (0.2%)
	Cumulative assessment for grey seal			**397.5 (1.65%) Low**
Harbour seal	Piling at SEP	220km^2	0.21/km^2	60
	Piling at DEP	220km^2	0.24/km^2	18
	Disturbance from two geophysical surveys in the North Sea area	157.08km^2	0.044/km^2	6.9 (0.023%)
	Cumulative assessment for harbour seal			**84.8 (0.28%) Negligible**

768. As assessed in **Table 10-109**, the potential magnitude of the temporary effect is low for harbour porpoise and grey seal and negligible for bottlenose dolphin, white-beaked dolphin, minke whale and harbour seal. **Table 10-109** presents the assessment for two offshore wind farm geophysical surveys occurring at the same time as piling at SEP and DEP.

10.7.1.2.3 Potential for Disturbance from Aggregate Extraction and Dredging

769. Taking into account the small potential impact ranges, distances of the aggregate extraction and dredging projects from SEP and DEP, the potential for contribution to cumulative impacts is very small. Therefore, risk of PTS or TTS for all marine mammal species from aggregate extraction and dredging has been screened out from further consideration in the CIA.

770. As a precautionary approach, a total of 11 aggregate extraction and dredging projects are included in the CIA for the potential cumulative disturbance of harbour porpoise.

10.7.1.2.3.1 *Sensitivity to Disturbance*

771. As outlined in **Section 10.6.1.1.1**, harbour porpoise are assessed as having medium sensitivity to disturbance from underwater noise sources.

10.7.1.2.3.2 *Magnitude of Potential Disturbance*

772. As outlined in **Appendix 10.2 Underwater Noise Modelling Report**, the underwater noise modelling indicates the risk of PTS TTS for dredging and vessels is less than 100m for all marine mammal species, with the exception of 200m TTS impact range for harbour porpoise.

773. As outlined in the BEIS (2020a) RoC HRA for the SNS SAC, studies have indicated that harbour porpoise may be displaced by dredging operations within 600m of the activities (Diederichs *et al*., 2010).

774. Based on a precautionary level of behavioural displacement of harbour porpoise out to 600m, there is potential for an area of 1.13km^2 to be affected (BEIS, 2020a). As a worst-case scenario, assuming all 11 sites are active at the same time, the area of potential disturbance of harbour porpoise is up to 12.43km^2.

775. **Table 10-110** presents the assessment for disturbance of harbour porpoise from aggregate extraction and dredging at the same time as piling at SEP and DEP.

Table 10-110: Quantified CIA for the Potential Disturbance of Harbour Porpoise for Aggregate Extraction and Dredging at the Same Time as Piling at SEP and DEP

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Harbour porpoise	Piling at SEP	2,123.7km^2	0.888/km^2	1,886
	Piling at DEP	2,123.7km^2	0.888/km^2	1,886

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
	Disturbance from 11 aggregate and dredging projects	12.43km^2	0.52/km^2	6 (0.002%)
	Cumulative assessment for harbour porpoise			**3,778 (1.09%) Low**

776. As assessed in **Table 10-110**, the potential magnitude of the temporary effect is low for harbour porpoise.

10.7.1.2.4 Potential for Disturbance from Oil and Gas Seismic Surveys

10.7.1.2.4.1 *Sensitivity to Disturbance*

777. As outlined in **Section 10.6.1.1.1**, harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources.

10.7.1.2.4.2 *Magnitude of Potential Disturbance*

778. It is currently not possible to estimate the number of potential oil and gas seismic surveys that could be undertaken at the same time as construction and potential piling activity at SEP and DEP.

779. The BEIS (2020a) RoC HRA reports that, between 2008 and 2017, there were 61 seismic surveys in the SNS SAC during the summer and winter periods, resulting in an average of 6.1 surveys per year. The average number of days per year was 60.4 days (up to 17% of 365 days per year). Taking this into account it is unlikely that more than two seismic surveys will be conducted in the SNS at exactly the same time. However, as a worst-case scenario, the CIA is based on potentially be up to two oil and gas seismic surveys in the North Sea at any one time, during construction of SEP and DEP.

780. This assessment for the potential disturbance due to oil and gas seismic surveys is based on the following for each marine mammal species:

- Harbour porpoise
  - The potential impact area during seismic surveys, based on a radius of 12km (452.4km^2), following the current SNCB guidance for the assessment of impact on harbour porpoise in the SNS SAC. Therefore, the potential impact area for two oil and gas seismic surveys is 904.8km^2.
- Bottlenose dolphin and white-beaked dolphin
  - Strong avoidance of bottlenose dolphin from a 2D seismic survey (with 470 cubic inch airguns, and a peak sound source level of 243 dB re 1 µPa @1m) was modelled at between 1.8km and 11km (based on site specific underwater noise modelling using the dBht method) (DECC, 2011d). This equates to an area of 380.13km^2, assuming the largest potential disturbance range of 11km. A potential disturbance range of 11km (disturbance area of 380.13km^2) has therefore been used in the assessment for each seismic survey.

- The potential impact area for two oil and gas seismic surveys is 760.3km^2.

- Minke whale

  As for dolphin species, there is little available information on the potential for disturbance from seismic surveys, however, observations of behavioural changes in other baleen whale species have shown avoidance reactions in up to 10km for a seismic survey (Macdonald *et al*., 1995). A potential disturbance range of 10km (314.1km^2) will therefore be applied to minke whale due to a lack of species-specific information. The potential impact area for two oil and gas seismic surveys is 628.2km^2.

- Grey seal and harbour seal
  - As for both dolphin species and minke whale, there is little available information on the potential for disturbance from seismic surveys for either grey seal or harbour seal, however, observations of behavioural changes in other seal species have shown avoidance reactions up to 3.6km from the source for a seismic survey (Harris *et al*., 2001). A more recent assessment of potential for disturbance to seal species, as a result of seismic surveys, shows potential disturbance ranges from 13.3km to 17.0km from source (BEIS, 2020b). These ranges are based on modelled impact ranges, using the NMFS Level B harassment threshold of 160dB, for a noise source of 3,070 cubic inches, 4,240 cubic inches, or 8,000 cubic inches.
  - A potential disturbance range of 17.0km (907.9km^2) will therefore be applied to both grey seal and harbour seal due to a lack of species-specific information. The potential impact area for two oil and gas seismic surveys is 1,815.8km^2.

781. The densities for each marine mammal species are as outlined for the offshore wind farm geophysical surveys.

782. **Table 10-111** presents the cumulative impact assessment for two oil and gas seismic surveys occurring at the same time as piling at SEP and DEP.

Table 10-111: Quantified CIA for the Potential Disturbance of Marine Mammals for Oil and Gas Seismic Surveys at the Same Time as Piling at SEP and DEP

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Harbour porpoise	Piling at SEP	2,123.7km^2	0.888/km^2	1,886
	Piling at DEP	2,123.7km^2	0.888/km^2	1,886
	Disturbance from two seismic surveys	904.8km^2	0.52/km^2	470 (0.14%)

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
	in the North Sea area			
	Cumulative assessment for harbour porpoise			**4,242 (1.22%) Low**
Bottlenose dolphin	Piling at SEP	$0.44km^2$	$0.0298/km^2$	0.013
	Piling at DEP	$0.44km^2$	$0.0298/km^2$	0.013
	Disturbance from two seismic surveys in the North Sea area	$760.3km^2$	$0.0298/km^2$	22.7 (1.1%)
	Cumulative assessment for bottlenose dolphin			**22.7 (1.1%) Low**
White-beaked dolphin	Piling at SEP	$0.44km^2$	$0.002/km^2$	0.001
	Piling at DEP	$0.44km^2$	$0.002/km^2$	0.001
	Disturbance from two seismic surveys in the North Sea area	$760.3km^2$	$0.002/km^2$	1.5 (0.0003%)
	Cumulative assessment for white-beaked dolphin			**1.5 (0.0003%) Negligible**
Minke whale	Piling at SEP	$1,100km^2$	$0.010/km^2$	11
	Piling at DEP	$1,100km^2$	$0.010/km^2$	11
	Disturbance from two seismic surveys in the North Sea area	$628.2km^2$	$0.010/km^2$	6.28 (0.03%)
	Cumulative assessment for minke whale			**28.28 (0.14%) Negligible**

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Grey seal	Piling at SEP	220km^2	0.47/km^2	188
	Piling at DEP	220km^2	0.009/km^2	163
	Disturbance from two seismic surveys in the North Sea area	1,815.8km^2	0.301/km^2	546.6 (2.3%)
	Cumulative assessment for grey seal			**896.8 (3.72%) Low**
Harbour seal	Piling at SEP	220km^2	0.21/km^2	60
	Piling at DEP	220km^2	0.24/km^2	18
	Disturbance from two seismic surveys in the North Sea area	1,815.8km^2	0.044/km^2	79.9 (0.26%)
	Cumulative assessment for harbour seal			**157.8 (0.52%) Negligible**

783. As assessed in **Table 10-111**, the potential magnitude of the temporary effect is low for harbour porpoise, bottlenose dolphin, and grey seal and negligible for white-beaked dolphin, minke whale, and harbour seal.

10.7.1.2.5 Potential for Disturbance from Subsea Cables and Pipelines

784. As indicated in underwater noise modelling in **Appendix 10.2 Underwater Noise Modelling Report** and **Table 10-60**, the underwater noise that could be generated during the sea bed preparation, ploughing / jetting / pre-trenching or cutting for installation of cables / pipelines, rock dumping for protection of the cable / pipelines, and installation vessels, would be restricted to the area of installation (less than 100m) for all marine mammals species, with the exception of TTS in harbour porpoise during rock placement (1km) and suction dredging (200m). Therefore, assessments have only been undertaken for harbour porpoise.

10.7.1.2.5.1 *Sensitivity to Disturbance*

785. As outlined in **Section 10.6.1.1.1**, harbour porpoise are assessed as having medium sensitivity to disturbance from underwater noise sources. Any impacts would be temporary.

10.7.1.2.5.2 *Magnitude of Potential Disturbance*

786. As a precautionary approach, six subsea cable and pipeline projects are included in the CIA for the potential cumulative disturbance of harbour porpoise.

787. For harbour porpoise, the potential impact has been based on impact range of 1km, with the potential impact area of 3.14km^2 for each project and 18.84km^2 for the six projects.

788. **Table 10-112** presents the assessment for disturbance of harbour porpoise from aggregate extraction and dredging at the same time as piling at SEP and DEP.

Table 10-112: Quantified CIA for the Potential Disturbance of Harbour Porpoise for Aggregate Extraction and Dredging at the Same Time as Piling at SEP and DEP

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Harbour porpoise	Piling at SEP	2,123.7km^2	0.888/km^2	1,886
	Piling at DEP	2,123.7km^2	0.888/km^2	1,886
	Disturbance from 6 subsea cable and pipeline projects	18.84km^2	0.52/km^2	10 (0.003%)
	Cumulative assessment for harbour porpoise			**3,781 (1.09%) Low**

789. As assessed in **Table 10-112**, the potential magnitude of the temporary effect is low for harbour porpoise.

10.7.1.2.6 Potential for Disturbance from UXO Clearance

10.7.1.2.6.1 *Sensitivity to Disturbance*

790. As outlined in **Section 10.6.1.1.1**, harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources.

10.7.1.2.6.2 *Magnitude of Potential Disturbance*

791. As for piling, the potential risk of PTS in marine mammals from cumulative impacts has been screened out from further consideration in the CIA. As if there is the potential for any PTS, suitable mitigation would be put in place to reduce any risk to marine mammals. Therefore the CIA only considers potential disturbance effects.

792. This assessment has been based on the potential for disturbance due to UXO clearance activities for other projects, cumulatively with the construction of SEP and DEP.

793. The magnitude of the potential disturbance from UXO clearance has been estimated based on the following:

- Harbour porpoise

  - The potential impact area of 2,123.7km^2 per project, based on 26km EDR for UXO detonation, following the current SNCB guidance for the assessment of impact to harbour porpoise in the SNS SAC
- Bottlenose dolphin and white-beaked dolphin
  - The potential impact area during a single UXO clearance event, based on the modelled worst-case impact range at SEP and DEP for TTS / fleeing response (unweighted SPL_{peak}) of 1.3km (5.3km^2)
- Minke whale
  - The potential impact area during a single UXO clearance event, based on the modelled worst-case impact range at SEP and DEP for TTS / fleeing response (weighted SEL_{ss}) of 103km (33,329.2km^2)
- Grey seal and harbour seal
  - The potential impact area during a single UXO clearance event, based on the modelled worst-case impact range at SEP and DEP for TTS / fleeing response (unweighted SPL_{peak}) of 20km (1,256.6km^2)

794. However, as outlined in the BEIS (2020a) RoC HRA, due to the nature of the sound arising from the detonation of UXO, i.e. each blast lasting for a very short duration, marine mammals, including harbour porpoise, are not predicted to be significantly displaced from an area, any changes in behaviour, if they occur, would be an instantaneous response and short-term. Existing guidance suggests that disturbance behaviour is not predicted to occur from UXO clearance if undertaken over a short period of time (JNCC, 2010a).

795. Mitigation measures required for UXO clearance include the use of low-order clearance techniques, which could include a small donor charge, rather than full high-order detonation which is only used as a last resort. It is therefore highly unlikely that more than one UXO high-order detonation would occur at exactly the same time or on the same day as another UXO high-order detonation, even if they had overlapping UXO clearance operation durations. The CIA is therefore based on potential for disturbance from one UXO high-order detonation without mitigation (worst-case).

796. The densities for each marine mammal species are as outlined for the offshore wind farm geophysical surveys. **Table 10-113** presents the cumulative impact assessment for one UXO high-order detonation with no mitigation occurring at the same time as piling at SEP and DEP. UXO clearance at SEP and DEP will be assessed as part of a separate ML.

Table 10-113: Quantified CIA for the Potential Disturbance of Marine Mammals for UXO Clearance at the Same Time as Piling at SEP and DEP

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Harbour porpoise	Piling at SEP	2,123.7km^2	0.888/km^2	1,886
	Piling at DEP	2,123.7km^2	0.888/km^2	1,886
	Disturbance from one UXO high-order detonation in the North Sea area	2,123.7km^2	0.52/km^2	1,104 (0.32%)
	Cumulative assessment for harbour porpoise		4,876 (1.41%) **Low**	
Bottlenose dolphin	Piling at SEP	0.44km^2	0.0298/km^2	0.013
	Piling at DEP	0.44km^2	0.0298/km^2	0.013
	Disturbance from one UXO high-order detonation in the North Sea area	5.3km^2	0.0298/km^2	0.16 (0.008%)
	Cumulative assessment for bottlenose dolphin		0.18 (0.009%) **Negligible**	
White-beaked dolphin	Piling at SEP	0.44km^2	0.002/km^2	0.001
	Piling at DEP	0.44km^2	0.002/km^2	0.001
	Disturbance from one UXO high-order detonation in the North Sea area	5.3km^2	0.002/km^2	0.011 (0.00002%)
	Cumulative assessment for white-beaked dolphin		0.012 (0.00003%) **Negligible**	

Species	Activity	Area of disturbance	Density estimate	Potential number disturbed (% of reference population)
Minke whale	Piling at SEP	1,100km^2	0.010/km^2	11
	Piling at DEP	1,100km^2	0.010/km^2	11
	Disturbance from one UXO high-order detonation in the North Sea area	33,329.2km^2	0.010/km^2	333.3 (1.66%)
	Cumulative assessment for minke whale		355.3 (1.77%) **Low**	
Grey seal	Piling at SEP	220km^2	0.47/km^2	188
	Piling at DEP	220km^2	0.009/km^2	163
	Disturbance from one UXO high-order detonation in the North Sea area	1,256.6km^2	0.301/km^2	378.2 (1.57%)
	Cumulative assessment for grey seal		728.5 (3.02%) **Low**	
Harbour seal	Piling at SEP	220km^2	0.21/km^2	60
	Piling at DEP	220km^2	0.24/km^2	18
	Disturbance from one UXO high-order detonation in the North Sea area	1,256.6km^2	0.044km^2	55.3 (0.18%)
	Cumulative assessment for harbour seal		133.2 (0.44%) **Negligible**	

797. As assessed in **Table 10-113**, the potential magnitude of the temporary effect is low for harbour porpoise, minke whale and grey seal, and negligible for bottlenose dolphin, white-beaked dolphin and harbour seal.

10.7.1.3 Overall Cumulative Underwater Noise Impacts (Impacts 1 and 2)

10.7.1.3.1 Overall CIA Magnitude

798. **Table 10-114** provides a summary of the number of each marine mammal species that could be disturbed from all cumulative noise sources, including piling at SEP and DEP as a worst-case scenario.

799. For harbour porpoise, up to 18,016 individuals (5.2% of NS MU) could be disturbed as a result of cumulative underwater noise (**Table 10-114**). The potential magnitude of the temporary impact is assessed as medium, with between 5% and 10% of the reference population potentially impacted.

800. For bottlenose dolphin, 28.1 individuals (1.4% of GNS MU) could be disturbed as a result of cumulative underwater noise (**Table 10-114**). The potential magnitude of the temporary impact is assessed as low, with between 1% and 5% of the reference population potentially impacted.

801. For white-beaked dolphin, up to 0.8 individuals (0.002% of CGNS MU) could be disturbed as a result of cumulative underwater noise (**Table 10-114**). The potential magnitude of the temporary impact is assessed as negligible, with less than 1% of the reference population potentially impacted.

802. For minke whale, up to 823 individuals (4.1% of CGNS MU) could be disturbed as a result of cumulative underwater noise (**Table 10-114**). The potential magnitude of the temporary impact is assessed as low, with between 1% and 5% of the reference population potentially impacted.

803. For grey seal and harbour seal, up to 1,394 and 272 individuals (5.8% and 0.9% of the reference populations), respectively, could be disturbed as a result of cumulative underwater noise (**Table 10-114**). The potential magnitude of the temporary impact is assessed as low for grey seal and negligible for harbour seal.

804. **Table 10-115** provides a summary of the number of each marine mammal species that could be disturbed from all cumulative noise sources, including piling at SEP or DEP.

805. The potential magnitude of temporary disturbance from cumulative underwater noise during piling at SEP or DEP is assessed as medium for harbour porpoise, low for minke whale and grey seal and negligible for bottlenose dolphin, white-beaked dolphin and harbour seal.

Table 10-114: Quantified CIA for the Potential Disturbance of Marine Mammals from Cumulative Underwater Noise Sources during Piling at SEP and DEP (Worst-Case)

Cumulative underwater noise	Potential number of harbour porpoise disturbed	Potential number of bottlenose dolphin disturbed	Potential number of white-beaked dolphin disturbed	Potential number of minke whale disturbed	Potential number of grey seal disturbed	Potential number of harbour seal disturbed
Piling at SEP	1,886	0.013	0.001	11	188	60
Piling at DEP	1,886	0.013	0.001	11	163	18
Piling at other OWFs (**Table 10-98** to **Table 10-102**)	12,538	0.052	0.11	459	71	52
Construction at other OWFs (**Table 10-104** to **Table 10-108**)	34	0.15	0.34	0.55	0.2	0.27
Two OWF geophysical surveys (**Table 10-109**)	82	5	0.31	1.57	47.3	6.9
Aggregate extraction and dredging (**Table 10-110**)	6	0	0	0	0	0
Two oil and gas seismic surveys (**Table 10-111**)	470	22.7	1.5	6.28	546.6	79.9
Subsea cables and pipelines (**Table 10-112**)	10	0	0	0	0	0
One high-order UXO detonation without mitigation (**Table 10-113**)	1,104	0.16	0.011	333.3	378.2	55.3
Total	**18,016**	**28.1**	**2.3**	**823**	**1,394**	**272**
% of reference population	**5.2**	**1.4**	**0.005**	**4.1**	**5.8**	**0.89**
Magnitude	**Medium**	**Low**	**Negligible**	**Low**	**Medium**	**Negligible**

Table 10-115: Quantified CIA for the Potential Disturbance of Marine Mammals from Cumulative Underwater Noise Sources during Piling at SEP or DEP in Isolation

Cumulative underwater noise	Potential number of harbour porpoise disturbed	Potential number of bottlenose dolphin disturbed	Potential number of white-beaked dolphin disturbed	Potential number of minke whale disturbed	Potential number of grey seal disturbed	Potential number of harbour seal disturbed
Piling at SEP or DEP	1,886	0.013	0.001	11	103	46
Piling at other OWFs (**Table 10-98** to **Table 10-102**)	12,538	0.052	0.11	459	93	94
Construction at other OWFs (**Table 10-104** to **Table 10-108**)	34	0.15	0.34	0.55	0.27	0.27
Two OWF geophysical surveys (**Table 10-109**)	82	5	0.31	1.57	47.3	6.9
Aggregate extraction and dredging (**Table 10-110**)	6	0	0	0	0	0
Two oil and gas seismic surveys (**Table 10-111**)	470	22.7	1.5	6.28	546	79.9
Subsea cables and pipelines (**Table 10-112**)	10	0	0	0	0	0
One high-order UXO detonation without mitigation (**Table 10-113**)	1,104	0.16	0.011	333.3	378.2	55.3
Total	**16,130**	**28.1**	**2.3**	**812**	**1,168**	**282**
% of reference population	**4.7**	**1.4**	**0.005**	**4.0**	**4.8**	**0.6**
Magnitude	**Low**	**Low**	**Negligible**	**Low**	**Low**	**Negligible**

806. If all included activities were being undertaken at the same time as piling at SEP and DEP, there is the potential for a negligible to medium magnitude of impact (dependent on species), however, it is highly unlikely that all these activities would be conducted at exactly the same time as piling at SEP and DEP. In addition, with the implementation of any management measures for the SNS SAC, the potential impacts could be managed and reduced. Any mitigation measures to reduce the disturbance of harbour porpoise in the project specific SIPs would also reduce the potential disturbance of white-beaked dolphin, minke whale, bottlenose dolphin, as well as grey and harbour seal.

807. The contribution of the number of animals impacted by piling at SEP and DEP (which is the worst-case scenario for cumulative impacts) as a proportion of the overall cumulative impact of disturbance from underwater noise is summarised in **Table 10-116**.

808. The contribution of the number of animals impacted by piling at SEP or DEP isolation to the overall cumulative impact of disturbance from underwater noise is summarised in **Table 10-117**.

Table 10-116: Contribution of SEP and DEP to Quantified CIA for the Potential Disturbance of Marine Mammals from Cumulative Underwater Noise Sources during Piling at SEP and DEP

Cumulative underwater noise	Total for CIA	Contribution of SEP and DEP	% of CIA total
Potential number of harbour porpoise disturbed	18,016	3,772	21%
Potential number of bottlenose dolphin disturbed	28.1	0.026	0.09%
Potential number of white-beaked dolphin disturbed	2.3	0.002	0.09%
Potential number of minke whale disturbed	823	22	2.7%
Potential number of grey seal disturbed	1,394	351	25.2%
Potential number of harbour seal disturbed	272	78	28.7%

Table 10-117: Contribution of SEP or DEP to Quantified CIA for the Potential Disturbance of Marine Mammals from Cumulative Underwater Noise Sources during Piling at SEP or DEP in Isolation

Cumulative underwater noise	Total for CIA	Contribution of SEP or DEP	% of CIA total
Potential number of harbour porpoise disturbed	16,130	1,886	12%
Potential number of bottlenose dolphin disturbed	28.1	0.013	0.05%
Potential number of white-beaked dolphin disturbed	2.3	0.001	0.04%
Potential number of minke whale disturbed	812	11	1.4%

Cumulative underwater noise	Total for CIA	Contribution of SEP or DEP	% of CIA total
Potential number of grey seal disturbed	1,168	188	16.1%
Potential number of harbour seal disturbed	282	60	21.3%

10.7.1.3.2 Overall CIA Impact Significance

809. Taking into account the medium receptor sensitivity for all marine mammal species, the negligible to medium potential magnitude, the overall impact significance for disturbance to marine mammals from cumulative underwater noise including piling at both SEP and DEP is **moderate adverse (significant)** for harbour porpoise and **minor (not significant)** for all other marine mammal species. Mitigation and management measures in the project specific **In Principle SIP for the SNS SAC** (document reference 9.6) (**Table 10-3**) would manage and reduce potential for disturbance of harbour porpoise to **minor adverse (not significant)** (**Table 10-118**).

810. The overall impact significance for disturbance to marine mammals from cumulative underwater noise including piling at either SEP or DEP in isolation is **minor adverse (not significant)** for all marine mammal species (**Table 10-119**).

811. The confidence for this cumulative impact assessment is relatively high as it is deemed precautionary enough to comfortably encompass the likely uncertainty and variability. Throughout the assessment it has been made clear where multiple and compounding precautionary assumptions have been taken. Additionally, where possible the uncertainty in the data typically used to inform assessments and the quantification of impacts when based on published ESs has been removed by using a standard impact range for disturbance and the SCANS-III and seal-at sea density estimates for all offshore wind farm sites.

Table 10-118: Overall Cumulative Impact Significance for Disturbance of Marine Mammals from Cumulative Underwater Noise during Piling at both SEP and DEP

Potential Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigation	Residual Impact
Overall cumulative impact of disturbance to marine mammals during piling at SEP and DEP	Harbour porpoise	Medium	Medium	**Moderate adverse**	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance of harbour porpoise	**Minor adverse**
	Bottlenose dolphin		Low	**Minor adverse**		**Minor adverse**
	White-beaked dolphin		Negligible	**Minor adverse**		**Minor adverse**
	Minke whale		Low	**Minor adverse**		**Minor adverse**
	Grey seal		Medium	**Moderate adverse**		**Minor adverse**
	Harbour seal		Negligible	**Minor adverse**		**Minor adverse**

Table 10-119: Overall Cumulative Impact Significance for Disturbance of Marine Mammals from Cumulative Underwater Noise during Piling at Either SEP or DEP in isolation

Potential Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigation	Residual Impact
Overall cumulative impact of disturbance to marine mammals during piling at SEP or DEP	Harbour porpoise	Medium	Low	Minor	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance of harbour porpoise	**Minor adverse**
	Bottlenose dolphin		Low	Minor		**Minor adverse**
	White-beaked dolphin		Negligible	Minor		**Minor adverse**
	Minke whale		Low	Minor		**Minor adverse**
	Grey seal		Low	Minor		**Minor adverse**
	Harbour seal		Negligible	Minor		**Minor adverse**

10.8 Transboundary Impacts

812. The highly mobile nature of marine mammals included within this assessment means that there is the potential for transboundary impacts. This has been taken into account throughout the assessment, as the study area for each species is based on their relevant MU (or area within which the same individuals are considered to part of one larger overall population). The MUs (and therefore reference populations) for each species covers an area wider than the UK (**Table 10-120**). This approach has been taken through all of the assessments.

Table 10-120: Other Countries Considered in the Marine Mammal Assessments Through the Relevant MU Reference Populations

Country	Marine mammal species	Inclusion within assessments
Netherlands	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Part of the reference population area (Wadden Sea region) for both grey seal and harbour seal.
Germany	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Part of the reference population area (Wadden Sea region) for both grey seal and harbour seal.
France	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Not part of the grey seal and harbour seal reference population area, and therefore no potential for transboundary impacts.

Country	Marine mammal species	Inclusion within assessments
Belgium	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Not part of the grey seal and harbour seal reference population area, and therefore no potential for transboundary impacts.
Denmark	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Part of the reference population area (Wadden Sea region) for both grey seal and harbour seal.
Sweden	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Not part of the grey seal and harbour seal reference population area, and therefore no potential for transboundary impacts.
Norway	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	White-beaked dolphin and minke whale	Part of the Celtic and Greater North Seas MU for both white-beaked dolphin and minke whale.
	Bottlenose dolphin	Part of the Greater North Sea MU for bottlenose dolphin.
	Grey seal and harbour seal	Not part of the grey seal and harbour seal reference population area, and therefore no potential for transboundary impacts.

813. There is a substantial level of marine development being undertaken, and being planned, by other countries (including Belgium, the Netherlands, Germany and Denmark) in the SNS. Each of these countries have their own independent environmental assessment requirements and controls. As noted above, marine mammals are highly mobile and there is therefore the potential for transboundary impacts, especially with regard to noise. In addition, if there is potential for SEP and DEP to impact marine mammals from other designated sites, this is assessed in the **RIAA** (document reference 5.4). The potential for transboundary impacts has been assessed with the other cumulative impacts, as these are based on the wide MU areas; and European wind farms, where relevant, are included in the CIA.

10.9 Inter-relationships

814. For marine mammals, potential inter-relationships between impact pathways are already covered as part of the marine mammal assessments provided above. **Table 10-121** provides a signposting to where these potential inter-relationship impacts have already been assessed.

Table 10-121: Marine Mammal Inter-Relationships

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Underwater noise from vessels	**Chapter 13 Shipping and Navigation**	**Section 10.6.1.4** for construction and **Section 10.6.2.3** for operation and maintenance	Increased vessel traffic associated with the Projects could affect the level of disturbance for marine mammals.
Increased risk of collision with vessels	**Chapter 13 Shipping and Navigation**	**Section 10.6.1.6** for construction and **Section 10.6.2.5** for operation and maintenance	Increased vessel traffic associated with the Projects could affect the level of collision risk for marine mammals.
Changes to prey availability	**Chapter 9 Fish and Shellfish Ecology**	**Section 10.6.1.8** for construction and **Section 10.6.2.7** for operation and maintenance	Potential impacts on fish species could affect the prey resource for marine mammals.
Changes to water quality	**Chapter 7 Marine Water and Sediment Quality**	**Section 10.6.1.9** for construction and **Section 10.6.2.8** for operation and maintenance	Potential changes to water quality, such as increased SSC, could affect marine mammals directly or indirectly as a result of impacts on prey species.

10.10 Interactions

815. The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts due to that interaction.

816. The areas of potential interaction between impacts are presented in **Table 10-122**. This provides a screening tool for which impacts have the potential to interact.

817. The worst-case impacts assessed within the chapter take these interactions into account, and therefore the impact assessments are considered conservative and robust. Synergistic impacts of potential disturbance from underwater noise during construction from all potential noise sources have been assessed as potential barrier effects in the following tables.

818. In **Table 10-123** the impacts are assessed relative to each development phase (assessment for construction, operation and maintenance or decommissioning) to determine if (for example) multiple construction impacts affecting the same receptor could increase the level of impact upon that receptor. The lifetime assessment considers the potential for impacts to affect receptors across all development phases.

819. The significance of each individual impact is determined by the sensitivity of the receptor and the magnitude of effect; the sensitivity is constant whereas the magnitude may differ. Therefore, when considering the potential for impacts to be additive it is the magnitude of effect which is important – the magnitudes of the different effects are combined upon the same sensitivity receptor.

Table 10-122: Interaction Between Impacts - Screening of Potential for Interaction Impacts

Potential Interaction between Impacts											
Construction											
	Auditory injury from UXO	**UXO Disturban-ce**	**Impact 1**	**Impact 2**	**Impact 3**	**Impact 4**	**Impact 5**	**Impact 6**	**Impact 7**	**Impact 8**	**Impact 9**
Auditory Injury from Underwater Noise Associated with UXO Clearance (Appendix 10.4 Marine Mammal UXO Assessment)	-	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Disturbance from Underwater Noise Associated with UXO Clearance (Appendix 10.4 Marine Mammal UXO Assessment)	Yes	-	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 1: Auditory Injury from Underwater Noise Associated with Piling (Section 10.6.1.1)	Yes	Yes	-	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 2: Disturbance from Underwater Noise Associated with Piling Activities (Section 10.6.1.2)	Yes	Yes	Yes	-	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 3: Disturbance from Underwater Noise Associated with Other Construction Activities (Section 10.6.1.3)	Yes	Yes	Yes	Yes	-	Yes	Yes	No	Yes	Yes	Yes
Impact 4: Impacts from Underwater Noise and Disturbance Associated with Construction Vessels (Section 10.6.1.4)	Yes	Yes	Yes	Yes	Yes	-	Yes	No	Yes	Yes	Yes
Impact 5: Barrier Effects from Underwater Noise (Section 10.6.1.5)	Yes	Yes	Yes	Yes	Yes	Yes	-	No	Yes	Yes	Yes
Impact 6: Increased Risk of Collision with Vessels during Construction (Section 10.6.1.6)	No	No	No	No	No	No	No	-	No	No	No
Impact 7: Disturbance at Seal Haul-Out Sites (Section 10.6.1.7)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	-	Yes	Yes
Impact 8: Changes to Prey Availability (Section 10.6.1.8)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	-	Yes
Impact 9: Changes to Water Quality (Section 10.6.1.9)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	-

Potential Interaction between Impacts								
Operation								
	Impact 1	**Impact 2**	**Impact 3**	**Impact 4**	**Impact 5**	**Impact 6**	**Impact 7**	**Impact 8**
Impact 1: Impacts from Underwater Noise Associated with Operational Wind Turbines (Section 10.6.2.1)	-	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 2: Impacts from Underwater Noise Associated with Operation and Maintenance Activities (Section 10.6.2.2)	Yes	-	Yes	Yes	No	Yes	Yes	Yes
Impact 3: Impacts from Underwater Noise and Disturbance Associated with Operation and Maintenance Vessels (Section 10.6.2.3)	Yes	Yes	-	Yes	No	Yes	Yes	Yes
Impact 4: Barrier Effects from Underwater Noise (Section 10.6.2.4)	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes
Impact 5: Increased Risk of Collision with Vessels during Operation (Section 10.6.2.5)	No	No	No	No	-	No	No	No
Impact 6: Disturbance at Seal Haul-Out Sites (Section 10.6.2.6)	Yes	Yes	Yes	Yes	No	-	Yes	Yes
Impact 7: Changes to Prey Availability (Section 10.6.2.7)	Yes	Yes	Yes	Yes	No	Yes	-	Yes
Impact 8: Changes to Water Quality (Section 10.6.2.8)	Yes	Yes	Yes	Yes	No	Yes	Yes	-
Decommissioning								
It is anticipated that the decommissioning impacts will be no greater than construction.								

Table 10-123: Interaction Between Impacts – Phase and Lifetime Assessment

	Highest residual significance level				
Receptor	Construction	Operation	Decommissioning	Phase assessment	Lifetime assessment
Harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal	Minor adverse	Minor adverse	Minor adverse	**No greater than individually assessed impact** ***Construction*** The MMMP (for both UXO and piling) will reduce the risk of injury for mammals and therefore during UXO clearance or piling there will be no pathway for interaction of potential injury with disturbance effects (i.e. all individuals are assumed to be disturbed if within range and excluded from the disturbance footprint). Likewise, there is no pathway for vessel interaction or effects on prey resource to interact with noise impacts as it is assumed that individuals will be excluded from the disturbance footprint (i.e. there cannot be a vessel interaction if the individual is excluded from the vicinity of the construction works). Once noisy activities have ceased the footprint of disturbance and changes to prey resource will be highly localised. It is therefore considered that the interaction of these impacts would not represent an increase in the significance level.	**No greater than individually assessed impact** The greatest magnitude of effect will be the spatial footprint of construction noise (i.e. UXO clearance and piling). Once this disturbance impact has ceased all further impact during construction and operation will be small scale, highly localised and episodic. There is no evidence of long term displacement of marine mammals from operational wind farms. It is therefore considered that over the project lifetime these impacts would not combine and represent an increase in the significance level.

	Highest residual significance level				
				Operation Operational noise impacts from wind turbines will be highly localised to within 0.1km of each wind turbine, whilst the majority of change to habitat for prey species will also be confined to the immediate footprint of wind turbine. The magnitude of effect is negligible and relates to largely the same spatial footprint. Therefore, there is no greater impact as a result of any interaction of these impacts. There is potential for interaction with maintenance noise disturbance and vessel interaction, but given the negligible magnitudes of effect and episodic nature of these impacts it is not considered that that the interaction of these impacts would not represent an increase in the significance level	

10.11 Potential Monitoring Requirements

820. Monitoring requirements are described in the **Offshore IPMP** (document reference 9.5) submitted alongside the DCO application and will be further developed and agreed with stakeholders prior to construction based on the **Offshore IPMP** and taking account of the final detailed design of the Projects.

821. The **Offshore IPMP** (document reference 9.5) identifies relevant offshore monitoring as required by the Deemed Marine Licence conditions, establishes the objectives of such monitoring and sets out the guiding principles for delivering any monitoring measures as required.

822. It should be noted, however, that monitoring of wide ranging species, such as marine mammals, in particular harbour porpoise in the SNS SAC, is best undertaken by a strategic approach.

823. The Applicant would be supportive of a strategic approach to monitoring, should it be implemented, for example within the SNS SAC.

10.12 Assessment Summary

824. The potential impacts on marine mammals during the construction, operation, maintenance and decommissioning phases of SEP or DEP in isolation, including cumulative impacts are summarised in **Table 10-124**.

825. The potential impacts on marine mammals during the construction, operation, maintenance and decommissioning phases of SEP and DEP (i.e. the worst-case scenario), including cumulative impacts are summarised in **Table 10-125**.

Table 10-124: Summary of Potential Impacts during Construction, Operation, Maintenance and Decommissioning of SEP or DEP in Isolation, Including Cumulative Impacts on Marine Mammals

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Construction						
Impact 1: Auditory Injury from Underwater Noise Associated with Piling (10.6.1.1)						
PTS from single strike of starting or maximum hammer energy	All species	High	Negligible	Minor adverse	MMMP for piling	**Minor adverse**
PTS during piling from cumulative exposure	Harbour porpoise	High	Medium to Low	Major to Moderate adverse	MMMP for piling	**Minor adverse**
	Bottlenose dolphin and white-beaked dolphin	High	Negligible	Minor adverse		**Minor adverse**
	Minke whale	High	Low to Negligible	Moderate to minor adverse		**Minor adverse**
	Grey seal and harbour seal	High	Medium to Negligible	Major to Minor adverse		**Minor adverse**
TTS from single strike of maximum hammer energy	All species	Medium	Negligible	Minor adverse	MMMP for piling	**Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
TTS during piling from cumulative exposure	Harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale and harbour seal	Medium	Negligible	Minor adverse	MMMP for piling	**Minor adverse**
	Grey seal	Medium	Low to Negligible	Minor adverse	MMMP for piling	**Minor adverse**
Impact 2: Disturbance from Underwater Noise Associated with Piling Activities (10.6.1.2)						
ADD activation	All species	Medium	Negligible	Minor adverse	Not applicable	**Minor adverse**
Disturbance (26km & 15km EDR)	Harbour porpoise	Medium	Low to Negligible	Minor adverse	SIP for the SNS SAC	**Minor adverse**
Possible behavioural response	Harbour porpoise	Medium	Negligible	Minor adverse	SIP for the SNS SAC	**Minor adverse**
Impact 3: Disturbance from Underwater Noise Associated with Other Construction Activities (10.6.1.3)						
TTS from cumulative SEL and disturbance during other construction activities	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 4: Impacts from Underwater Noise and Disturbance Associated with Construction Vessels (10.6.1.4)						
TTS from cumulative SEL and disturbance for construction vessels	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 5: Barrier Effects from Underwater Noise during Construction (10.6.1.5)						
Barrier effects from underwater noise	All species	Medium	Negligible	Minor adverse	No mitigation proposed. However, measures in SIP will reduce potential significant disturbance of harbour porpoise (and other marine mammals)	**Minor adverse**
Impact 6: Increased Risk of Collision with Vessels during Construction (10.6.1.5)						
Increased collision risk	Harbour porpoise	High	Low	Moderate adverse	Good practice as outlined in the PEMP	**Negligible** to **Minor adverse**
	bottlenose dolphin grey and harbour seal	High	Medium	Major adverse		**Negligible** to **Minor adverse**
	White-beaked dolphin and minke whale	High	Negligible	Minor adverse		**Negligible** to **Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 7: Disturbance at Seal Haul-Out Sites (10.6.1.7)						
Disturbance at seal haul-out sites	Grey and harbour seal	Medium to Low	Negligible	Minor adverse to Negligible	No further mitigation proposed or proposed other than good practice.	**Negligible** to **Minor adverse**
Impact 8: Changes to Prey Availability (10.6.1.8)						
Change in prey availability during piling	Harbour porpoise and minke whale	Medium to Low	Negligible	Minor adverse to Negligible	No mitigation proposed for prey. However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	**Negligible** to **Minor adverse**
	Bottlenose dolphin and white-beaked dolphin	Low	Negligible	Negligible		**Negligible**
	Grey and harbour seal	Low	Low	Minor adverse		**Negligible** to **Minor adverse**
Impact 9: Changes to Water Quality (10.6.1.9)						
Changes in water quality	All species	Negligible	Negligible	Negligible	No further mitigation proposed other than embedded mitigation.	**Negligible**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Operation						
Impact 1: Impacts from Underwater Noise Associated with Operational Wind Turbines (10.6.2.1)						
Underwater noise from operational turbines	All species	Low to Medium	Negligible	Negligible to Minor adverse	No mitigation proposed	**Negligible** to **Minor adverse**
Impact 2: Impacts from Underwater Noise Associated with Operation and Maintenance Activities (10.6.2.2)						
Underwater noise from maintenance activities	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 3: Impacts from Underwater Noise and Disturbance Associated with Operation and Maintenance Vessels (10.6.2.3)						
Underwater noise from operation and maintenance vessels	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 4: Barrier Effects from Underwater Noise during Operation and Maintenance (10.6.2.4)						
No barrier effects as a result of underwater noise during operation and maintenance.						
Impact 5: Increased Risk of Collision with Vessels during Operation and Maintenance (10.6.2.5)						
Less than for construction						
Impact 6: Disturbance at Seal Haul-Out Sites (10.6.2.6)						
Disturbance at seal haul-out sites	Grey and harbour seal	Low to medium	Negligible	Negligible to Minor adverse	No further mitigation proposed or proposed other than good practice.	**Negligible** to **Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 7: Changes to Prey Availability (10.6.2.7)						
Change in prey availability during operation and maintenance	Harbour porpoise and minke whale	Low to medium	Negligible	Negligible to Minor adverse	No mitigation proposed for prey.	**Negligible** to **Minor adverse**
	Bottlenose dolphin, white-beaked dolphin, grey and harbour seal	Low	Negligible	Negligible		**Negligible**
Impact 8: Changes to Water Quality (10.6.2.8)						
Changes in water quality	All species	Negligible	Negligible	Negligible	No further mitigation proposed other than embedded mitigation.	**Negligible**
Decommissioning						
Same or less than for construction						
Cumulative Impacts (10.7)						
Overall cumulative impact of disturbance to marine mammals during piling at SEP or DEP	Harbour porpoise	Medium	Low	Minor adverse	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance of harbour porpoise	**Minor adverse**
	Bottlenose dolphin		Low	Minor adverse		**Minor adverse**
	White-beaked dolphin		Negligible	Minor adverse		**Minor adverse**
	Minke whale		Low	Minor adverse		**Minor adverse**
	Grey seal		Low	Minor adverse		**Minor adverse**
	Harbour seal		Negligible	Minor adverse		**Minor adverse**

Table 10-125: Summary of Potential Impacts during Construction, Operation, Maintenance and Decommissioning of SEP and DEP, Including Cumulative Impacts on Marine Mammals

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Construction						
Impact 1: Auditory Injury from Underwater Noise Associated with Piling (10.6.1.1)						
PTS from single strike of starting or maximum hammer energy	All species	High	Negligible	Minor adverse	MMMP for piling	**Minor adverse**
PTS during piling from cumulative exposure	Harbour porpoise	High	Medium	Major adverse	MMMP for piling	**Minor adverse**
	Bottlenose dolphin and white-beaked dolphin	High	Negligible	Minor adverse		**Minor adverse**
	Minke whale	High	Medium to Low	Major to Moderate adverse		**Minor adverse**
	Grey seal	High	Medium to Low	Major to Moderate adverse		**Minor adverse**
	Harbour seal	High	Medium to Negligible	Major to Minor adverse		**Minor adverse**
PTS from sequential piling	Harbour porpoise	High	Medium	Major adverse		**Minor adverse**
	Bottlenose dolphin and white-beaked dolphin	High	Negligible	Minor adverse		**Minor adverse**
	Minke whale	High	Medium	Major adverse		**Minor adverse**
	Grey and harbour seal	High	Medium	Major adverse		**Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
PTS from simultaneous piling	Harbour porpoise	High	Medium	Major adverse		**Minor adverse**
	Bottlenose dolphin and white-beaked dolphin	High	Negligible	Minor adverse		**Minor adverse**
	Minke whale	High	Medium to Low	Major to Moderate adverse		**Minor adverse**
	Grey and harbour seal	High	Medium	Major adverse		**Minor adverse**
TTS from single strike of maximum hammer energy	All species	Medium	Negligible	Minor adverse	MMMP for piling	**Minor adverse**
TTS during piling from cumulative exposure	Harbour porpoise, bottlenose dolphin, white-beaked dolphin, and minke whale	Medium	Negligible	Minor adverse		**Minor adverse**
	Grey and harbour seal	Medium	Low	Minor adverse		**Minor adverse**
TTS from sequential piling	All species except seals	Medium	Negligible	Minor adverse		**Minor adverse**
	Grey and harbour seal	Medium	Low	Minor adverse		**Minor adverse**
TTS from simultaneous piling	All species except seals	Medium	Negligible	Minor adverse		**Minor adverse**
	Grey and harbour seal	Medium	Low	Minor adverse		**Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 2: Disturbance from Underwater Noise Associated with Piling Activities (10.6.1.2)						
ADD activation	All species	Medium	Negligible	Minor adverse	Not applicable	**Minor adverse**
Disturbance (26km & 15km EDR)	Harbour porpoise	Medium	Low to Negligible	Minor adverse	SIP for the SNS SAC	**Minor adverse**
Possible behavioural response	Harbour porpoise	Medium	Low to Negligible	Minor adverse	SIP for the SNS SAC	**Minor adverse**
Impact 3: Disturbance from Underwater Noise Associated with Other Construction Activities (10.6.1.3)						
TTS from cumulative SEL and disturbance during other construction activities	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 4: Impacts from Underwater Noise and Disturbance Associated with Construction Vessels (10.6.1.4)						
TTS from cumulative SEL and disturbance for construction vessels	All species	Medium	Negligible to Low	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 5: Barrier Effects from Underwater Noise during Construction (10.6.1.5)						
Barrier effects from underwater noise	All species	Medium	Negligible	Minor adverse	No mitigation proposed.	**Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
					However, measures in SIP will reduce potential significant disturbance of Harbour porpoise (and other marine mammals)	
Impact 6: Increased Risk of Collision with Vessels during Construction (10.6.1.6)						
Increased collision risk	Harbour porpoise	High	Low	Moderate	Good practice	**Negligible** to **Minor adverse**
	Bottlenose dolphin grey and harbour seal	High	Medium	Major		**Negligible** to **Minor adverse**
	White-beaked dolphin and minke whale	High	Negligible	Minor		**Negligible** to **Minor adverse**
Impact 7: Disturbance at Seal Haul-Out Sites (10.6.1.7)						
The same as SEP and DEP separately						
Impact 8: Changes to Prey Availability (10.6.1.8)						
Change in prey availability during piling	Harbour porpoise and minke whale	Medium to Low	Negligible	Minor adverse to Negligible	No mitigation proposed for prey.	**Negligible** to **Minor adverse**
	Bottlenose dolphin and white-beaked dolphin	Low	Negligible	Negligible		**Negligible**
	Grey and harbour seal	Low	Low	Minor adverse		**Negligible** to **Minor adverse**

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
					However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	
Impact 9: Changes to Water Quality (10.6.1.9)						
The same as SEP and DEP separately						
Operation						
Impact 1: Impacts from Underwater Noise Associated with Operational Wind Turbines (10.6.2.1)						
Underwater noise from operational turbines	All species	Low to Medium	Negligible	Negligible to Minor adverse	No mitigation proposed	**Negligible** to **Minor adverse**
Impact 2: Impacts from Underwater Noise Associated with Operation and Maintenance Activities (10.6.2.2)						
Underwater noise from maintenance activities	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 3: Impacts from Underwater Noise and Disturbance Associated with Operation and Maintenance Vessels (10.6.2.3)						
Underwater noise from operation and maintenance vessels	All species	Medium	Negligible	Minor adverse	No mitigation proposed	**Minor adverse**
Impact 4: Barrier Effects from Underwater Noise during Operation and Maintenance (10.6.2.4)						
No barrier effects as a result of underwater noise during operation and maintenance.						
Impact 5: Increased Risk of Collision with Vessels during Operation and Maintenance (10.6.2.5)						
Less than for construction						

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 6: Disturbance at Seal Haul-Out Sites (10.6.2.6)						
The same as SEP and DEP separately						
Impact 7: Changes to Prey Availability (10.6.2.7)						
The same as SEP and DEP separately						
Impact 8: Changes to Water Quality (10.6.2.8)						
The same as SEP and DEP separately						
Decommissioning						
Same or less than for construction						
Cumulative Impacts (10.7)						
Overall cumulative impact of disturbance to marine mammals during piling SEP and DEP	Harbour porpoise	Medium	Medium	Moderate adverse	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance of harbour porpoise	**Minor adverse**
	Bottlenose dolphin		Low	Minor adverse		**Minor adverse**
	White-beaked dolphin		Negligible	Minor adverse		**Minor adverse**
	Minke whale		Low	Minor adverse		**Minor adverse**
	Grey seal		Medium	Moderate adverse		**Minor adverse**
	Harbour seal		Negligible	Minor adverse		**Minor adverse**

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