Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions

Preliminary Environmental Information Report

Volume 1

Chapter 12 - 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
BND	Bottlenose dolphin
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
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 Extension Project
DEPONS	Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea
DOW	Dudgeon Offshore Wind Farm
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
ES	Environmental Statement
ETG	Expert Topic Group
EU	European Union
FCS	Favourable Conservation Status
GBS	Gravity Based Structure
Gescha	Effects of noise-mitigated offshore pile driving on harbour porpoise abundance in the German Bight
GS	Grey seal
HDD	Horizontal Directional Drilling
HF	High-Frequency
HP	Harbour porpoise
HRA	Habitats Regulations Assessment
HS	Harbour seal
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	kilometer
km^2	kilometer squared
km/h	kilometers per hour
lb	pound
LF	Low Frequency
m	meter

m/s	meters per second
MF	Medium-Frequency
ML	Marine Licence
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
MU	Management Units
MW	Megawatt
MW	Minke whale
N	North
NE	North East
NMFS	National Marine Fisheries Service
NNR	National Nature Reserve
NOAA	National Oceanic and Atmospheric Administration
NPS	National Policy Statements
NS	North Sea
NSIPs	Nationally Significant Infrastructure Projects
O&M	Operation and Maintenance
OSP	Offshore Substation Platform
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PEMP	Project Environmental Management Plan
PDV	Phocine Distemper Virus
PINS	Planning Inspectorate
PTS	Permanent Threshold Shift
PW	Pinnipeds in water
RMS	Root Mean Square
RoC	Review of Consents
S	South
SAC	Special Area of Conservation
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 Extension Project
SIP	Site Integrity Plan
SMRU	Sea Mammal Research Unit
SNBCs	Statutory Nature Conservation Bodies
SNS	Southern North Sea
SoS	Secretary of State
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
UXO	Unexploded Ordnance
VHF	Very High Frequency
W	West
WBD	White-beaked dolphin
WDC	Whale and Dolphin Conservation
WS	West Scotland
WTG	Wind Turbine Generator
WWT	The Wildfowl and Wetlands Trust

Glossary of Terms

The Applicant	Equinor New Energy Limited
Array cables	Cables which link the wind turbine generators to the offshore substation platforms.
Dudgeon Offshore Wind Farm Extension site	The Dudgeon Offshore Wind Farm Extension offshore wind farm boundary.
The Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure.
Designated site	Sites designated for nature conservation under the Habitats Directive and Birds Directive. This includes candidate Special Areas of Conservation, Sites of Community Importance, Special Areas of Conservation and Special Protection Areas, 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 EIA and HRA for certain topics.
Grid option	Mechanism by which DEP and SEP will connect to the existing electricity network. This may either be an integrated grid option providing transmission infrastructure which serves both of the wind farms, or a separated grid option, which allows DEP and SEP to transmit electricity entirely separately.
Horizontal directional drilling (HDD) zones	The areas within the onshore cable route which would house HDD entry or exit points.
Interlink cables	Buried offshore cables which link offshore substation platform/s.
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 export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall.
Offshore scoping area	An area that encompasses all planned offshore infrastructure, including landfall options at both Weybourne and Bacton, and allows sufficient room for receptor identification and environmental surveys. This will be refined following further site selection and consultation.
Offshore substation platform	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.
PEIR boundary	The area subject to survey and preliminary impact assessment to inform the PEIR, including all permanent and temporary works for DEP and SEP. The PEIR boundary will be refined down to the final DCO boundary ahead of the application for development consent.
Study area	Area where potential impacts from the project could occur, as defined for each individual EIA topic.
Sheringham Shoal Offshore Wind Farm Extension site	Sheringham Shoal Offshore Wind Farm Extension offshore wind farm boundary.
The Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure.

12. MARINE MAMMALS

12.1 Introduction

1. This chapter of the Preliminary Environmental Information Report (PEIR) considers the potential impacts of the proposed Dudgeon Extension Offshore Wind Farm Project (DEP) and Sheringham Shoal Extension Offshore Wind Farm Project (SEP) 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 DEP and SEP.

2. The chapter has been written by Royal HaskoningDHV, with the assessment 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 **Section 12.4**.

3. The assessment should be read in conjunction with following linked chapters:
   - **Chapter 3 Policy and Legislative Context**;
   - **Chapter 5 Project Description**;
   - **Chapter 6 EIA Methodology**;
   - **Chapter 9 Marine Water and Sediment Quality**;
   - **Chapter 10 Benthic Ecology**;
   - **Chapter 11 Fish and Shellfish Ecology**; and
   - **Chapter 14 Shipping and Navigation**.

4. Additional information to support the marine mammal assessment includes:
   - **Appendix 12.1** Marine Mammal Information and Survey Data;
   - **Appendix 12.2** Underwater Noise Modelling Report; and
   - **Appendix 12.3** Marine Mammal Cumulative Impact Assessment Screening.

12.2 Consultation

5. Consultation with regard to marine mammals has been undertaken in line with the general process described in **Chapter 6 EIA Methodology**. The key elements to date have included scoping and the ongoing Evidence Plan Process (EPP) via the Marine Mammal Expert Topic Group (ETG). 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) are not directly involved in the ETG, to date, but are informed on the DEP and SEP development. The feedback received has been considered in preparing the PEIR. **Table 12-1** provides a summary of how the consultation responses received to date have influenced the approach that has been taken.

6. This chapter will be updated following the consultation on the PEIR in order to produce the final assessment that will be submitted with the Development Consent Order (DCO) application. Full details of the consultation process will also be presented in the Consultation Report alongside the DCO application.

Table 12-1: Consultation responses

Consultee	Date/ Document	Comment	Project Response
Planning Inspectorate (PINS)	Scoping Opinion, November 2019	Barrier effects from underwater noise – operation: The Scoping Report proposes to assess barrier effects from construction and decommissioning activities only. No justification has been provided for excluding an assessment in the operational stage and paragraph 741 acknowledges the potential for disturbance from underwater noises during operation and maintenance. In the absence of a suitable justification, the Inspectorate does not agree to scope out barrier effects from underwater noise during operation.	The proposed approach to assessing any potential barrier effects as a result of underwater noise during operation is outlined in **Section 12.6.2.4**.
PINS	Scoping Opinion, November 2019	Barrier effects from physical presence of wind farm during construction, operation and decommissioning: The Scoping Report states that the DEP and SEP are not located on any known marine mammal migration routes and that data from operational wind farms show no evidence of exclusion of marine mammals. The Inspectorate agrees that barrier effects from the physical presence of the wind farm are unlikely to be significant and can therefore be scoped out of the Environmental Statement (ES).	Barrier effects from the physical presence of the wind farm have not been assessed. However, any potential barrier effects from underwater noise during the construction, operation and maintenance has been assessed in **Sections 12.6.1.6.6.3**, and **12.6.2.4**.
PINS	Scoping Opinion, November 2019	Electromagnetic Fields (EMF) direct effects during construction, operation and decommissioning: The Inspectorate agrees that given the referenced literature in the Scoping Report, significant effects on marine mammals due to direct effects of EMF are unlikely. The	Direct effects from EMF have not been assessed. However, the potential indirect effects from any changes in prey availability have been assessed in **Section 12.6.2.7.2.3**.

Consultee	Date/ Document	Comment	Project Response
		Inspectorate is also content that indirect effects from changes to prey availability resulting from EMF during operation will be assessed, therefore, the Inspectorate agrees that direct effects from EMF can be scoped out of the ES.	
PINS	Scoping Opinion, November 2019	Underwater noise during unexploded ordnance (UXO) clearance and piling – operation and decommissioning: The Inspectorate agrees that these matters are only relevant to the construction phase with no significant effects anticipated during operation and decommissioning and therefore can be scoped out of the assessment for operation and decommissioning.	Underwater noise from UXO clearance and piling during operation and decommissioning have not been assessed. However, the potential impacts of UXO clearance during construction have been in **Sections 12.6.1.1** and **12.6.1.2**.
PINS	Scoping Opinion, November 2019	Underwater noise from wind turbines – operation: The Inspectorate agrees that this matter is only relevant to the operational phase with no significant effects anticipated during operation and decommissioning and therefore can be scoped out of the assessment for construction and decommissioning.	The potential impacts of underwater noise from operational turbines have been assessed in **Section 12.6.2.1**.
PINS	Scoping Opinion, November 2019	Cumulative barrier effects during construction, operation and decommissioning: The Scoping Report does not scope out barrier effects during operation from the Project alone. Therefore, the Inspectorate considers that likely significant cumulative effects may also occur and should be assessed in the ES.	The cumulative impact assessment has considered the potential for cumulative effects from underwater noise, including barrier effects in **Sections 12.7.3.3**.

Consultee	Date/ Document	Comment	Project Response
PINS	Scoping Opinion, November 2019	Cumulative assessment – commercial fisheries: The Scoping Report states that the impact from commercial fisheries will not be addressed directly in the cumulative assessment as these are ongoing activities that are factored into the baseline conditions. The Inspectorate is content that the assessment of cumulative impacts from commercial fisheries will be informed with reference to ongoing activities in the baseline conditions. The Applicant is advised to have regard to the advice contained in the Inspectorate' Advice Note Seventeen when preparing their assessment of cumulative impacts.	**Appendix 12.3** outlines the justification for plans, projects and activities not included in the cumulative impact assessment, including commercial fisheries.
PINS	Scoping Opinion, November 2019	Existing environment: The ES should provide details of likely feeding areas; known birthing areas/haul out sites; nursery grounds; and known migration or commuting routes.	Information on the baseline environment for marine mammals is outlined in **Section 12.5** and **Appendix 12.2**. This includes (where possible) details of likely feeding areas; known birthing areas/haul out sites; nursery grounds; and known migration or commuting routes.
PINS	Scoping Opinion, November 2019	Potential area of effects: Paragraph 325 of the Scoping Report states that all of the potential impacts screened in for further assessment will be related to the potential area of effect. The ES should clearly explain and justify the potential area of effect.	The PEI Report includes an explanation of the potential area of effect under each impact assessment, and clearly explains and justifies the potential area of effect used in the assessments.

Consultee	Date/ Document	Comment	Project Response
PINS	Scoping Opinion, November 2019	Reference populations: The Applicant should make efforts to agree with Natural England the relevant reference populations to be used in the assessment.	The reference populations, as outlined for each species in **Section 12.5** and summarised in **Section 12.5.7** are based on the latest data and information available, and agreed with Natural England and the ETG as part of the EPP.
PINS	Scoping Opinion, November 2019	Impacts from underwater noise: The Scoping Report identifies a number of potential impacts from underwater noise on marine mammals, including physical injury, death, permanent/temporary auditory injury, disturbance and behavioural effects and barrier effects. The Scoping Report provides limited detail regarding the extent to which these impacts are anticipated to affect the marine mammals. The assessment should explain and assess the consequences of the indirect effects that would result from these impacts, for example the inability to forage.	**Sections 12.6.1.1 - 12.6.1.6.6.3** and **12.6.2.1 - 12.6.2.4** assess the potential impacts of underwater noise. These assessments take into account the potential direct and indirect effects that could result from these impacts, such as the inability to forage.
PINS	Scoping Opinion, November 2019	Underwater noise from UXO clearance: Paragraph 138 of the Scoping Report explains that consent for UXO removal will be sought in a future Marine Licence application, when geophysical survey data of suitable spatial resolution is available to identify and quantify UXO risk. The Inspectorate welcomes that despite this, the Scoping Report proposes to assess the potential impacts of underwater noise that could result from UXO clearance.	Consent for UXO removal will be sought in a future Marine Licence application, once further detail on potential risk of UXO is available. However, an initial assessment on the potential impacts of underwater noise from any UXO clearance has been included in **Sections 12.6.1.1** and **12.6.1.2**.

Consultee	Date/ Document	Comment	Project Response
PINS	Scoping Opinion, November 2019	Water quality: Where significant effects are likely to occur, the ES should assess the extent to which changes in water quality, including increases in suspended sediment, may affect foraging for relevant marine mammal species.	The potential impact of any changes to water quality on marine mammals' ability to forage during construction, operation and maintenance is assessed in **Sections 12.6.1.10.5.2** and **12.6.2.8**.
PINS	Scoping Opinion, November 2019	Species density estimates: The methodology used to determine species density estimates should be clearly explained within the ES.	The methodology to derive species density estimates is provided in **Appendix 12.1**. These have been based on the latest data and information available, as well as the aerial survey where possible, and have been agreed with Natural England and the ETG as part of the EPP.
PINS	Scoping Opinion, November 2019	Guidance: The Applicant should ensure that guidance relied upon in the assessment is sufficiently up to date and robust for its purpose. The Inspectorate is aware that the Chartered Institute of Ecology and Environmental Management (CIEEM): Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal were updated in 2019. The ES should describe the guidance used and (where necessary) explain how it differs from more up to date guidance. This comment also applies to the Ecology and Ornithology aspect chapter.	**Section 12.4.1** takes into account the relevant and latest guidance, policy and legislation.

Consultee	Date/ Document	Comment	Project Response
PINS	Scoping Opinion, November 2019	European Protected Species (EPS) licences: The ES should set out in full the potential risk to EPS and confirm if any EPS licences will be required for example, for harbour porpoises and grey seals.	**Section 12.4.1.5** outlines the approach to determining the requirement for an EPS licence for cetacean species.
Natural England	Scoping Opinion, November 2019	Natural England is satisfied with the species to be included in the marine mammal assessment, namely harbour porpoise, minke whale, white-beaked dolphin, grey seal and harbour seal.	The baseline environment for harbour porpoise, minke whale, white-beaked dolphin, grey seal and harbour seal is outlined in **Section 12.5** with additional information provided in **Appendix 12.1**. Note that in addition, bottlenose dolphin have been included in the assessments, due to the very recent increase in presence of the species in the nearby area (see **Sections 12.3.1** and **12.5.2**).
Natural England	Scoping Opinion, November 2019	Natural England is content with the potential impacts to be included in the assessment and that direct impacts to marine mammals from EMF may be scoped out.	**Sections 12.6** and **12.7** provide assessments of the potential impacts for marine mammals.
Natural England	Scoping Opinion, November 2019	Paragraph states digital aerial surveys for offshore ornithology and marine megafauna began in May 2018, but Table 2-16 says these surveys began in May 2019. Please can clarification be provided as to which date is correct.	As outlined in **Section 12.4.2.1**, the monthly aerial surveys have been undertaken since May 2018 and were completed in April 2020, with 24 months of data collected for the DEP and SEP sites.

Consultee	Date/ Document	Comment	Project Response
Natural England	Scoping Opinion, November 2019	Consideration should also be given within the ES to the possible requirement for a European Protected Species licence.	**Section 12.4.1.5** outlines the approach to determining the requirement for an EPS licence for cetacean species.
Marine Management Organisation (MMO)	Scoping Opinion, November 2019	Recommendation: The use of soft start procedures on commencement of piling. The MMO's technical advisers Cefas recommend a 20-minute soft-start in accordance with the Joint Nature Conservation Committee (JNCC) protocol for minimising the risk of injury to marine mammals and other fauna from piling noise (JNCC, 2010b). Should piling cease for a period greater than 10 minutes, then the soft-start procedure must be repeated.	**Sections 12.3.4** outlines the approach to developing a Marine Mammal Mitigation Protocol (MMMP) for piling.
MMO	Scoping Opinion, November 2019	Recommendation: The use of air bubble curtains to reduce or mitigate the impacts of noise and vibration from piling.	**Section 12.3.4** outlines the approach to developing a MMMP for piling.
Natural England	Expert Topic Group (ETG) Meeting 1: 3rd December 2019	Results of the aerial surveys should be used when calculating seal density if possible, in addition to published SMRU data, and the highest density should be used in the assessment.	The methodology used to derive species density estimates is included within **Appendix 12.1**. These have been based on the latest data and information available, as well as the aerial survey where possible, and have been agreed with Natural England and the ETG as part of the EPP.

Consultee	Date/ Document	Comment	Project Response
Natural England	ETG Meeting 1: 3rd December 2019	There will be an update to the Management Unit (MU) reference populations, but the date of the update is unknown.	Noted. The updated information on the MU reference populations was not available at the time of writing of the PEIR. However, when available these updates will be included in the ES.
Natural England	ETG Meeting 1: 3rd December 2019	NE request the use of NOAA (National Oceanic and Atmospheric Administration) thresholds because they are familiar and comparable to other recent assessment.	**Section 12.6.1.3.2.1** outlines that the Southall *et al.* (2019) use the same thresholds as NOAA, just that names of some of the species hearing groups have been changed.
The Wildlife Trust (TWT)	ETG Meeting 1: 3rd December 2019	TWT suggest that UXO surveys as undertaken previously for nearby project infrastructure could be useful.	The number of UXO can vary considerably over a small distance, but the available data sources including the number of UXO identified at nearby wind farms on other project infrastructure have been used to inform the assessment, as outlined in **Section 12.6.1.1**.
Natural England	ETG Meeting 2: 18th June 2020	Lucke *et al*. (2009) was incorporated in Southall *et al*. (2019) for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) and therefore does not have to be considered separately. Lucke *et al*. (2009) can still be used for behavioural response in harbour porpoise.	The potential for behavioural response of harbour porpoise to piling, based on the Lucke *et al*. (2009) thresholds, is assessed in **Section 12.6.1.4.2.4.**

Consultee	Date/ Document	Comment	Project Response
Natural England	ETG Meeting 2: 18th June 2020	UXO clearance at other sites should be included in the in-combination assessment.	**Section 12.7.3.2.1** provides an assessment for the potential for cumulative impacts as a result of UXO clearance at other projects.
MMO	Marine Mammal Method Statement comments, letter by email, 7th August 2020	The MMO understand that the mitigation measures will be finalised once an assessment of the potential impacts has been undertaken. Section 1.6 of the method statement outlines the embedded mitigation that will be incorporated into the design of the development to prevent or reduce any significant adverse effects. These measures will include soft start/ramp up of piling activity, and a mitigation zone, and are the standard measures that are typically seen for such developments. The method statement further states that if further mitigation is required and possible, these will be reviewed in the relevant impact sections of the PEIR and ES.	**Section 12.3.4** outlines the approach to developing a MMMP for piling. Any further modelling will be considered after consultation on the PEIR.
MMO	Marine Mammal Method Statement comments, letter by email, 7th August 2020	The MMO recommend the use of noise abatement technologies (i.e. bubble curtains) to reduce the risk of potential impact on marine receptors. Ideally, the MMO recommend that noise modelling is undertaken to assess the reduction in PTS/TTS zones that applying noise abatement measures will bring. Further steps on this are provided in Faulkner *et al*. (2018), and, on noise abatement, in Merchant (2019) and the report of the recent workshop at the Royal Society (Merchant and Robinson, 2020).	**Section 12.3.4** outlines the approach to developing a MMMP for piling. If required, further underwater noise modelling will be undertaken following consultation on the PEIR to include any mitigation / noise abatement measures required to reduce noise levels to

Consultee	Date/ Document	Comment	Project Response
			reduce any potential significant impacts.
MMO	Marine Mammal Method Statement comments, letter by email, 7th August 2020	If more than one pile (monopile or pin pile) is anticipated to be installed within 24 hours, then the assessment (pile driving sequence) should account for this.	**Section 12.6.1.3.2.1** outlines the methodology of the underwater noise modelling for piling, including the assumptions made with regard to cumulative piling in a 24 hour period. Further underwater noise modelling will be undertaken following consultation on the PEIR if more than one pile will be installed during 24 hour period.

12.3 Scope

12.3.1 Marine Mammal Species

7. Site characterisation has been undertaken using site specific data for DEP and SEP, as well as existing data from other offshore wind farms in the area and other available information for the region (see **Appendix 12.1**). The key species and therefore the focus of the assessments are:

- Harbour porpoise – present throughout the year, although there may be variations in seasonal occurrence;
- Bottlenose dolphin – 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 – seasonal occurrence in low numbers;
- Minke whale – seasonal occurrence in low numbers;
- Grey seal – present throughout the year; and
- Harbour seal – present throughout the year.

12.3.2 Study Area

8. The study area for marine mammals has been defined on the basis of marine mammals being highly mobile and transitory in nature; therefore, it is necessary to examine species occurrence not only within DEP and SEP, but also over the wider area. For each species of marine mammal, the following study areas have been defined based on the relevant Management Units (MUs) (see **Appendix 12.1**), current knowledge and understanding of the biology of each species:

- Harbour porpoise: North Sea (NS) MU;
- Bottlenose dolphin: Greater North Sea and Coastal East Scotland MUs;
- White-beaked dolphin: Celtic and Greater North Seas MU;
- Minke whale: Celtic and Greater North Seas MU;
- Grey seal: South-east England, North-east England and UK East Coast MUs, and the Wadden Sea region; and
- Harbour seal: South-east England MU and the Wadden Sea region.

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

10. There is the potential for seals from haul-out sites to move along the coast and offshore to forage in and around the proposed Project areas. Key haul-out sites for both seal species within the vicinity of the DEP and SEP 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 12-15** and **Table 12-17** for further details).

12.3.3 Realistic Worst-Case Scenario

12.3.3.1 General Approach

11. The final design of DEP and SEP 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 (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 6 EIA Methodology**.
12. The realistic worst-case scenarios relevant for the marine mammal assessment are summarised in **Table 12-2**. These are based on the project parameters described in **Chapter 5 Project Description**, which provides further details regarding specific activities and their durations.
13. In addition to the design parameters set out in **Table 12-2**, consideration is also given to how DEP and SEP will be built out as described in **Section 12.3.3.2**. This accounts for the fact that whilst DEP and SEP are the subject of one DCO application, it is possible that either one or both of the projects will be developed, and if both are developed, that construction may be undertaken either concurrently or sequentially.
14. The potential impacts on marine mammals are:
    - Underwater noise (including, UXO clearance, piling, other construction activities, vessels, operational turbines, O&M activities 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.

Table 12-2: Realistic worst-case parameters for marine mammal assessments

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Construction				
Underwater noise during unexploded ordnance (UXO) clearance	Various possible types and sizes of UXO. Worst case identified by Sheringham Shoal OWF and Dudgeon OWF: 2,000lb German air dropped bomb (Trinitrotoluene (TNT) equivalent of 525kg) Possible number of UXO unknown			Indicative only. A detailed UXO survey would be completed prior to construction. The exact type, size and number of possible detonations and duration of UXO clearance operations is therefore not known at this stage. N.B. Assessments for UXO clearance are for information only and are not part of the DCO application (separate Marine Licence (ML) application/s will be made prior to construction).
Underwater noise during piling (alternative foundation types are also considered but do	Installation of up to **32 turbines** (between 17 and 32 ranging from 14MW to 26MW) and **one offshore**	Installation of up to **24 turbines** (between 13 and 24 ranging from 14MW to 26MW) and **one OSP** comprising in the SEP wind farm site	Installation of up to **56 turbines** (between 30 and 56 ranging from 14MW to 26MW) and **two OSPs** (one in DEP North and one in SEP)	Maximum number of wind turbines and OSPs. The worst case scenario for DEP and SEP together assumes DEP

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
not represent the worst-case for underwater noise)	**substation platform** (OSP) in DEP North			(North & South) and SEP are developed in a separated grid option (each having their own OSP).
	Options for piled foundations: • 1 monopile per WTG foundation; or • 4 pin-piles per WTG 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 turbine foundations: • Up to **32 monopiles**; or • Up to **128 pin-piles**	Number of piled turbine foundations: • Up to **24 monopiles**; or • Up to **96 pin-piles**	Number of piled turbine foundations: • Up to **56 monopiles**; or • Up to **224 pin-piles**	Worst-case is up to 56 monopiles plus 8 pin-piles; or up to 240 pin-piles based on maximum number of piled foundations for 14MW WTGs and up to two OSPs The worst case scenario for DEP and SEP together assumes DEP (North & South) and SEP are developed in a
	Up to **8 piled OSP foundations** (1 OSP)	Up to **8 piled OSP foundations** (1 OSP)	Up to **16 piled OSP foundations** (2 OSPs)	

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
				separated grid option (each having their own OSP).
	Maximum **hammer energy for monopiles** • Up to **5,000kJ for 14 MW** WTG • Up to **5,500kJ for 18+MW** WTG Maximum **hammer energy for pin-piles**: up to **3,000kJ**			This is the worst-case scenario. 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 14MW WTG • Up to 16m for 18+MW WTG Maximum **pile diameter for pin-piles**: • Up to **3m for 14MW** WTG • Up to **4m for 18+MW** WTG • 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: **12 months**	Duration of wind turbine foundation installation: **12 months**	Duration of wind turbine foundation installation: **24 months** (sequential construction, with gap)	This is the maximum duration of all offshore activities to install wind turbines, however, piling will only be a relatively

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
				small duration within this overall period.
	Total piling time per wind turbine foundation (14MW or 18+MW) Monopiles: up to **128 hours** for 32 WTGs (4 hours per WTG) or Pin-piles: up to **384 hours** for 32 WTGs (3 hours per pin-pile x 4 piles per foundation = up to 12 hours per foundation)	**Total piling time** per wind turbine foundation (14MW or 18+MW) Monopiles: up to **96 hours** for 24 WTGs (4 hours per WTG) or Pin-piles: up to **288 hours** for 24 WTGs (3 hours per pin-pile x 4 piles per foundation = up to 12 hours per foundation)	**Total piling time** per wind turbine foundation (14MW or 18+MW) Monopiles: up to **224 hours** (9.3 days) for 56 WTGs (4 hours per WTG) or Pin-piles: up to **672 hours** (28 days) for 56 WTGs (3 hours per pin-pile x 4 piles per foundation = up to 12 hours per foundation)	Total piling time includes soft-start and ramp-up, and providing allowance for issues such as low blow rate, refusal, etc. More likely worst-case scenario is up to 3.2 hours per monopile, totaling 179.2 hours for 56 WTGs. Worst-case average (for all WTGs) active piling time for 13m or 16m pin-piles is 2.5 hours (150). With soft-start and ramp-up the total average piling time is 180 minutes per pin-pile, or 720 minutes per WTG.
	Total OSP piling time 3 hours per pin-pile x 8 piles per foundation = up	**Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation =	**Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation = up	Total piling time includes soft-start and ramp-up, and providing allowance

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	to **24 hours** per foundation	up to **24 hours** per foundation	to 24 hours per foundation. Two OSPs = **48 hours**	for issues such as low blow rate, refusal, etc. The worst case scenario for DEP and SEP together assumes DEP (North & South) and SEP are developed in a separated grid option (each having their own OSP).
	Maximum total active piling time for wind turbines and platforms: **408 hours (17 days)**, based on pin-pile foundations for WTGs and one OSP For WTG monopile scenario: 152 hours (6.3 days)	**Maximum total active piling time** for wind turbines and platforms: **312 hours (13 days)**, based on pin-pile foundations for WTGs and one OSP For WTG monopile scenario: 120 hours (5 days)	**Maximum total active piling time** for wind turbines and platforms: **720 hours (30 days)**, based on pin-pile foundations for WTGs and up to two OSPs For WTG monopile scenario: 272 hours (11.3 days)	Worst-case scenario is pin-piles for all WTGs.
	Activation of Acoustic Deterrent Devices (ADDs) For example: 10 minutes per pile, or 2,400 minutes (40 hours) for 240 pin-piles.			Indicative only.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	No concurrent piling at DEP	No concurrent piling at SEP	Potential for concurrent piling between DEP and SEP depending on build scenario (see **Section 12.3.3.2**)	Concurrent piling between DEP and SEP represents worst-case.
	Number of monopiles to be installed per 24 hour period = 1 Number of pin-piles to be installed per 24 hour period = 1	Number of monopiles to be installed per 24 hour period = 1 Number of pin-piles to be installed per 24 hour period = 1	Number of monopiles to be installed per 24 hour period = 1 Number of pin-piles to be installed per 24 hour period = 1	Assessments have been based on one pile per 24 hour, as during the installation of the first pile in any 24 hour period, marine mammals would move away from the area and would not be at risk of any further cumulative impacts from subsequent piles in the same 24 hour period. If required, this will be reviewed and updated for the ES.
Underwater noise during other construction activities (Underwater noise from activities such as seabed	Seabed clearance methods: Pre-lay grapnel run, boulder grab, plough, pre-sweeping, dredging			
	Cable installation methods: Jetting / ploughing / trenching / mechanical cutting			Assumed equal amounts of jetting and cutting.
	Underwater noise modelling for all construction activities and vessels			

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
preparations, cable installation and rock placement)	**Wind farm site:** Two wind farm areas (DEP North and South) totalling **103.50km²**	**Wind farm site:** One wind farm area totalling **92.6km²**	**Wind farm sites:** Three wind farm areas totalling **196.10km²** (DEP North, DEP South and SEP)	Maximum wind farm area(s)
	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 **1 year** Duration of offshore export cable installation: **110 days**	
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**	**Vessel movements:** • Maximum number of construction vessels on site at any one time: up to **25** (in total if both DEP and SEP constructed concurrently) • Construction vessel trips to port: **1,196**	Maximum number of construction vessels. Construction port/s will not be confirmed until nearer the start of construction.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
		over 2 year construction period	during 4 year construction period if constructed sequentially	
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.
Disturbance at seal haul-out sites	Distance of DEP and SEP and vessel routes to seal haul-out sites as identified within **Section 12.5.5** and **12.5.6** for grey seal and harbour seal, respectively.			Construction port/s will not be confirmed until nearer the start of construction.
Changes to prey resources	Impacts to prey species and habitat as described in **Chapter 11 Fish and Shellfish Ecology** and **Chapter 10 Benthic Ecology**. Underwater noise parameters as outlined for construction noise-related impacts above (UXO, piling, other construction activities and vessels).			
Changes to water quality	Impacts to water quality as described in **Chapter 9 Marine Water and Sediment Quality**.			

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Operation				
Underwater noise from operational turbines	Turbine parameters (e.g. size and number) as outlined above and underwater noise parameters described in **Appendix 12.2**.			Underwater noise modelling for operational turbines
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) • 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 (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) • Reburial of 1% infield cabling every 10 years (900m)	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); • Reburial of 1% of interlink cabling every 10 years (1,540m) • Two infield cable repairs every 10 years (5,000m in total)	

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
	• Reburial of 1% of infield cabling every 10 years (1,350m)		• Reburial of 1% infield cabling every 10 years (2,250m)	
Underwater noise from vessels, and vessel collision risk	**Vessel movements:** • Maximum number of vessels on site at any one time: **7** • Operation and maintenance vessel trips to port per year: approximately 690 (although majority (624) will be (small O&M vessel (CTV))	**Vessel movements:** • Maximum number of vessels on site at any one time: **7** • Operation and maintenance vessel trips to port per year: approximately 690 (although majority (624) will be (small O&M vessel (CTV))	**Vessel movements:** • Maximum number of vessels on site at any one time: **9** (in total if both DEP and SEP constructed concurrently) • Operation and maintenance vessel trips to port per year: approximately 694 (although majority (624) will be (small O&M vessel (CTV))	Where possible, DEP and SEP will use existing O&M programme for Dudgeon and Sheringham Shoal Offshore Wind Farms respectively.
Barrier effect from underwater noise	Maximum impact range from operation phase underwater noise assessments (above).			The maximum spatial area of potential impact, and duration of impacts, are considered to cause the worst-case barrier impact.

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Disturbance at seal haul-out sites	Distance of DEP and SEP to haul-out sites as identified within **Section 12.5.5** and **12.5.6** for grey seal and harbour seal, respectively.			
	O&M base location: Great Yarmouth			O&M activities could happen at any time of year.
Changes to prey resources	Impacts to prey species and habitat as described in **Chapter 11 Fish and Shellfish Ecology** and **Chapter 10 Benthic Ecology**. Underwater noise parameters as outlined for operation noise-related impacts above (operational turbines, maintenance activities, vessels).			
Changes to water quality	Impacts to water quality (as described in **Chapter 9 Marine Water and Sediment Quality**).			
Decommissioning				
Underwater noise from foundation removal of WTGs and substations	Assumed to be no worse than during construction.			
Underwater noise from other decommissioning activities	Assumed to be no worse than during construction.			

Impact	DEP in Isolation	SEP in Isolation	DEP & SEP Together	Notes and Rationale
Underwater noise from vessels, and vessel collision risk	Assumed to be no worse than during construction.			
Barrier effect from underwater noise	Assumed to be no worse than during construction.			
Disturbance at seal haul-out sites	Assumed to be no worse than during construction.			
Changes to prey resources	Assumed to be no worse than during construction.			
Changes to water quality	Assumed to be no worse than during construction.			

12.3.3.2 Construction Scenarios

15. The following principles set out the framework for how DEP and SEP may be constructed:

- DEP and SEP may be constructed at the same time, or at different times;
- If built at the same time both projects could be constructed in four years, with offshore construction being undertaken over two years (likely years three and four) of the overall construction period;
- If built at different times, either project could be built first;
- If built at different times, the first project would require a four year period of construction including a two year offshore construction period, and the second project would require three years to construct including a two year offshore construction period;
- If built at different times, the duration of the gap 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;
    - If the gap between the projects is less than two years, the first project would wait for the second project in order to be constructed together.
- Assuming a maximum construction period per project, and taking the above into account, the maximum construction period over which the construction of both projects could take place is seven years.
- The earliest construction start date is 2024 and the latest is 2028.

16. In order to determine which construction scenario presents the realistic worst case for each species and impact, the assessment considers both maximum duration effects and maximum peak effects, in addition to each project being developed in isolation, drawing out any differences between DEP and SEP.

17. The three construction scenarios considered by the marine mammal assessments are therefore:

- Build DEP or build SEP in isolation;
- Build DEP and SEP concurrently – reflecting the maximum peak effects; and
- Build one project followed by the other with a gap of up to four years (sequential) – reflecting the maximum duration of effects. This would result in a maximum gap in offshore construction of one year.

18. Any differences between DEP and SEP, or differences that could result from the manner in which the first and the second Projects are built (concurrent or sequential and the length of any gap) are identified and considered where relevant in the impact assessment section of this chapter (**Section 12.6**). For each potential impact 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 12.6**.

12.3.3.3 Operation Scenarios

19. Operation scenarios are described in detail in **Chapter 5 Project Description**. The marine mammal assessments consider the following three scenarios:
    - Only DEP in operation;
    - Only SEP in operation; and
    - The two projects operating at the same time, with a gap of up to three years between each project commencing operation.
20. The operational lifetime of each project is expected to be 35 years.

12.3.3.4 Decommissioning Scenarios

21. Decommissioning scenarios are described in detail in **Chapter 5 Project Description**. Decommissioning arrangements will be agreed through the submission of a Decommissioning Plan, however for the purpose of this assessment it is assumed that decommissioning of DEP and SEP could be conducted separately, or at the same time, and that any potential effects would be the same or less than for construction.

12.3.4 Summary of Mitigation

12.3.4.1 Mitigation Embedded in the Design

22. This section outlines the embedded mitigation relevant to the marine mammal assessment, which has been incorporated into the design of the projects (**Table 12-3**). Where other mitigation measures are proposed, as outlined in **Section 12.3.4.2**, these are also detailed in the relevant impact assessments (**Section 12.6**).
23. 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 12-3: Embedded mitigation measures

Parameter	Mitigation Measures Embedded into the Design of DEP and SEP
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.

Parameter	Mitigation Measures Embedded into the Design of DEP and SEP
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.
Water Quality	
Pollution prevention	As outlined in **Chapter 9 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 Project Environmental Management Plan (PEMP) will be developed and 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.

12.3.4.2 Other Mitigation Measures

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

Table 12-4: 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 permanent auditory injury (PTS), for example, the activation of acoustic deterrent devices (ADDs) prior to the soft-start.
MMMP for UXO Clearance	

<table>
<tr><th>Parameter</th><th>Additional Mitigation Measures</th></tr>
<tr><td>MMMP for UXO</td><td>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, 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 physical and auditory injury (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 disposal technique, such as deflagration;
• The use of bubble curtains (taking into consideration the environmental limitations);
• All detonations 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 during daylight hours and suitable visibility;
• The activation of ADDs;
• 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 the use of scare charge; multiple detonations, if UXO are located in close proximity; avoidance of UXO; or relocation of UXO.</td></tr>
<tr><td colspan="2">Site Integrity Plan (SIP)</td></tr>
<tr><td>Southern North Sea (SNS) Special Area of Conservation (SAC) Site Integrity Plan (SIP)</td><td>In addition to the MMMPs for piling and UXO clearance, a SNS SAC SIP 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 will be 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.</td></tr>
</table>

Parameter	Additional Mitigation Measures
	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 MMO.

12.3.5 Summary of Monitoring Requirements

25. Post-consent, the final detailed design of DEP and SEP and the development of the relevant Management Plan will refine the worst-case parameters assessed. It is recognised that monitoring is an important element in the management and verification of the actual impacts.

26. Where they are necessary, monitoring requirements will be described in the In-Principle Monitoring Plan (IPMP) submitted alongside the DCO application and further developed and agreed with stakeholders prior to construction based on the IPMP and taking account of the final detailed design of DEP and SEP.

12.4 Impact Assessment Methodology

12.4.1 Policy, Legislation and Guidance

12.4.1.1 National Policy Statements

27. 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), 2011a);
- NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b); and
- NPS for Electricity Networks Infrastructure (EN-5) (DECC, 2011c).

28. The specific assessment requirements for marine mammals, as detailed in the EN-3, are summarised in **Table 12-5** together with an indication of the section of the PEIR chapter where each is addressed.

Table 12-5: NPS assessment requirements.

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	Paragraphs 2.6.90-2.6.91 of the NPS EN-3 (July 2011).	**Section 12.3.3** provides an overview of the worst-case scenario for possible piling works. **Sections 12.6.1.3** and **12.6.1.4**

NPS Requirement	NPS Reference	Section Reference
piling associated with an offshore windfarm 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."		provides an assessment of pile driving (including noise modelling results).
"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).	**Section 12.5** and **Appendix 12.1** provide a description of the existing environment. **Section 12.6.1** details the assessment of impacts during construction, including pile driving. **Section 12.6.2** provide the assessment of operational noise.
"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).	**Section 12.6.1** details the assessment of impacts during construction, including pile driving and mitigation measures. The proposed DEP and SEP projects has consulted with Natural England (**Table 12-1**) through the

NPS Requirement	NPS Reference	Section Reference
		Evidence Plan Process (EPP).
"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 windfarm foundations pose a collision risk to marine mammals."	Paragraphs 2.6.94 to 2.6.96 of the NPS EN-3 (July 2011).	**Chapter 5 Project Description** describes the foundation options under consideration for proposed DEP and SEP projects. **Section 12.3.3** 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. 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	Paragraphs 2.6.97 to 2.6.99 of the NPS EN-3 (July 2011).	An IPMP and draft MMMP will be submitted with the DCO application. These plans will be developed in consultation with the relevant SNCBs and MMO post-consent and will identify any necessary

NPS Requirement	NPS Reference	Section Reference
the piling before significant adverse impacts are caused”.		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 12.4.1.6**.
“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).	An IPMP will be submitted with the DCO application.
“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 12.3.3.2**.

12.4.1.2 National and Regional Marine Policies

29. 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:
    - The Marine Strategy Framework Directive (MSFD) 2008/56/EC (EC, 2008);
    - The Marine Policy Statement (MPS) (HM Government, 2011); and
    - The East Inshore and East Offshore Marine Plans (HM Government, 2014).

30. Further detail is provided in **Appendix 12.1** and **Chapter 3 Policy and Legislative Context**.

12.4.1.3 National and International Legislation for Marine Mammals

31. **Appendix 12.1** provides an overview of national and international legislation in relation to marine mammals.

12.4.1.4 Guidance Documents for Marine Mammals

32. 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).

12.4.1.5 European Protected Species Guidance

33. 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.

34. Further information is provided in **Appendix 12.1**.

35. If required, the EPS licence 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 the construction of the windfarm, as well as the mitigation measures that will be in place following the development of MMMPs for piling and UXO clearance.

12.4.1.6 Favourable Conservation Status (FCS)

36. Member states report back to the European Union (EU) every six years on the Conservation Status of marine EPS. Based on the most recent 2013-2018 reporting by JNCC in 2019 (**Table 12-6**).

Table 12-6: FCS assessment of marine mammals species in Annex IV of the Habitats Directive occurring in UK and adjacent waters (JNCC, 2019) relevant to DEP and SEP

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

12.4.2 Data and Information Sources

12.4.2.1 Site specific surveys

37. 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 DEP and SEP, including 4km buffer. Further detail of the survey method is provided in **Appendix 12.1**. 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 the DEP and SEP sites, over 29 individual survey days (further details are provided in **Appendix 12.1**).

12.4.2.2 Other available sources

38. Other sources that have been used to inform the assessment are listed in **Table 12-7**.

Table 12-7: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.*, 2017)	North Sea and European Atlantic waters	Summer 2016	Provides information including abundance and density estimates of cetaceans in European Atlantic

Data set	Spatial coverage	Year	Notes
			waters in summer 2016, including the proposed offshore development area.
Management Units (MUs) for cetaceans in UK waters (Inter-Agency Marine Mammal Working Group (IAMMWG), 2015)	UK waters	2015	Provides information on MU 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.
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 southern North Sea area.
Distribution of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008 (The Wildfowl	UK areas of the North Sea	2001-2008	Provides information for on species in the North Sea area.

Data set	Spatial coverage	Year	Notes
and Wetlands Trust (WWT), 2009)			
MARINElife surveys from ferries routes across the southern North Sea area (MARINElife, 2020)	Southern North Sea	2017-2019	Provides information on species in southern North Sea area.
Sea Watch Foundation volunteer sightings off eastern England (Sea Watch Foundation, 2020)	East coast of England	2019-2020	Provides information on species sighted along east coast of England.
UK seal at sea density estimates and usage maps (Russell *et al*., 2017)	North Sea	1988-2016	Provides information on abundance and density estimates 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, 2019).	North Sea	2019	Provides information on seal species.
Counts of grey seal in the Wadden Sea (Brasseur *et al*., 2020).	Wadden Sea	Winter 2019 to Spring 2020	Counts of grey seal during moult season.
Counts of harbour seal counts in the Wadden Sea (Galatius *et al*., 2020).	Wadden Sea	August 2020	Counts of harbour seal during pupping season.

12.4.3 Impact Assessment Methodology

39. **Chapter 6 EIA Methodology** provides a summary of the general impact assessment methodology applied to DEP and SEP. The following sections confirm the methodology used to assess the potential impacts on marine mammals.

40. 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).

41. 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 will be defined within the PEIR and ES, following the definitions set out in **Sections 12.4.3.1** and **12.4.3.2**.

12.4.3.1 Definitions

42. 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 12-8** and **Table 12-10** respectively.

43. The sensitivity of a receptor is determined through its ability to accommodate change and on its ability to recover if it is affected (**Table 12-8**). 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.

44. 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 12-8: 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.

45. 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.

46. 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.

47. 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.

48. **Table 12-9** 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 12-9: 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.

49. 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 12-10**).

50. 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.

51. 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.

52. 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 12-10: 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.

Magnitude	Definition
	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 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

Magnitude	Definition
	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.

12.4.3.2 Impact Significance

53. 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 6 EIA Methodology** for further details). The determination of significance is guided by the use of an impact significance matrix, as shown in **Table 12-11**. Definitions of each level of significance are provided in **Table 12-12**.

54. 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 12-11: 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 12-12: 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.

Significance	Definition
Negligible	No discernible change in receptor condition.
No change	No impact, therefore no change in receptor condition.

12.4.4 Cumulative Impact Assessment Methodology

55. The cumulative impact assessment (CIA) considers other plans, projects and activities that may impact cumulatively with DEP and SEP. As part of this process, the assessment considers which of the residual impacts assessed for DEP and/or SEP 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 6 EIA Methodology** provides further details of the general framework and approach to the CIA.

56. 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.

57. 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.

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

- Other offshore wind farms;
- Other renewables developments;
- Mariculture;
- Aggregate extraction and dredging;
- Licenced disposal sites;
- Shipping and navigation;
- Planned construction sub-sea cables and pipelines;

- Potential port/harbour development;
- Oil and gas development and operation, including seismic surveys; and
- UXO clearance.

59. Commercial fishing activity is not considered in the CIA.

60. 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.

61. 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 windfarm 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.

62. 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.

63. 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.

64. The project tiers considered in the CIA for marine mammals are outlined in **Table 12-13** and the CIA screening is provided in **Appendix 12.3*.***

Table 12-13: Tiers in relation to project category which have been screened into the CIA

Project Category	UK	Other
Other offshore windfarms	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

Project Category	UK	Other
Planned construction of sub-sea cables and pipelines	Tier 1,2,3	Screened out

12.4.5 Transboundary Impact Assessment Methodology

65. The transboundary assessment considers the potential for transboundary effects to occur on marine mammal species as a result of the Projects; either those that might arise within the Exclusive Economic Zone (EEZ) of European Economic Area (EEA) states. **Chapter 6 EIA Methodology** provides further details of the general framework and approach to the assessment of transboundary effects.

66. 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).

67. The assessment of effects on transboundary Designated Sites is presented in the draft Information for **Habitats Regulations Assessment (HRA) Report**.

12.4.6 Assumptions and Limitations

68. 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.

69. 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 12.1** seeks to address these limitations by estimating a correction factor in order to determine estimated absolute density estimates from the site specific aerial surveys.

70. 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.

12.5 Existing Environment

71. As outlined in **Section 12.3.1**, the key marine mammal species are:

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

- Harbour seal.

72. **Appendix 12.1** 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.

12.5.1 Harbour Porpoise

73. Within the southern North Sea 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 seabed 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.

74. Distribution and abundance maps have been developed by Waggitt *et al.* (2020) 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.

75. For harbour porpoise, the distribution maps show a clear pattern of high harbour porpoise density in the southern North Sea, and the coasts of south-east England, for both January and July (Waggitt *et al*., 2020). Examination of this data, including all 10km grids that overlap with the DEP and SEP areas, including export cable areas, indicates an average annual density estimate of:

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

76. Results from the SCANS-III survey (the most recent available; undertaken in summer 2016; Hammond *et al.,* 2017) 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 DEP and SEP sites including export cable areas both in SCANS-III survey block O where:

- Abundance = 53,485 harbour porpoise (Coefficient of Variation (CV) = 0.21; 95% Confidence Interval (CI) = 37,413-81,695); and
- Density = 0.888 harbour porpoise/km^2 (CV=0.21; 95% CI = 37,413-81,695).

77. Data from the DEP and SEP sites specific surveys have also been used to generate abundance and density estimates for the sites with a 4km buffer (see **Appendix 12.1**).

78. 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.

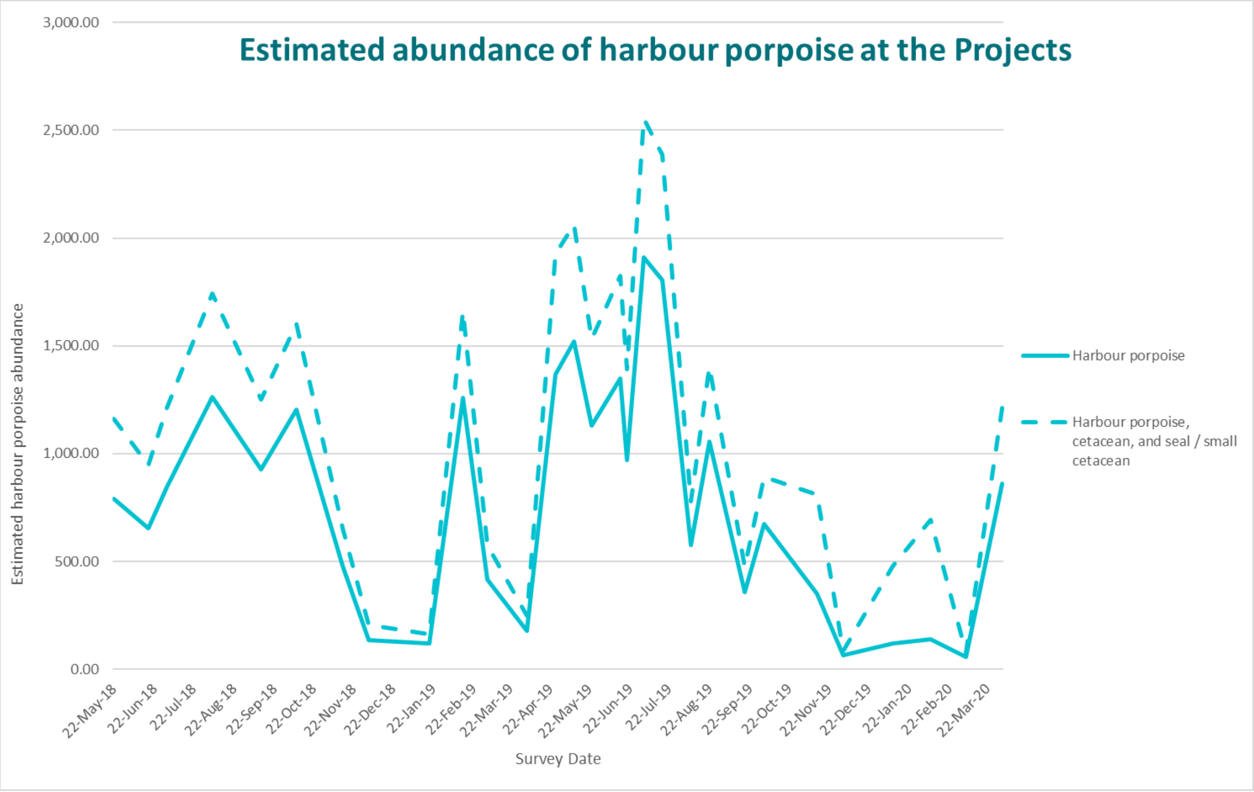
79. The average of the winter months, summer months, and annual density has then been calculated based on the maximum calculated for each month. **Table 12-14** shows the densities for harbour porpoise, based on all individuals that have the potential to be harbour porpoise.

Table 12-14: Maximum harbour porpoise summer, winter and annual density estimate for DEP and SEP survey areas plus 4km buffer

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

80. In addition to the density estimates, abundance estimates of harbour porpoise at DEP and SEP 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 12-1**).

Plate 12-1: Estimated abundance of harbour porpoise within whole survey area, corrected for availability bias



81. The distribution of harbour porpoise within DEP and SEP varied, with individuals present across the survey area (both DEP and SEP, 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.

82. The Inter-Agency Marine Mammal Working Group (IAMMWG, 2015) defined three MUs for harbour porpoise: North Sea (NS); West Scotland (WS); and the Celtic and Irish Sea (CIS). DEP and SEP including the export cable routes are located in the North Sea MU.

83. The SCANS-III estimate of harbour porpoise abundance in the North Sea MU is 345,373 (CV = 0.18; 95%; CI = 246,526-495,752) with a density estimate of 0.52/km^2 (CV = 0.18; Hammond *et al.,* 2017).

84. The reference population for harbour porpoise to be used in the assessments is the North Sea MU, which, based on the latest SCANS-III survey has an estimated abundance of 345,373 harbour porpoise (Hammond *et al*., 2017).

12.5.2 Bottlenose Dolphin

85. 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.

86. 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.

87. 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 southern North Sea (and near to both DEP and SEP) 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).

88. The SCANS-III survey shows a similar distribution pattern, with no bottlenose dolphin identified within the southern North Sea (including survey block O, in which DEP and SEP sites including export cable areas are located), with higher densities in survey block R off the east coast of Scotland (Hammond *et al.*, 2017).

89. For bottlenose dolphin, the distribution maps (developed by Waggitt *et al.,* 2020) 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.,* 2020). Examination of this data, including all 10km grids that overlap with DEP, SEP and export cable areas, indicates an average annual density estimate of:

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

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

91. 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.

92. 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 0.0016/km^2 (CV = 0.24; 95% CI = 11,404-29,670; Hammond *et al.*, 2017).

93. There is currently no density estimate for bottlenose dolphin in and around DEP or SEP, therefore, the number of bottlenose dolphins that could be impacted has been based on the SCANS-III density estimates for the adjacent survey block R, as there is no estimate for survey block O in which DEP, SEP and the export cable areas are located.

94. The impact assessments for bottlenose dolphin, are based on the SCANS-III survey data for survey block R (Hammond *et al.*, 2017):

- Abundance = 1,924 bottlenose dolphin (CV=0.86; 95% CI=0-5,048); and
- Density = 0.03 bottlenose dolphin/km^2 (CV=0.86; 95%).

95. As there is currently no reference population estimate for bottlenose dolphin for the Greater North Sea MU (IAMMWG, 2015), in which DEP and SEP including the export cable areas are located, the reference population for survey block R of 1,924 bottlenose dolphin is used in the assessments. In addition, the assessments are put into the context of the Coastal East Scotland (CES) MU; with a population estimate for the bottlenose dolphin of 195 (95% CI = 162 -253; IAMMWG, 2015).

12.5.3 White-beaked Dolphin

96. 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 southern North Sea (and near to both DEP and SEP) 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).

97. The SCANS-III surveys show a similar distribution pattern, with no white-beaked dolphin identified within the southern North Sea survey block L, and low but increasing densities with the more northerly North Sea survey blocks (O and R) (Hammond *et al.*, 2017).

98. For white-beaked dolphin, the distribution maps (developed by Waggitt *et al.,* 2020) 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*., 2020). Examination of this data, including all 10km grids that overlap with DEP, SEP and export cable areas, indicates an average annual density estimate of:

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

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

100. 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 0.030/km^2 (CV = 0.29; 95% CI = 18,694-61,869; Hammond *et al.*, 2017). DEP and SEP are located in SCANS-III survey block O (Hammond *et al*., 2017) and is within the Celtic and Greater North Seas (CGNS) MU:

- Abundance = 143 white-beaked dolphin (CV=0.2997; 95% CI= 0-490); and
- Density = 0.002 white-beaked dolphin/km^2 (CV=0.97; 95% CI= 0-490).

101. 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.* (2020), with a density estimate of 0.006 individuals per km^2 for DEP and SEP, including export corridor areas.

102. There is a single MU for white-beaked dolphin, the CGNS MU. The reference population for white-beaked dolphin in the CGNS MU is 15,895 animals (CV=0.29; 95% CI=9,107-27,743; IAMMWG, 2015).

12.5.4 Minke Whale

103. 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 southern North Sea (97.5% CI 0-0.02 – 0.08 per km^2), below the Humber Estuary and Flamborough Head.

104. For minke whale, the distribution maps (developed by Waggitt *et al.,* 2020) 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*., 2020). Examination of this data, including all 10km grids that overlap with DEP and SEP, including export corridor areas, indicates an average annual density estimate of:

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

105. During the DEP and SEP 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.

106. For the entire SCANS-III survey area, minke whale abundance in the summer of 2016 was estimated to be 14,759 with an overall estimated density of 0.0008/km^2 (CV = 0.327; 95% CI = 7,908-27,544; Hammond *et al.*, 2017).

107. Within the impact assessments for minke whale, density estimates from the SCANS-III surveys are used. DEP and SEP including export cable area are located in SCANS-III survey block O and the CGNS MU (Hammond *et al*., 2017):

- Abundance = 603 minke whale (CV=0.2962; 95% CI=109-1,670); and
- Density = 0.01 minke whale/km^2 (CV=0.62; 95% CI=109-1,670).

108. There is single MU for minke whale, the CGNS MU. The reference population for minke whales in the CGNS MU is 23,528 animals (CV = 0.27; 95% CI = 13,989-39,572; IAMMWG, 2015).

12.5.5 Grey Seal

109. There is a considerable amount of movement of grey seals that occurs (as observed from telemetry data; see **Appendix 12.1**) 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, 2019).

110. 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, 2019).

111. DEP and SEP are located approximately 24.8km and 13.6km offshore (at the closest point), respectively. Principal grey seal haul-out sites are included in **Table 12-15**, which shows the approximate distance to the closest point of DEP and SEP, and the most recent grey seal count for each location.

Table 12-15: The most recent grey seal count at each of the nearby haul-out sites, and the distance to DEP and SEP

Haul-out site	Distance to DEP and SEP	Grey seal count
Blakeney Point National Nature Reserve (NNR)	12km from landfall 12km from export cable corridor 38km from DEP 22km from SEP	360 (2018 grey seal count; SCOS, 2019)
Horsey Corner	44km from landfall 44km from the export cable corridor 50km from DEP 50km from SEP	1,698 adults recorded at any one time; 2,069 pups born over the 2018-2019 season (Friends of Horsey Seals, 2019)
The Wash	58km from landfall 58km from export cable corridor 75km from DEP 57km from SEP	253 (2018 grey seal count; SCOS, 2019)
Scroby Sands	59km from landfall 58km from the export cable corridor	497 (2018 grey seal count; SCOS, 2019)

Haul-out site	Distance to DEP and SEP	Grey seal count
	64km from DEP 64km from SEP	
Donna Nook	87km from landfall 86km from export cable corridor 68km from DEP 66km from SEP	6,288 (2018 grey seal count; SCOS, 2019)

112. A relatively low number of grey seal were recorded during the site-specific aerial surveys for DEP and SEP 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.

113. 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.

114. Due to the low number of grey seal sightings, absolute density and abundance estimates were not possible to derive. However, relative density and abundance estimates were calculated (see **Appendix 12.1**). These have been provided in order to provide site-specific information on the number of grey seal expected to be present at DEP and SEP, however, impact assessments will be based on absolute densities as derived from desk-based sources.

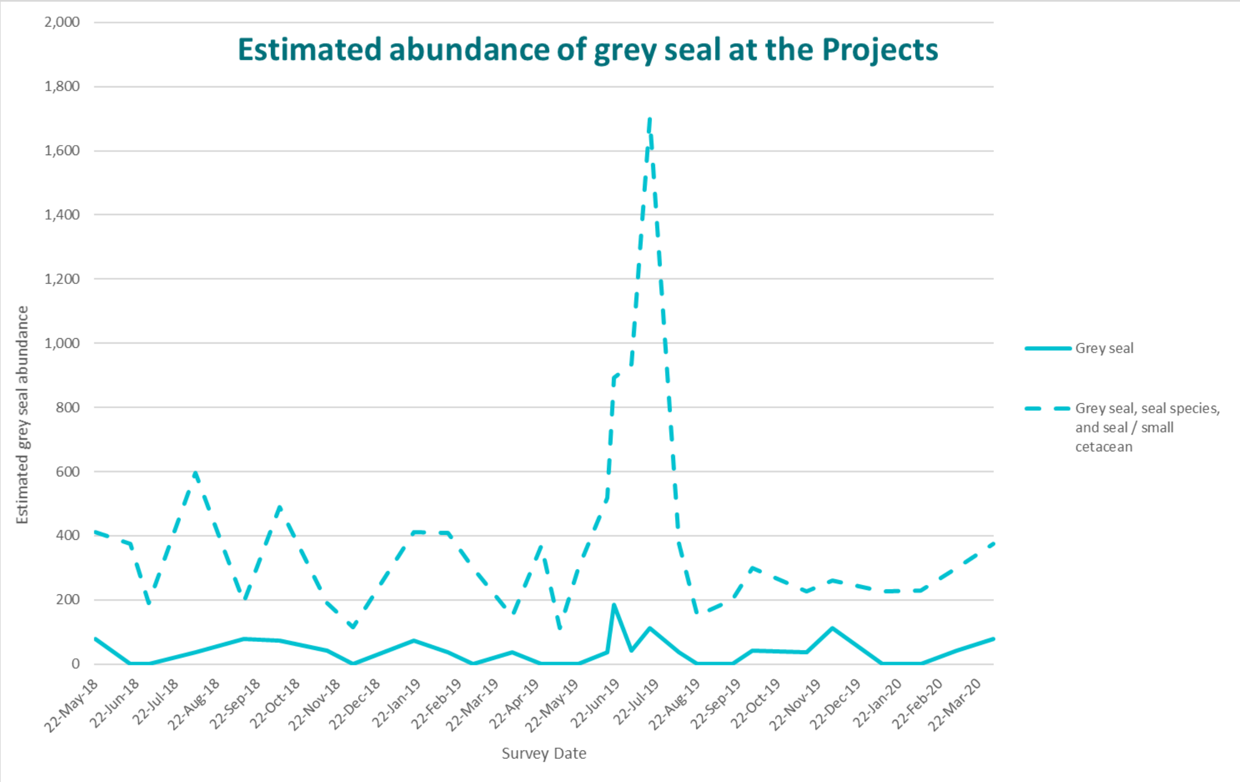
115. The average of the annual density has then been calculated based on the maximum calculated for each month. **Table 12-16** shows the densities based all individuals that have the potential to be grey seal.

Table 12-16: Maximum grey seal relative density estimates for DEP and SEP survey areas plus 4km buffer

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

116. In addition to the density estimates, abundance estimates of grey seal at DEP and SEP have been derived. These relative abundance estimates (**Plate 12-2**) 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 12-2: Estimated abundance of grey seal within the survey area, corrected for availability bias



117. The latest seal at sea maps (Russell *et al.,* 2017) by SMRU are 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 mean seal usage (seals per 5km x 5km grid cell) around the UK coastline).

118. The grey seal density estimates for DEP and SEP have been calculated from the seal at sea usage amps (Russell *et al.,* 2017) based on the 5km x 5km grids that overlap with DEP and SEP, including the export cable areas (**Figure 12.1**). The upper at-sea density estimates for these areas have been used in the assessments, as the worst-case:

- 0.09 individuals per km^2 for DEP;
- 0.47 individuals per km^2 for SEP; and
- 0.35 individuals per km^2 for DEP, SEP and export cable areas.

119. 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, 2019) and the Waddenzee population (Brauseur *et al.*, 2020), to take into account the wide ranging movement of grey seal as indicated by tagging studies (see **Appendix 12.1**).

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

- South-east England MU = 8,199 grey seal (SCOS, 2019);

- North-east England MU = 6,502 grey seal (SCOS, 2019); and
- Waddenzee population = 9,375 grey seal (adults and pups; Brauseur *et al.*, 2020).

121. The total reference population for the assessment is 24,076 grey seal.

122. 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.

12.5.6 Harbour Seal

123. DEP and SEP are located approximately 24.8km and 13.6km offshore (at the closest point), respectively. Principal harbour seal haul-out sites are included in **Table 12-17**, which shows the approximate distance to the closest point of DEP and SEP, and the most recent harbour seal count for each location.

Table 12-17: The most recent harbour seal count at each of the nearby haul-out sites, and the distance to DEP and SEP

Haul-out site	Distance to DEP and SEP	Harbour seal count
Blakeney Point NNR	12km from landfall 12km from export cable corridor 38km from DEP 22km from SEP	218 (2018 harbour seal count; SCOS, 2019)
The Wash	58km from landfall 58km from export cable corridor 75km from DEP 57km from SEP	3,632 (2018 harbour seal count; SCOS, 2019)
Scroby Sands	59km from landfall 58km from the export cable corridor 64km from DEP 64km from SEP	210 (2018 harbour seal count; SCOS, 2019)
Donna Nook	87km from landfall 86km from export cable corridor 68km from DEP 66km from SEP	146 (2018 harbour seal count; SCOS, 2019)

124. 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 are expected to be harbour seal.

125. 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.

126. Due to the low number of harbour seal sightings, absolute density and abundance estimates were not possible to derive. However, relative density and abundance estimates were calculated. These have been provided in order to provide site-specific information on the number of harbour seal expected to be present at DEP and SEP, however, impact assessments will be based on absolute densities as derived from desk-based sources.

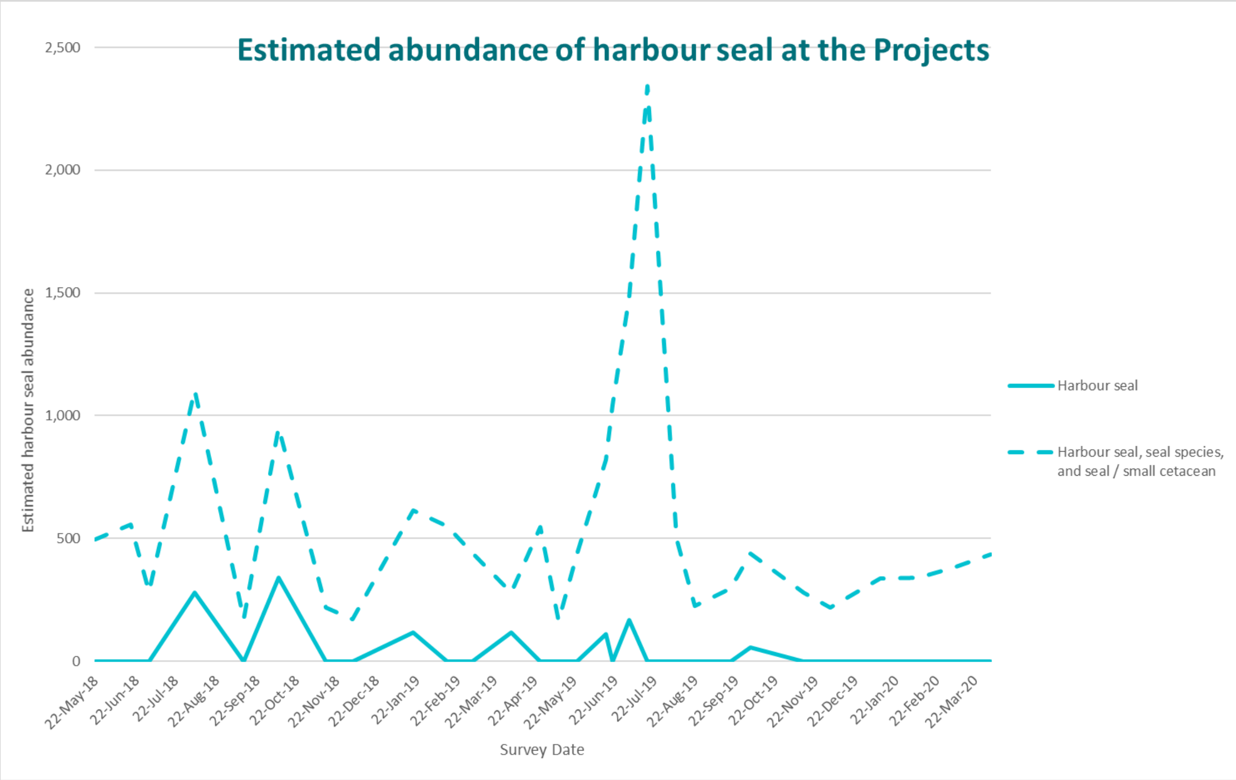
127. The average of the annual density has then been calculated based on the maximum calculated for each month. **Table 12-18** shows the densities for all individuals that have the potential to be harbour seal

Table 12-18: Maximum harbour seal relative density estimates for DEP and SEP survey areas plus 4km buffer

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

128. In addition to the density estimates as described above, abundance estimates of harbour seal at DEP and SEP have been derived. These abundance estimates (**Plate 12-3**) indicate increased sightings in the summer periods, with a peak in sightings in July 2019.

Plate 12-3: Estimated abundance of harbour seal at DEP and SEP, corrected for availability bias



129. The harbour seal density estimates for DEP and SEP have been calculated from the latest seal at sea maps produced by SMRU (Russell *et al.,* 2017), based on the 5km x 5km grids that overlap with each project area (**Figure 11.2**). The upper at-sea density estimates for these areas have been used in the assessment, as the worst-case:

- 0.24 individuals per km^2 for DEP;
- 0.21 individuals per km^2 for SEP;
- 0.19 individuals per km^2 for SEP, DEP, and export cable areas.

130. 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, 2019) and the Waddenzee population (Galatius *et al.,* 2020).

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

- South-east England MU = 4,961 harbour seal (SCOS, 2019); and
- Waddenzee population = 41,700 harbour seal (adults and pups; Galatius *et al.,* 2020).

132. The total reference population for the assessment is 46,661 harbour seal.

133. 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.

12.5.7 Summary of Marine Mammal Densities and Reference Populations for Assessments

134. **Table 12-19** and **Table 12-20** provide a summary of the reference populations and the density estimates for the marine mammal species used in the impact assessment.

135. 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 12-10** for definitions of magnitude).

Table 12-19: Summary of marine mammal reference populations used in the impact assessments

Species	Reference population extent	Year of estimate	Population	Source
Harbour porpoise	North Sea MU (NS MU)	2016	345,373 (CV = 0.18; 95% CI = 246,526-495,752)	SCANS-III (Hammond *et al.,* 2017)
Bottlenose dolphin	Abundance in SCANS-III survey block R	2016	1,924 (CV=0.86; 95% CI=0-5,048)	SCANS-III (Hammond *et al.,* 2017)
	Coastal East Scotland (CES MU)	2016	195 (95% CI = 162 -253)	IAMMWG (2015)
White-beaked dolphin	Celtic and Greater North Seas (CGNS MU)	2016	15,895 (CV=0.29; 95% CI=9,107-27,743)	IAMMWG (2015)
Minke whale	Celtic and Greater North Seas (CGNS MU)	2016	23,528	IAMMWG (2015)

Species	Reference population extent	Year of estimate	Population	Source
			(CV = 0.27; 95% CI = 13,989-39,572)	
Grey seal	South-east England MU; North-east England MU; Wadden Sea population (Ref Pop)	2018; 2018; 2020	8,199 + 6,502 + 9,375 = 24,076	SCOS (2019) Brauseur *et al.* (2020)
	South-east England MU (SE MU)	2016	8,199	SCOS (2019)
Harbour seal	South-east England MU; Wadden Sea population (Ref Pop)	2016; 2017	4,961 + 41,700 = 46,661	SCOS (2019) Galatius *et al.* (2020)
	South-east England MU (SE MU)	2016	4,961	SCOS (2019)

Table 12-20: 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	DEP, SEP and export cable areas	Average winter: 0.65 Average summer: 1.46 Average annual: 1.05	Site specific survey

Species	Area of density estimate	Density estimate (individuals per km^2)	Source
	DEP	Average winter: 0.85 Average summer: 2.43 Average annual: 1.64	Site specific survey
	SEP	Average winter: 0.52 Average summer: 0.63 Average annual: 0.57	Site specific survey
	SCANS-III Block O	0.888	Hammond *et al*. (2017)
Bottlenose dolphin	SCANS-III Block R	0.03	Hammond *et al*. (2017)
White-beaked dolphin	DEP, SEP and export cable areas	0.006	Waggitt *et al.* (2020)
Minke whale	SCANS-III Block O	0.01	Hammond *et al*. (2017)
Grey seal	DEP, SEP and export cable areas	0.35	Russell *et al.* (2017)
	DEP	0.09	
	SEP	0.47	
Harbour seal	DEP, SEP and export cable areas	0.19	Russell *et al.* (2017)
	DEP	0.24	
	SEP	0.21	

12.5.8 Climate Change and Natural Trends

136. The existing baseline conditions for marine mammals are considered to be relatively stable. The baseline environment of the Southern North Sea has been influenced by the oil and gas industry since the 1960s, fishing by various methods for hundreds of years and the construction and operation of offshore 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.

137. 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)

138. 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*., 2017). 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 southern North Sea. 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).

139. 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*., 2017), 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).

140. As outlined in **Section 12.5.2**, 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.

141. 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.

142. Currently there is limited information on the natural trends for minke whale in the North Sea and the potential effects of climate change. 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 the reproductive success of humpback whales 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).

143. There has been a continual increase in the total UK grey seal pup production since regular surveys began in the 1960s (SCOS, 2019). Grey seal pup production at colonies in the North Sea increased rapidly up to 2016, with an annual increase of 8% per year from 2014 to 2016, slightly lower than the 10.8% growth between 2012 and 2014 and the 12% increase between 2010 and 2012 (SCOS, 2019). 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, 2019).

144. 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, 2019). However, there are significant differences in the population dynamics between regions with general declines in counts of harbour seals in several regions around Scotland. However, the declines are not universal with some populations either stable or increasing (SCOS, 2019). Populations along the English East coast, from Kent to the Scottish border have generally increased year on year, with those increases punctuated by major declines associated with two major Phocine Distemper Virus (PDV) epidemics in 1988 and 2002. Recent trends, i.e. those that incorporate the last 10 years (2006 to 2016) show significant growth in both English seal MUs, but now show clear signs of levelling off (SCOS, 2019). The adjacent European colonies in the Wadden Sea experienced continuous rapid growth after the epidemic, but again, the counts over the last 5 years suggest that the rate of increase has slowed dramatically (SCOS, 2019).

145. 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 DEP and SEP. However, the latest changes in population distribution and abundance have been taken into account in the assessments that has been undertaken.

12.6 Potential Impacts

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

147. Prior to construction, MMMPs 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 12.3.4.1**). A combined draft MMMP will be submitted with the DCO application for both UXO clearance and piling, however, two separate MMMPs, one for piling and one for UXO clearance will be prepared in-consultation with the relevant SNCBs, during the pre-construction period.

12.6.1 Potential Impacts during Construction

148. 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 is also considered.

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

- Physical injury, auditory injury and disturbance impacts resulting from the underwater noise associated with clearance of UXO;
- Auditory injury and disturbance or behavioural impacts resulting from underwater noise during piling;
- Disturbance impacts resulting from underwater noise during other construction activities, including seabed preparations, rock placement and cable installation;
- Barrier effects as a result of underwater noise;
- Impacts resulting from the deployment of construction vessels:
    - Underwater noise and disturbance from construction vessels;
    - Vessel interaction (collision risk); and
- Disturbance at seal haul-out sites;
- Changes to prey resource; and
- Changes to water quality.

150. The realistic worst case scenario on which the assessments are based for marine mammal species is outlined in **Table 12-2**.

12.6.1.1 Impact 1: Auditory Injury from Underwater Noise Associated with UXO Clearance

151. It is important to note, the assessments for UXO clearance are for information only, but are not part of DCO application. A separate Marine Licence (ML) application will be submitted, when a detailed UXO survey will be completed prior to construction and a detailed assessment can be conducted based on the latest available information prior to construction.

152. Prior to construction, there is the potential for UXO clearance to be required. While any identified UXO will either be avoided or removed and disposed of onshore in a designated place, there is the potential that underwater detonation could be required where it is necessary and unsafe to remove the UXO.

153. A detailed UXO survey will be completed prior to construction. Therefore, the number of possible detonations and duration of UXO clearance operations that could be required are currently unknown.

154. For the assessment, a conservative estimate has been made, based on the best available information from other offshore wind farm UXO clearance operations nearby, and other published information. It is not currently known the size or type of the UXO that could be present, therefore a range of charge sizes has been assessed, with the maximum charge weight of up to 525kg.

155. At the existing Sheringham Shoal Offshore Wind Farm, just one UXO was found, out of a potential 52 targets investigated, that was required to be cleared prior to construction; a German air dropped bomb of 250lbs (113.4kg) (Scira Offshore Energy, 2010). For Dudgeon Offshore Wind Farm, a total of 243 targets were identified as potential UXO targets for further investigation. Of those, 20 were identified were identified as UXO requiring clearance, in addition to three partial UXO that would also require clearance. The UXO cleared at Dudgeon Offshore Wind Farm included one 2,000lb (907.2kg), three 1,000lb (453.6kg), six 500lb (226.8kg), and two 250lb (113.4kg) German air dropped bombs, seven 6 inch projectiles (of 45kg), one Mk17 mine, and two mine sinkers (Statoil, 2015). At Hornsea Project Two, similar UXO to those found at Dudgeon were identified, with a total of 38 UXO were confirmed within project area, ranging from 2,000lb (907.2kg), 1,000lb (453.6kg), 500lb (226.8kg), and 50kg air-delivered bombs, Mk17 mines, 12 inch projectiles, and German land mines (Orsted, 2019).

156. When an item of UXO detonates on the seabed underwater, several effects are generated, most of which are localised at the point of detonation, such as crater formation and movement of sediment and dispersal of nutrients and contaminants. After detonation, there is the rapid expansion of gaseous products known as the “bubble pulse”. Once it reaches the surface, the energy of the bubble is dissipated in a plume of water and the detonation shock front rapidly attenuates at the water/air boundary. Fragmentation (that is shrapnel from the weapon casing and surrounding seabed materials) is also ejected but does not pose a significant hazard beyond 10m from source.

157. The potential effects of underwater explosions on marine mammals include: (i) physical injury from direct or indirect blast wave effect of the high amplitude shock waves and sound wave produced by underwater detonation, which could result in immediate or eventual mortality; (ii) auditory impairment (from exposure to the acoustic wave), resulting in a temporary or permanent loss in hearing sensitivity such as temporary threshold shift (TTS) or permanent threshold shift (PTS); or (iii) behavioural change, such as disturbance to feeding, mating, breeding, and resting (Richardson *et al.,* 1995; Ketten, 2004; von Benda-Beckmann *et al.,* 2015).

158. The severity of the consequences of UXO detonation will depend on many variables, but principally, on the charge weight and its proximity to the receptor. After detonation, the shock wave will expand spherically outwards and will travel in a straight line (i.e. line of sight), unless the wave is reflected, channelled or meets an intervening obstruction.

159. There are limited acoustic measurements for underwater explosions, and there can be large differences in the noise levels, depending on the charge size, as well as water depth, bathymetry and seabed sediments at the site, which can also influence noise propagation. The water depth in which the explosion occurs has a significant influence on the effect range for a given charge mass (von Benda-Beckmann *et al.,* 2015).

160. It is important to note that assessments are based on the worst-case for high-order UXO detonations with no mitigation, which is highly unlikely, as the preferred and first option for any UXO requiring detonation would be a low-order method. Or if high-order detonation was required, then a bubble curtain would be used.

12.6.1.1.1 Sensitivity of Marine Mammals

161. In this assessment, all species of marine mammal are considered to have high sensitivity to UXO detonations if they are within the potential impact ranges for physical injury or permanent auditory injury (PTS). Marine mammals within the potential impact area are considered to have very limited capacity to avoid such effects, and unable to recover from physical injury or auditory injury.

162. The sensitivity of marine mammals to TTS onset and flee response / likely disturbance as a result of underwater UXO detonations is considered to be medium in this assessment as a precautionary approach. This is for animals within the potential TTS onset and flee response / likely disturbance range, but beyond the potential impact range for permanent auditory injury. Marine mammals within the potential impact area are considered to have limited capacity to avoid such effects, although any impacts on marine mammals would be temporary and they would be expected to return to the area once the activity had ceased.

12.6.1.1.2 Underwater Noise Modelling

163. A number of UXOs with a range of charge weights could be located within DEP and / or SEP. There is expected to be a variety of explosive types, which will have been subject to degradation and burying over time. Two otherwise identical explosive devices are therefore likely to produce different blasts where one has been submitted to different environmental factors.

164. A selection of explosive sizes has been considered in the estimation of the underwater noise levels produced by detonation of UXO. The assessment assumes the maximum explosive charge.

165. The noise produced by the detonation of explosives is affected by a number of different elements (e.g. its design, composition, age, position, orientation, whether it is covered by sediment) which are unknown and cannot be directly considered in an assessment. This leads to a high degree of uncertainty in the estimation of the source noise level (i.e. the noise level at the position of the UXO). A worst-case estimation has therefore been used for calculations, assuming that the UXO to be detonated is not buried, degraded or subject to any other significant attenuation. The consequence of this is that the noise levels produced, particularly by the larger explosives under consideration, are likely to be over-estimated as they are likely to be covered by sediment and degraded.

166. The assessment also does not take into account the variation in the noise level at different depths. Where animals are swimming near the surface, the acoustics at the surface cause the noise level, and hence the exposure, to be lower at this position. The risk to animals near the surface may therefore be lower than indicated by the range estimate and therefore this can be considered conservative in respect of impact at different depths.

167. The potential impact has been assessed based on the latest Southall *et al*. (2019) thresholds and criteria for marine mammals that could be present in the area. The thresholds indicate the onset of PTS, the point at which there is an increase in risk of permanent hearing damage in an underwater receptor (although not all individuals within the maximum PTS range will have permanent hearing damage, this is assumed as a worst case scenario).

168. The Sound Exposure Level (SEL) criteria are weighted, which takes into account 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 hearing sensitivity into account.

169. Both SPL_{peak} and SEL values based on the impulsive and non-impulsive criteria are included in the assessments. However, 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 1 μPa and all SEL values are referenced to 1 $\mu Pa^2 s$.

170. Peak noise levels are difficult to predict accurately in a shallow water environment (von Benda Beckmann *et al.,* 2015) and would tend to be significantly over-estimated by the modelling over increased distances from the source. With increased distance from the source, impulsive noise, such as UXO detonation, noise becomes more of a non-impulsive noise, unfortunately it is currently difficult to determine the distance at which an impulsive noise becomes more like a non-impulsive noise. Therefore, modelling was conducted using both the impulsive and non-impulsive criteria for PTS weighted SEL to give an indication of the difference between maximum potential impact ranges.

171. Impulsive noise sources are described as having a rapid rise time, short duration and high peak pressure. A study into the distance at which underwater noise sources (from offshore windfarm piling and seismic surveys) 'transformed' from an impulsive to a non-impulsive noise revealed that, at a distance of between 2 and 3km the noise sources no longer contained the characteristics (in particular a high enough peak pressure) to be classed as an impulsive noise (Hastie *et al.*, 2019). However, this study was completed in a shallow water environment, with a relatively flat seabed, and the actual range at which a sound source transforms into a non-impulsive noise is likely to be dependent on a number of environmental variables and other sound source characteristics (Hastie *et al*., 2019).

12.6.1.1.2.1 Methodology

172. The range of equivalent charge weights for the potential UXO devices that could be present within the SEP and DEP site boundaries have been estimated as 25kg, 55kg, 120kg, 240kg and 525kg. **Table 12-21** provides the source level used for the underwater noise modelling (further details on how these were calculated is provided in **Appendix 12.2**).

173. The underwater noise modelling has been based on the worst-case scenario for high-order detonation with no mitigation.

Table 12-21: Source levels used for UXO modelling

Charge weight	25kg	55kg	120kg	240kg	525kg
SPL_{peak} source level (dB re 1 µPa @ 1m)	284.9	287.4	290.0	292.2	294.8
SEL_{ss} source level (dB re 1 µPa^{2}s @ 1m)	227.9	230.1	232.3	234.2	236.4

12.6.1.1.2.2 Results

174. The results of the underwater noise modelling for range of potential charge weights are presented in **Table 12-22** and **Table 12-23**, for PTS and TTS / fleeing response, respectively. The potential impact has been assessed based on the latest Southall *et al*. (2019) thresholds and criteria. The impact ranges (and areas) are used to inform the impact assessments.

Table 12-22: Potential maximum impact ranges (and areas) of permanent auditory injury (PTS) for marine mammals during UXO clearance without mitigation (the maximum potential impact range and area for each species are shown in bold)

Potential maximum charge weight	Maximum predicted impact range (km) (and area (km^2))		
	PTS SPL_{peak} Unweighted [Impulsive criteria]	PTS SEL Weighted [Impulsive criteria]	PTS SEL Weighted [Non-impulsive criteria]
Harbour porpoise			
Threshold	**202 dB re 1 µPa**	**155 dB re 1 µPa^{2}s**	**173 dB re 1 µPa^{2}s**

Potential maximum charge weight	Maximum predicted impact range (km) (and area (km²))		
	PTS SPL_{peak} Unweighted [Impulsive criteria]	PTS SEL Weighted [Impulsive criteria]	PTS SEL Weighted [Non-impulsive criteria]
25kg	4.6km (66.48km²)	0.56km (0.99km²)	0.05km (0.008km²)
55kg	6.0km (113.10km²)	0.74km (1.72km²)	0.05km (0.008km²)
120kg	7.7km (186.27km²)	0.95km (2.84km²)	0.07km (0.02km²)
240kg	9.8km (301.72km²)	1.1km (3.80km²)	0.1km (0.03km²)
525kg	**13.0km (530.93km²)**	1.4km (6.16km²)	0.13km (0.05km²)
Bottlenose dolphin and white-beaked dolphin			
Threshold	**230 dB re 1 μPa**	**185 dB re 1 μPa²s**	**198 dB re 1 μPa²s**
25kg	0.26km (0.21km²)	0.05km (0.008km²)	0.05km (0.008km²)
55kg	0.34km (0.36km²)	0.05km (0.008km²)	0.05km (0.008km²)
120kg	0.45km (0.64km²)	0.05km (0.008km²)	0.05km (0.008km²)
240kg	0.56km (0.99km²)	0.05km (0.008km²)	0.05km (0.008km²)
525kg	**0.73km (1.67km²)**	0.05km (0.008km²)	0.05km (0.008km²)
Minke whale			
Threshold	**219 dB re 1 μPa**	**183 dB re 1 μPa²s**	**199 dB re 1 μPa²s**
25kg	0.81km (2.06km²)	2.1km (13.85km²)	0.12km (0.05km²)
55kg	1.0km (3.14km²)	3.2km (32.17km²)	0.19km (0.11km²)
120kg	1.3km (5.31km²)	4.6km (66.48km²)	0.28km (0.25km²)
240kg	1.7km (9.08km²)	6.5km (132.73km²)	0.39km (0.48km²)
525kg	2.2km (15.21km²)	**9.5km (283.53km²)**	0.57km (1.02km²)
Grey seal and harbor seal			
Threshold	**218 dB re 1 μPa**	**185 dB re 1 μPa²s**	**201 dB re 1 μPa²s**
25kg	0.9km (2.55km²)	0.38km (0.45km²)	0.05km (0.008km²)
55kg	1.1km (3.80km²)	0.56km (0.99km²)	0.05km (0.008km²)

Potential maximum charge weight	Maximum predicted impact range (km) (and area (km^2))		
	PTS SPL$_{peak}$ Unweighted [Impulsive criteria]	PTS SEL Weighted [Impulsive criteria]	PTS SEL Weighted [Non-impulsive criteria]
120kg	1.5km (7.07km^2)	0.83km (2.16km^2)	0.05km (0.008km^2)
240kg	1.9km (11.34km^2)	1.1km (3.80km^2)	0.07km (0.015km^2)
525kg	**2.5km (19.64km^2)**	1.6km (8.04km^2)	0.1km (0.03km^2)

Table 12-23: Potential maximum impact ranges (and areas) of temporary auditory injury (TTS) / fleeing response for marine mammals during UXO clearance without mitigation (the maximum potential impact range and area for each species are shown in bold)

Potential maximum charge weight	Maximum predicted impact range (km) (and area (km^2))		
	TTS SPL$_{peak}$ Unweighted [Impulsive criteria]	TTS SEL Weighted [Impulsive criteria]	TTS SEL Weighted [Non-impulsive criteria]
Harbour porpoise			
Threshold	**196 dB re 1 μPa**	**140 dB re 1 μPa^{2}s**	**153 dB re 1 μPa^{2}s**
25kg	8.5km (226.98km^2)	2.4km (18.10km^2)	0.73km (1.67km^2)
55kg	11km (380.13km^2)	2.8km (24.63km^2)	0.94km (km^2)
120kg	14km (615.75km^2)	3.2km (32.17km^2)	1.1km (3.80km^2)
240kg	18km (1,017.88km^2)	3.5km (38.48km^2)	1.4km (6.16km^2)
525kg	**23km (1,661.90km^2)**	4km (50.27km^2)	1.7km (9.08km^2)
Bottlenose dolphin and white-beaked dolphin			
Threshold	**224 dB re 1 μPa**	**170 dB re 1 μPa^{2}s**	**178 dB re 1 μPa^{2}s**
25kg	0.49km (0.75km^2)	0.15km (0.07km^2)	0.05km (0.008km^2)

Potential maximum charge weight	Maximum predicted impact range (km) (and area (km²))		
	TTS SPL_{peak} Unweighted [Impulsive criteria]	TTS SEL Weighted [Impulsive criteria]	TTS SEL Weighted [Non-impulsive criteria]
55kg	0.64km (1.29km²)	0.21km (0.14km²)	0.06km (0.01km²)
120kg	0.83km (2.16km²)	0.3km (0.28km²)	0.08km (0.02km²)
240kg	1km (3.14km²)	0.39km (0.48km²)	0.11km (0.04km²)
525kg	**1.3km (5.31km²)**	0.53km (0.88km²)	0.16km (0.08km²)
Minke whale			
Threshold	**213 dB re 1 μPa**	**168 dB re 1 μPa²s**	**179 dB re 1 μPa²s**
25kg	1.5km (7.07km²)	29km (2,642.08km²)	4.4km (60.82km²)
55kg	1.9km (11.34km²)	41km (5,281.02km²)	6.4km (128.68km²)
120kg	2.5km (19.63km²)	57km (10,207.03km²)	9.3km (271.72km²)
240kg	3.2km (32.17km²)	76km (18,145.84km²)	13km (530.93km²)
525kg	4.1km (52.81km²)	**103km (33,329.16km²)**	19km (1,134.11km²)
Grey seal and harbor seal			
Threshold	**212 dB re 1 μPa**	**170 dB re 1 μPa²s**	**181 dB re 1 μPa²s**
25kg	1.6km (8.04km²)	5.2km (84.95km²)	0.78km (1.91km²)
55kg	2.1km (13.85km²)	7.4km (172.03km²)	1.1km (3.80km²)
120kg	2.8km (24.63km²)	11km (380.13km²)	1.6km (8.04km²)

Potential maximum charge weight	Maximum predicted impact range (km) (and area (km²))		
	TTS SPL_{peak} Unweighted [Impulsive criteria]	TTS SEL Weighted [Impulsive criteria]	TTS SEL Weighted [Non-impulsive criteria]
240kg	3.5km (38.48km²)	14km (615.75km²)	2.3km (16.62km²)
525kg	4.6km (66.48km²)	**20km (1,256.64km²)**	3.3km (34.21km²)

12.6.1.1.3 Magnitude for DEP or SEP in Isolation

12.6.1.1.3.1 Permanent Auditory Injury (PTS)

175. The number of harbour porpoise, white-beaked dolphin, minke whale, bottlenose dolphin, grey seal and harbour seal that could potentially be impacted by a high-order UXO detonation without any mitigation has been estimated for DEP and SEP (i.e. where there are separate density estimates available for DEP and SEP), based on the maximum potential PTS impact ranges per UXO detonation (**Table 12-24**). Note that the impact ranges (and therefore areas) are the same for UXO detonations, where UXO clearance takes place in DEP or SEP. The impact assessments are based on the worst-case impact range (and area) modelled for each species for a 525kg UXO.

176. The resulting magnitude is assessed to be medium for harbour porpoise, and minke whale, low for bottlenose dolphin, negligible for white-beaked dolphin, at both DEP and SEP. Grey seal has a magnitude of low at DEP and medium at SEP, due to the difference in density estimate for the species between the sites, and harbour seal have a magnitude of medium at DEP and low at SEP, again, due to the difference in density estimates (**Table 12-24**).

Table 12-24: Maximum number of marine mammals potentially at risk of PTS onset, based on the maximum impact ranges for 525kg UXO

Species	Maximum impact range (and area)	Maximum number of individuals	% of reference population	Magnitude (permanent impact)
DEP				
Harbour porpoise	13.0km (530.93km²)	870.73 (DEP density of 01.64/km²) 471.47 (SCANS-III density of 0.888/km²)	0.25% 0.14%	**Medium**

Species	Maximum impact range (and area)	Maximum number of individuals	% of reference population	Magnitude (permanent impact)
Bottlenose dolphin	0.73km (1.67km^2)	0.05 (SCANS-III density of 0.03/km^2)	0.003% (0.03% of CES MU)	**Low (medium)**
White-beaked dolphin	0.73km (1.67km^2)	0.01 (DEP and SEP density of 0.006/km^2)	0.00006%	**Negligible**
Minke whale	9.5km (283.53km^2)	2.84 (SCANS-III density of 0.01/km^2)	0.01%	**Medium**
Grey seal	2.5km (19.63km^2)	1.8 (DEP density of 0.09/km^2)	0.007% (or 0.02% of SE MU)	**Low (medium)**
Harbour seal	2.5km (19.63km^2)	4.7 (DEP density of 0.24/km^2)	0.01% (or 0.095% of SE MU)	**Medium (medium)**
SEP				
Harbour porpoise	13.0km (530.93km^2)	302.63 (SEP density of 0.57/km^2) 471.47 (SCANS-III density of 0.888/km^2)	0.09% 0.14%	**Medium**
Bottlenose dolphin	0.73km (1.67km^2)	0.05 (SCANS-III density of 0.03/km^2)	0.003% (0.03% of CES MU)	**Low (medium)**
White-beaked dolphin	0.73km (1.67km^2)	0.01 (DEP and SEP density of 0.006/km^2)	0.0001%	**Negligible**
Minke whale	9.5km (283.53km^2)	2.84 (SCANS-III	0.01%	**Medium**

Species	Maximum impact range (and area)	Maximum number of individuals	% of reference population	Magnitude (permanent impact)
		density of 0.01/km^2)		
Grey seal	2.5km (19.63km^2)	9.2 (SEP density of 0.47/km^2)	0.04% (or 0.1% of SE MU)	**Medium (medium)**
Harbour seal	2.5km (19.63km^2)	4.1 (SEP density of 0.21/km^2)	0.009% (or 0.08% of SE MU)	**Low (medium)**

12.6.1.1.3.2 Temporary Auditory Injury (TTS) and Fleeing Response

177. The number of harbour porpoise, white-beaked dolphin, minke whale, bottlenose dolphin, grey seal and harbour seal that could potentially be impacted by a high-order UXO detonation without any mitigation has been estimated for DEP and SEP (i.e. where there are separate density estimates available for DEP and SEP), based on the maximum potential TTS impact ranges per UXO detonation (**Table 12-25**). Note that the impact ranges (and therefore areas) are the same for UXO detonations, where UXO clearance takes place in DEP or SEP. The impact assessments are based on the worst-case impact range (and area) modelled for each species for a 525kg UXO.

178. The resulting magnitude is assessed to be negligible for harbour porpoise, white-beaked dolphin and bottlenose dolphin, low for minke whale at DEP and SEP. Negligible to low for grey seal at DEP, low to medium for grey seal at SEP, negligible to medium for harbour seal at DEP and SEP (**Table 12-25**).

Table 12-25: Maximum number of marine mammals potentially at risk of TTS onset, based on the maximum impact ranges for 525kg UXO

Species	Maximum impact range (and area)	Maximum number of individuals	% of reference population	Magnitude (temporary impact)
DEP				
Harbour porpoise	23.0km (1,661.90km^2)	2,725.52 (DEP density of 1.64/km^2) 1,475.77 (SCANS-III density of 0.888/km^2)	0.79% 0.43%	**Negligible**

Species	Maximum impact range (and area)	Maximum number of individuals	% of reference population	Magnitude (temporary impact)
Bottlenose dolphin	1.3km ($5.31km^2$)	0.16 (SCANS-III density of $0.03/km^2$).	0.008% (0.08% of CES MU)	**Negligible (negligible)**
White-beaked dolphin	1.3km ($5.31km^2$)	0.03 (DEP and SEP site of $0.006/km^2$)	0.0002%	**Negligible**
Minke whale	103km ($33,329.16km^2$)	333.29 (SCANS-III density of $0.01/km^2$)	1.42%	**Low**
Grey seal	20km ($1,256.64km^2$)	113.10 (DEP density of $0.09/km^2$)	0.47% (or 1.38% of SE MU)	**Negligible (low)**
Harbour seal	20km ($1,256.64km^2$)	301.6 (DEP density of $0.24/km^2$)	0.65% (or 6.08% of SE MU)	**Negligible (medium)**
SEP				
Harbour porpoise	23.0km ($1,661.90km^2$)	947.28 (SEP density of $0.57/km^2$) 1,475.77 (SCANS-III density of $0.888/km^2$)	0.27% 0.43%	**Negligible**
Bottlenose dolphin	1.3km ($5.31km^2$)	0.16 (SCANS-III density of $0.03/km^2$)	0.008% (0.08% of CES MU)	**Negligible (negligible)**
White-beaked dolphin	1.3km ($5.31km^2$)	0.03 (DEP and SEP density of $0.006/km^2$)	0.0002%	**Negligible**
Minke whale	103km ($33,329.16km^2$)	333.29 (SCANS-III	1.42%	**Low**

Species	Maximum impact range (and area)	Maximum number of individuals	% of reference population	Magnitude (temporary impact)
		density of 0.01/km^2)		
Grey seal	20km (1,256.64km^2)	590.62 (SEP density of 0.47/km^2)	2.45% (or 7.2% of SE MU)	**Low (medium)**
Harbour seal	20km (1,256.64km^2)	263.89 (SEP density of 0.21/km^2)	0.57% (or 5.32% of SE MU)	**Negligible (medium)**

12.6.1.1.4 Impact Significance

179. Taking into account the high sensitivity for all species to PTS from UXO clearance, the impact significance, for a high-order detonation without mitigation, has been assessed as major adverse for harbour porpoise, moderate adverse for bottlenose dolphin and minor adverse for white-beaked dolphin and minke whale for UXO clearance at either DEP or SEP. The impact significance for grey seal is moderate adverse for UXO clearance at DEP, and major adverse at SEP. Conversely, harbour seal have an impact significance of major adverse at DEP, and moderate adverse at SEP (**Table 12-26**).

180. For TTS, taking into account the medium sensitivity for all species to UXO clearance, the impact significance, for a high-order detonation without mitigation, has been assessed as minor adverse for harbour porpoise, white-beaked dolphin, minke whale and bottlenose dolphin at either DEP or SEP. The impact significance for grey seal is minor adverse for UXO clearance at DEP, and minor to moderate adverse at SEP, and minor to moderate adverse for harbour seal at DEP or SEP (**Table 12-26**).

181. It should be noted that the conclusion of major or moderate adverse (significant) without mitigation for PTS in all species except white-beaked dolphin, is very precautionary, as the assessment is based on the worst case scenario for the largest UXO device that may (or may not) be present within DEP or SEP.

182. Mitigation in the MMMP for UXO clearance would reduce the risk of any physical or permanent auditory injury in marine mammals (**Section 12.3.4.1**) and would also reduce the risk of TTS (**Section 12.3.4**).

12.6.1.1.5 Mitigation

183. As outlined in **Section 12.3.4.1**, a MMMP for UXO clearance will be produced post-consent in consultation with the MMO and relevant SNCBs, and will be based on the latest scientific understanding and guidance, pre-construction UXO surveys at both DEP and SEP, as well as detailed project design. The implementation of the mitigation measures within the UXO MMMP will reduce the risk of any permanent auditory injury (PTS) during any underwater detonation. . The mitigation measure would also reduce the risk of TTS.

184. The proposed mitigation measures for consideration in the MMMP for UXO clearance include, the use of low-order disposal techniques, such as deflagration, the use of bubble curtains and the use of ADDs.

185. The effective implementation of the UXO MMMP will reduce the risk of permanent auditory injury (PTS) to marine mammals during any underwater detonations at DEP or SEP.

186. An EPS licence application, if required, will be submitted post-consent. At this time, pre-construction UXO surveys would have been conducted, and full consideration will have been given to any necessary mitigation measures that may be required following the development of the MMMP for UXO clearance.

12.6.1.1.6 Residual Impact Significance

187. The residual impact of the potential risk of physical injury and permanent or temporary auditory injury (PTS or TTS / fleeing response) to marine mammals as a result of any underwater UXO clearance at either DEP or SEP is reduced to a negligible magnitude, taking into account the proposed mitigation to reduce the potential effects. Therefore, with high sensitivity for any physical injury or permanent auditory injury (PTS) and medium sensitivity for TTS / fleeing response, the potential impact significance for either DEP or SEP is reduced to minor adverse (not significant) (**Table 12-26**).

Table 12-26: Assessment of impact significance at DEP and SEP for UXO clearance

Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigation	Residual Impact Significance
Permanent auditory injury (PTS) during underwater UXO clearance	Harbour porpoise	High	Medium at DEP and SEP	Major adverse at DEP and SEP	MMMP for UXO Clearance	**Minor adverse**
	Bottlenose dolphin	High	Low at DEP and SEP	Moderate adverse at DEP and SEP		**Minor adverse**
	White-beaked dolphin	High	Negligible at DEP and SEP	Minor adverse at DEP and SEP		**Minor adverse**
	Minke whale	High	Medium at DEP and SEP	Major adverse at DEP and SEP		**Minor adverse**
	Grey seal	High	Low at DEP Medium at SEP	Moderate adverse at DEP Major adverse at SEP		**Minor adverse**

Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigation	Residual Impact Significance
	Harbour seal	High	Medium at DEP Low at SEP	Major adverse at DEP Moderate adverse at SEP		**Minor adverse**
Temporary auditory injury (TTS) / fleeing response during underwater UXO clearance	Harbour porpoise	Medium	Negligible at DEP and SEP	Minor adverse at DEP and SEP	MMMP for UXO Clearance	**Minor adverse**
	Bottlenose dolphin	Medium	Negligible at DEP and SEP	Minor adverse at DEP and SEP		**Minor adverse**
	White-beaked dolphin	Medium	Negligible at DEP and SEP	Minor adverse at DEP and SEP		**Minor adverse**
	Minke whale	Medium	Low at DEP and SEP	Minor adverse at DEP and SEP		**Minor adverse**
	Grey seal	Medium	Negligible to low at DEP Low to medium at SEP	Minor adverse at DEP Minor to moderate at SEP		**Minor adverse**
	Harbour seal	Medium	Negligible to medium at DEP and SEP	Minor to moderate at DEP and SEP		**Minor adverse**

12.6.1.1.7 Impact Assessment for DEP and SEP Together

188. The impact for DEP and SEP together would be the same as that presented above for DEP and SEP in isolation, as UXO clearance would be undertaken at one site at a time, i.e. there would be no concurrent UXO clearance between the two sites. Therefore, the impact assessment shown within **Table 12-26**, also provides the impact assessment for UXO clearance at DEP and SEP together.

12.6.1.2 Impact 2: Disturbance from Underwater Noise Associated with UXO Clearance

189. 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.

190. 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 12-23**, with the estimated number and percentage of reference populations in **Section 12.6.1.1.3.2** provide an indication of possible fleeing response.

191. As outlined in Southall *et al.* (2007) the onset of behavioural disturbance is proposed to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e. TTS-onset). Although, as Southall *et al.* (2007) recognise that this is not a behavioural effect per se, exposures to lower noise levels from a single pulse are not expected to cause disturbance. However, any compromise, even temporarily, to hearing functions could have the potential to affect behaviour.

12.6.1.2.1 Magnitude for DEP or SEP in Isolation

192. The SNCBs currently recommend that a potential disturbance range or Effective Deterrence Range (EDR) of 26km (approximate area of 2,124km^2) around UXO detonations is used to assess harbour porpoise disturbance in the Southern North Sea SAC (JNCC *et al*., 2020). DEP and SEP are not located within the Southern North Sea SAC, however, they are located within 26km, and therefore this is approach has been used for the EIA (as well as the HRA) for the assessment of harbour porpoise. As there are currently no agreed thresholds or criteria for modelling the potential disturbance of other marine mammal species from underwater noise.

193. As a precautionary approach the number of harbour porpoise that could potentially be disturbed in a 26km radius of a high-order UXO detonation without mitigation has been estimated for DEP and SEP (i.e. where there are separate density estimates available for DEP and SEP).

194. The resulting magnitude is assessed to be low to negligible for DEP and negligible for SEP (**Table 12-27**).

195. Further assessments in relation to the Southern North Sea SAC are provided in the information for the HRA.

Table 12-27: Estimated number of marine mammals that could potentially be disturbed during UXO clearance and magnitude of effect

Species	Location	Maximum impact area	Maximum number of individuals	% of reference population	Magnitude (temporary impact)
Harbour porpoise	DEP	2,124km^2	3,483.36 (DEP density of 1.64/km^2) 1,886.11 (SCANS-III	1.01%	**Low**

Species	Location	Maximum impact area	Maximum number of individuals	% of reference population	Magnitude (temporary impact)
			density of 0.888/km^2)	0.55%	**Negligible**
Harbour porpoise	SEP	2,124km^2	1,210.68 (SEP density of 0.57/km^2)	0.35%	**Negligible**
			1,886.11 (SCANS-III density of 0.888/km^2)	0.55%	**Negligible**

196. Only one UXO at a time would be detonated during UXO clearance operation, i.e. there would be no simultaneous UXO detonations. Although, potentially more than one UXO detonation could occur in a 24 hour period.

12.6.1.2.2 Impact Significance

197. Taking into account the medium sensitivity for harbour porpoise to disturbance from UXO clearance, the impact significance for a high-order detonation without mitigation, has been assessed as minor adverse for DEP and SEP (**Table 12-28**).

12.6.1.2.3 Mitigation

198. Mitigation techniques such as bubble curtain or low-order deflagration would reduce the potential disturbance impact range (**Section 12.3.4.2**).

12.6.1.2.4 Residual Impact Significance

199. The residual impact of the potential disturbance of harbour porpoise as a result of any underwater UXO clearance at either DEP or SEP will be reduced, taking into account the proposed mitigation, therefore with the potential impact significance is reduced to minor adverse (not significant) (**Table 12-28**).

Table 12-28: Assessment of impact significance for disturbance of harbour porpoise during UXO clearance

Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigation	Residual Impact Significance
Potential disturbance during underwater UXO clearance	Harbour porpoise	Medium	Low to Negligible at DEP and Negligible at SEP	Minor adverse at DEP and SEP	MMMP for UXO Clearance	**Minor adverse**

12.6.1.2.5 Impact Assessment for DEP and SEP Together

200. The impacts for DEP and SEP together would be the same as that presented for DEP and SEP separately. As UXO clearance would be undertaken at one site at time, i.e. there would be no concurrent UXO clearance between the two sites.

12.6.1.3 Impact 3: Auditory Injury from Underwater Noise Associated with Piling

201. A range of foundation options are being considered for DEP and SEP, including monopile, jacket (pin-piles), screw piles, Gravity Based Structure (GBS) and suction bucket (see **Section 12.3.3**). Of these, monopiles and jackets (pin-piles) may require piling. As a worst-case scenario for underwater noise, it has been assumed that all foundations could be piled.

202. 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.

203. 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.

204. 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.

12.6.1.3.1 Sensitivity of Marine Mammals

205. 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 12-29**). 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.

206. 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 12-29**).

207. 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 12-8**).

208. All marine mammal species are assessed as having medium sensitivity to TTS (**Table 12-29**). The sensitivity of each species to TTS onset is assumed to be the same as fleeing response. 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.

209. 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 12-8**).

210. 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).

211. 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.

212. The sensitivity of marine mammals to disturbance is considered to be medium in this assessment as a precautionary approach (**Table 12-29**). 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 12-8**).

Table 12-29: Summary of marine mammal sensitivity to noise impacts from pile driving

Species	Auditory Injury (PTS)	TTS / Fleeing Response	Disturbance
Harbour porpoise	High	Medium	Medium
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

12.6.1.3.2 Underwater Noise Modelling

213. 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 12.2**). 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 12.2** for further details).

214. 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.

12.6.1.3.2.1 Methodology

Piling Locations

215. Modelling has been undertaken at four representative locations, covering the extents of the SEP and DEP sites, with two positions modelled at each site, including the deepest point of the sites (typically the worst-case location; i.e. the deepest location where piling can take place, which tends to give the greatest noise propagation) (**Appendix 12.2**):

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

216. 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 used in the assessments were identified as:

- 'DEP SE'; and
- 'SEP E'.

Hammer Energy, Soft-start and Ramp-up

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

- Monopile with maximum diameter of 16m, maximum hammer energy of up to 5,500kJ and maximum starting energy of 1,000kJ.
  - However, the most likely worst-case scenario would be up to 4,500kJ with a starting hammer energy of 600kJ.
- Pin-pile with diameter of 3.5m, maximum hammer energy of up to 3,000kJ and maximum starting hammer energy of 400kJ.

218. 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.

219. As a worst-case scenario it is assumed to be 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.

220. 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.

221. The soft-start, ramp-up and piling duration used to assess SEL_{cum} for monopiles and pin-piles are summarised in **Table 12-30**.

Table 12-30: 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
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)					
Monopile – likely scenario						
Monopile hammer energy	600	600	1,500	2,500	3,500	4,500
Number of strikes	4	900	2,400	1,600	1,200	900
Strike rate	1 per 5 minutes	45 per minute	60 per minute	40 per minute	30 per minute	30 per minute
Duration (minutes)	20	20	40	40	40	30.3
Total duration	3.2 hours (7,004 total strikes)					

Parameter	Starting hammer energy	Ramp-up				Maximum hammer energy
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)					

Noise Source Levels

222. 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 (**Appendix 12.2**).

223. The unweighted SPL_{peak} and SEL_{ss} source levels estimated for this assessment are provided in **Table 12-31**.

Table 12-31: Unweighted SPL_{peak} and SEL_{ss} source levels used in underwater noise modelling for monopiles and pin-piles

Source Level	Maximum monopile (5,500kJ)	Most likely monopile (4,500kJ)	Maximum pin-pile (3,000kJ)
SPL_{peak} source levels (dB re 1 µPa @ 1 m)	243.6	243.3	241.4-241.6 (depending on location)
SEL_{ss} source levels (dB re 1 µPa^{2}s @ 1 m)	227.5	227.0	225.5-225.6 (depending on location)

Environmental Conditions

224. 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 seabed surrounding the SEP and DEP sites are generally made up of sand and sandy gravel.

225. Digital bathymetry, also from the EMODnet, has been used for this modelling; mean tidal depth has been used throughout (**Appendix 12.2**).

Thresholds and Criteria

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

227. 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.

228. 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.

229. 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 12.2**).

230. 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.

231. SEL_{cum} is the cumulative sound exposure level during the duration of piling including the soft-start, ramp-up and time required to complete the installation of the pile (**Table 12-30**). To determine SEL_{cum} ranges, 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 12.2**.

232. 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.

233. Southall *et al*. (2019) presents unweighted peak criteria (SPL_{peak}) 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.

234. 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 1 μPa and all SEL values are referenced to 1 $μPa^2s$. Assessments have been based on the criteria with the greatest predicted impact ranges.

235. 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.

236. The Southall *et al*. (2019) thresholds and criteria used in the assessments are summarised in **Table 12-32**.

Table 12-32: 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 $μPa^2s$)	
				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 harbor seal	Pinnipeds in water (PW)	PTS	218	185	201
		TTS	212	170	181

237. 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.

238. 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 12.2**). 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.

239. In addition, the unweighted impulsive single-strike criteria from Lucke *et al*. (2009) have also been included as part of this study covering TTS and behavioural thresholds for harbour porpoise, which are based on impulsive seismic airgun stimuli. The criteria are given as unweighted peak-to-peak SPL and unweighted single strike SEL:

- TTS in harbour porpoise at 199.7 dB re 1 µPa ($SPL_{peak\text{-}to\text{-}peak}$), and 164.3 dB re 1 μPa^2s (SEL_{ss}); and
- Behavioural reaction in harbour porpoise at 174 dB re 1 µPa ($SPL_{peak\text{-}to\text{-}peak}$), and 145 dB re 1 μPa^2s (SEL_{ss}).

240. Assessments have been based on the SEL criteria for behavioural reaction (145 dB re 1 μPa^2s) in harbour porpoise, which has the greatest predicted impact ranges based on the Lucke *et al*. (2009).

Assumptions and Considerations

241. 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.

242. 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 1 µPa) 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).

243. 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.

244. 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.

245. 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).

246. 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 $\mu Pa^2 s$; the point at which all animals are predicted to have PTS.

12.6.1.3.2.2 Results

247. **Table 12-33** presents the underwater noise modelling results for the predicted impact ranges and areas for permanent auditory injury (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 DEP SE and SEP E (worst-case locations at each site).

248. **Table 12-34** presents the underwater noise modelling results for the predicted impact ranges and areas for temporary auditory injury (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 DEP SE and SEP E (worst-case locations for each site).

249. Maximum and minimum range for SEL_{cum} has been included, where applicable, to indicate the variation for each location. Results of all underwater modelling is provided in **Appendix 12.2**.

250. **Table 12-35** presents the underwater noise modelling results for the predicted impact ranges and areas for temporary auditory injury (TTS) and behavioural response of harbour porpoise from a single strike of the starting hammer energy, single strike from the maximum hammer energy for monopile and pin-piles at DEP SE and SEP E (worst-case locations for each site).

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

252. The SE location at DEP has the largest ranges due to the deeper water at and surrounding this location.

*Table 12-33: Predicted impact ranges (and areas) for permanent auditory injury (PTS) from a single strike and from cumulative exposure based on Southall et al. (2019) thresholds and criteria (maximum impact range and area for each species indicated in **bold**)*

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile - Worst-Case Maximum impact range (km) and area (km²)		Monopile - Likely Maximum impact range (km) and area (km²)		Pin-pile Maximum impact range (km) and area (km²)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Harbour porpoise (VHF)	Auditory injury (PTS) from single strike (without mitigation)	SPL_{peak} Unweighted (202 dB re 1 µPa) Impulsive	DEP	**0.29km (0.27km²)**	**0.57km (1km²)**	0.2km (0.12km²)	0.55km (0.93km²)	0.13km (0.05km²)	**0.47km (0.67km²)**
			SEP	0.27km (0.22km²)	0.51km (0.82km²)	0.18km (0.1km²)	0.49km (0.76km²)	0.12km (0.04km²)	0.42km (0.54km²)
		SEL_{ss} Weighted (155 dB re 1 µPa²s) Impulsive	DEP	0.01km (0.03km²)	0.19km (0.11km²)	0.07km (0.02km²)	0.18km (0.1km²)	0.05km (<0.01km²)	0.16km (0.08km²)
			SEP	0.01km (0.03km²)	0.18km (0.1km²)	0.07km (<0.01m²)	0.18km (0.1km²)	0.05km (<0.01km²)	0.16km (0.08km²)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (155 dB re 1 µPa²s) Impulsive	DEP	N/A	**4-4.9km (61km²)**	N/A	2.1-3km (20km²)	N/A	**1.9-2.3km (13km²)**
			SEP	N/A	3.4-4.1km (43km²)	N/A	1.5-2.2km (10km²)	N/A	1.5-1.8km (8.5km²)
			DEP	**<0.05km**	**<0.05km**	<0.05km	<0.05km	<0.05km	**<0.05km**

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile - Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Bottlenose dolphin and white-beaked dolphin (HF)	Auditory injury (PTS) from single strike (without mitigation)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive		**(<0.01km^2)**	**(<0.01km^2)**	(<0.01km^2)	(<0.01km^2)	(<0.01km^2)	**(<0.01km^2)**
			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)
		SEL_{ss} Weighted (185 dB re 1 µPa^{2}s) Impulsive	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)
			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)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (185 dB re 1 µPa^{2}s) Impulsive	DEP	N/A	**0.1km (<0.1km^2)**	N/A	<0.1km (<0.1km^2)	N/A	**0.1km (<0.1km^2)**
			SEP	N/A	0.1km (<0.1km^2)	N/A	<0.1km (<0.1km^2)	N/A	0.1km (<0.1km^2)
Minke whale (LF)	Auditory injury (PTS) from single strike	SPL_{peak} Unweighted	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)
			SEP	<0.05km	<0.05km	<0.05km	<0.05km	<0.05km	<0.05km

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile - Worst-Case Maximum impact range (km) and area (km²)		Monopile - Likely Maximum impact range (km) and area (km²)		Pin-pile Maximum impact range (km) and area (km²)	
				Starting hammer energy (1,000kJ)	**Maximum hammer energy (5,500kJ)**	**Starting hammer energy (600kJ)**	**Maximum hammer energy (4,500kJ)**	**Starting hammer energy (400kJ)**	**Maximum hammer energy (3,000kJ)**
	(without mitigation)	(219 dB re 1 µPa) Impulsive		(<0.01km²)	(<0.01km²)	(<0.01km²)	(<0.01km²)	(<0.01km²)	(<0.01km²)
		SEL_{ss} Weighted (183 dB re 1 µPa²s) Impulsive	DEP	**0.19km (0.11km²)**	**0.39km (0.48km²)**	0.12km (0.05km²)	0.37km (0.43km²)	0.08km (0.02km²)	**0.31km (0.3km²)**
			SEP	0.17km (0.09km²)	0.35km (0.38km²)	0.11km (0.04km²)	0.33km (0.35km²)	0.07km (0.02km²)	0.28km (0.24km²)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (183 dB re 1 µPa²s) Impulsive	DEP	N/A	**5.7-8.3km (150km²)**	N/A	1.3-4.1km (24km²)	N/A	**2.8-3.8km (33km²)**
			SEP	N/A	4.8-6.2km (92km²)	N/A	0.4-1.9km (4.3km²)	N/A	2.1-2.7km (18km²)
Grey and harbor seal (PW)	Auditory injury (PTS) from single strike (without mitigation)	SPL_{peak} Unweighted (218 dB re 1 µPa) Impulsive	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)**
			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	<0.05km	<0.05km	<0.05km	<0.05km	<0.05km

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile - Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
		SEL_{ss} Weighted (185 dB re 1 µPa^2s) Impulsive		(<0.01km^2)	(<0.01km^2)	(<0.01km^2)	(<0.01km^2)	(<0.01km^2)	(<0.01km^2)
			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)
	PTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (185 dB re 1 µPa^2s) Impulsive	DEP	N/A	**0.6-0.7km (1.4km^2)**	N/A	<0.1km (<0.1km^2)	N/A	**0.15-0.2km (<0.1km^2)**
			SEP	N/A	0.45-0.55km (0.84km^2)	N/A	<0.1km (<0.1km^2)	N/A	0.1-0.15km (<0.1km^2)

N/A = Not Applicable

*Table 12-34: Predicted impact ranges (and areas) for temporary auditory injury (TTS) / fleeing response from a single strike and from cumulative exposure based on Southall et al. (2019) thresholds and criteria (maximum impact range and area for each species indicated in **bold**)*

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile – Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Harbour porpoise (VHF)	Temporary auditory injury (TTS) / fleeing from single strike (without mitigation)	SPL_{peak} Unweighted (196 dB re 1 µPa) Impulsive	DEP	0.71km (1.6km^2)	1.3km (5.3km^2)	0.49km (0.73km^2)	1.3km (5km^2)	0.31km (0.3km^2)	1.1km (3.7km^2)
			SEP	0.63km (1.3km^2)	1.2km (4.2km^2)	0.44km (0.59km^2)	1.1km (3.9km^2)	0.28km (0.25km^2)	0.96km (2.9km^2)
		SEL_{ss} Weighted (140 dB re 1 µPa^{2}s) Impulsive	DEP	0.73km (1.6km^2)	**1.3km (5.5km^2)**	0.52km (0.85km^2)	1.3km (5.1km^2)	0.38km (0.45km^2)	**1.2km (4.1km^2)**
			SEP	0.68km (1.4km^2)	1.2km (4.7km^2)	0.49km (0.76km^2)	1.2km (4.4km^2)	0.36km (0.4km^2)	1.1km (3.6km^2)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (140 dB re 1 µPa^{2}s) Impulsive	DEP	N/A	**12-19km (750km^2)**	N/A	10-17km (580km^2)	N/A	**9.3-15km (440km^2)**
			SEP	N/A	11-16km (530km^2)	N/A	9.2-14km (390km^2)	N/A	8.4-12km (300km^2)
			DEP	<0.05km	**<0.05km**	<0.05km	<0.05km	<0.05km	**<0.05km**

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile – Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Bottlenose dolphin and white-beaked dolphin (HF)	Temporary auditory injury (TTS) / fleeing from single strike (without mitigation)	SPL_{peak} Unweighted (224 dB re 1 µPa) Impulsive		(<0.01km^2)	**(<0.01km^2)**	(<0.01km^2)	(<0.01km^2)	(<0.01km^2)	**(<0.01km^2)**
			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)
		SEL_{ss} Weighted (170 dB re 1 µPa^{2}s) Impulsive	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)
			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)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP	N/A	**0.35-0.4km (0.44km^2)**	N/A	<0.1km (<0.1km^2)	N/A	**0.1-0.15km (<0.1km^2)**
			SEP	N/A	0.3-0.35km (0.33km^2)	N/A	<0.1km (<0.1km^2)	N/A	0.1-0.15km (<0.1km^2)
Minke whale (LF)	Temporary auditory injury (TTS) /	SPL_{peak} Unweighted	DEP	0.06km (<0.01km^2)	0.11km (0.04km^2)	<0.05km (<0.01km^2)	0.11km (0.03km^2)	<0.05km (<0.01km^2)	0.09km (0.02km^2)
			SEP	0.05km	0.1km	<0.05km	0.1km	<0.05km	0.08km

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile – Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
	fleeing from single strike (without mitigation)	(213 dB re 1 µPa) Impulsive		(<0.01km^2)	(0.03km^2)	(<0.01km^2)	(0.03km^2)	(<0.01km^2)	(0.02km^2)
		SEL_{ss} Weighted (168 dB re 1 µPa^2s) Impulsive	DEP	1.7km (9.4km^2)	**3.1km (30km^2)**	1.2km (4.7km^2)	3km (28km^2)	0.81km (2km^2)	**2.6km (21km^2)**
			SEP	1.5km (7.1km^2)	2.7km (22km^2)	1.1km (3.5km^2)	2.6km (21km^2)	0.7km (1.5km^2)	2.3km (16km^2)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (168 dB re 1 µPa^2s) Impulsive	DEP	N/A	**14-25km (1,100km^2)**	N/A	9.4-21km (650km^2)	N/A	**10-18km (590km^2)**
			SEP	N/A	12-20km (720km^2)	N/A	8-16km (380km^2)	N/A	9.1-14km (370km^2)
Grey and harbor seal (PW)	Temporary auditory injury (TTS) / fleeing from single strike	SPL_{peak} Unweighted (212 dB re 1 µPa) Impulsive	DEP	0.06km (<0.01km^2)	0.13km (0.05km^2)	<0.05km (<0.01km^2)	0.12km (0.05km^2)	<0.05km (<0.01km^2)	0.1km (0.03km^2)
			SEP	0.06km (<0.01km^2)	0.12km (0.04km^2)	<0.05km (<0.01km^2)	0.11km (0.04km^2)	<0.05km (<0.01km^2)	0.1km (0.03km^2)
			DEP	0.14km	**0.21km**	0.11km	0.2km	0.08km	**0.19km**

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile – Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
	(without mitigation	SEL_{ss} Weighted (170 dB re 1 µPa^2s) Impulsive		(0.06km^2)	**(0.13km^2)**	(0.04km^2)	(0.13km^2)	(0.02km^2)	**(0.11km^2)**
			SEP	0.13km (0.05km^2)	0.19km (0.11km^2)	0.1km (0.03km^2)	0.19km (0.11km^2)	0.08km (0.02km^2)	0.17km (0.09km^2)
	TTS from cumulative SEL (including soft-start and ramp-up)	SEL_{cum} Weighted (170 dB re 1 µPa^2s) Impulsive	DEP	N/A	**6.8-9.7km (220km^2)**	N/A	4.9-7.7km (300km^2)	N/A	**4.5-6.3km (90km^2)**
			SEP	N/A	6-7.7km (140km^2)	N/A	4.3-5.7km (75km^2)	N/A	3.8-4.8km (55km^2)

Table 12-35 Predicted impact ranges (and areas) for temporary auditory injury (TTS) / fleeing response and behavioural response in harbour porpoise from a single strike based on Lucke et al. (2009) thresholds and criteria

Species	Impact	Criteria and threshold (Lucke *et al*., 2009)	Location	Monopile – Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
Harbour porpoise	Temporary auditory injury (TTS) / Fleeing Response from single strike (without mitigation)	$SPL_{peak\text{-}to\text{-}peak}$ Unweighted (199.7 dB re 1 µPa) Impulsive	DEP	0.18km (0.1km^2)	0.34km (0.35km^2)	0.13km (0.05km^2)	0.33km (0.33km^2)	0.08km (0.02km^2)	0.28km (0.24km^2)
			SEP	0.16km (0.08km^2)	0.29km (0.25km^2)	0.11km (0.03km^2)	0.28km (0.24km^2)	0.08km (0.02km^2)	0.24km (0.17km^2)
		SEL_{ss} Unweighted (164.3 dB re 1 µPa^{2}s) Impulsive	DEP	3.9km (46km^2)	6.5km (120km^2)	3km (27km^2)	6.3km (110km^2)	2.1km (13km^2)	5.4km (84km^2)
			SEP	3.1km (27km^2)	4.9km (66km^2)	2.3km (16km^2)	4.8km (62km^2)	1.6km (7.6km^2)	4.1km (46km^2)
	Behavioural Response from single strike	$SPL_{peak\text{-}to\text{-}peak}$ Unweighted	DEP	5.4km (84km^2)	8.0km (170km^2)	4.2km (52km^2)	7.9km (170km^2)	3km (28m^2)	7.2km (140km^2)
			SEP	4.2km (48km^2)	6.0km (96km^2)	3.3km (30km^2)	5.9km (92km^2)	2.4km (16km^2)	5.3km (77km^2)

Species	Impact	Criteria and threshold (Lucke *et al*., 2009)	Location	Monopile – Worst-Case Maximum impact range (km) and area (km^2)		Monopile - Likely Maximum impact range (km) and area (km^2)		Pin-pile Maximum impact range (km) and area (km^2)	
				Starting hammer energy (1,000kJ)	Maximum hammer energy (5,500kJ)	Starting hammer energy (600kJ)	Maximum hammer energy (4,500kJ)	Starting hammer energy (400kJ)	Maximum hammer energy (3,000kJ)
	(without mitigation)	(174 dB re 1 µPa) Impulsive							
		SEL_{ss} Unweighted (145 dB re 1 µPa²s) Impulsive	DEP	19km (850km²)	**25km (1,400km²)**	17km (660km²)	25km (1,300km²)	14km (470km²)	**23km (1,100km²)**
			SEP	13km (450km²)	17km (700km²)	12km (350km²)	17km (680km²)	9.7km (240km²)	16km (590km²)

12.6.1.3.3 Magnitude for DEP or SEP in Isolation

12.6.1.3.3.1 Permanent Auditory Injury (PTS)

253. Permanent auditory injury is often defined as a Permanent Threshold Shift (PTS), in that following exposure to high noise levels there is a threshold shift in the marine mammal's hearing which does not return to normal once sound exposure has ceased, resulting in a permanent change in hearing sensitivity of the marine mammal.
254. 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}).
255. Assessments are based on high marine mammal sensitivity to PTS (**Section 12.6.1.3.1**).

PTS from First Strike of Soft-Start

256. 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 12-33**).
257. 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 12-36**.
258. 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, with 0.001% or less of the relevant reference populations anticipated to be exposed to any permanent effect (**Table 12-36**).

Table 12-36: Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from first strike of soft-start for monopile or pin-pile without mitigation, based on worst-case

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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 1 µPa) Impulsive	DEP	0.44 (0.00013% of NS MU) (DEP density of 1.64/km²) 0.24 (0.00007% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**	0.08 (0.000024% of NS MU) (DEP density of 1.64/km²) 0.04 (0.00001% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**
		SEP	0.13 (0.00004% of NS MU) (SEP density of 0.57/km²) 0.20 (0.000062% of NS MU) (SCANS-III	**Negligible**	0.02 (0.000007% of NS MU) (SEP density of 0.57/km²) 0.04 (0.00001% of NS MU) (SCANS-III	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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)
			density of $0.888/km^2$)		density of $0.888/km^2$)	
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of $0.03/km^2$)	**Negligible**	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of $0.03/km^2$)	**Negligible**
		SEP	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of $0.03/km^2$)	**Negligible**	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of $0.03/km^2$)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP	0.00006 (0.0000004% of CGNS MU) (DEP and SEP	**Negligible**	0.00006 (0.0000004% of CGNS MU) (DEP and SEP	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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)
			density of 0.006/km^2)		density of 0.006/km^2)	
		SEP	0.00006 (0.0000004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**	0.00006 (0.0000004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1 µPa^{2}s) Impulsive	DEP	0.001 (0.000005% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	0.0002 (0.0000009% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
		SEP	0.0009 (0.000004% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	0.0002 (0.0000009% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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 1 µPa) Impulsive	DEP	0.0009 (0.000004% of ref pop (or 0.00001% of SE MU) (DEP density of 0.09/km²)	**Negligible**	0.0009 (0.000004% of ref pop (or 0.00001% of SE MU) (DEP density of 0.09/km²)	**Negligible**
		SEP	0.005 (0.00002% of ref pop (or 0.00006% of SE MU) (SEP density of 0.47/km²)	**Negligible**	0.005 (0.00002% of ref pop (or 0.00006% of SE MU) (SEP density of 0.47/km²)	**Negligible**
Harbor seal (PW)	SPL_{peak} Unweighted (218 dB re 1 µPa) Impulsive	DEP	0.002 (0.000005% of ref pop (or 0.00005% of SE MU) (DEP density of 0.24/km²)	**Negligible**	0.002 (0.000005% of ref pop (or 0.00005% of SE MU) (DEP density of 0.24/km²)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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)
		SEP	0.002 (0.000005% of ref pop (or 0.00004% of SE MU) (SEP density of 0.21/km^2)	**Negligible**	0.002 (0.000005% of ref pop (or 0.00004% of SE MU) (SEP density of 0.21/km^2)	**Negligible**

PTS from Single Strike at Maximum Hammer Energy

259. 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 12-33**).

260. 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 12-37**.

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, with 0.001% or less of the relevant reference populations anticipated to be exposed to any permanent effect (**Table 12-37**).

Table 12-37: Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from single strike of monopile or pin-pile at maximum hammer energy without mitigation, based on worst-case

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa) Impulsive	DEP	1.64 (0.0005% of NS MU) (DEP density of 1.64/km²) 0.89 (0.0003% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**	1.10 (0.0003% of NS MU) (DEP density of 1.64/km²) 0.59 (0.0002% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**
		SEP	0.47 (0.0001% of NS MU) (SEP density of 0.57/km²) 0.73 (0.0002% of NS MU) (SCANS-III	**Negligible**	0.31 (0.00009% of NS MU) (SEP density of 0.57/km²) 0.48 (0.0001% of NS MU) (SCANS-III	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			density of 0.888/km²)		density of 0.888/km²)	
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**
		SEP	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted	DEP	0.00006 (0.0000004% of CGNS MU) (DEP and SEP	**Negligible**	0.00006 (0.0000004% of CGNS MU) (DEP and SEP	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa) Impulsive		density of $0.006/km^2$)		density of $0.006/km^2$)	
		SEP	0.00006 (0.0000004% of CGNS MU) (DEP and SEP density of $0.006/km^2$)	**Negligible**	0.00006 (0.0000004% of CGNS MU) (DEP and SEP density of $0.006/km^2$)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1 μPa^2s) Impulsive	DEP	0.005 (0.00002% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Negligible**	0.003 (0.00001% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Negligible**
		SEP	0.004 (0.00002% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Negligible**	0.002 (0.00001% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa) Impulsive	DEP	0.0009 (0.000004% of ref pop (or 0.00001% of SE MU) (DEP density of 0.09/km^2)	**Negligible**	0.0009 (0.000004% of ref pop (or 0.00001% of SE MU) (DEP density of 0.09/km^2)	**Negligible**
		SEP	0.005 (0.00002% of ref pop (or 0.00006% of SE MU) (SEP density of 0.47/km^2)	**Negligible**	0.005 (0.00002% of ref pop (or 0.00006% of SE MU) (SEP density of 0.47/km^2)	**Negligible**
Harbor seal (PW)	SPL_{peak} Unweighted (218 dB re 1 µPa) Impulsive	DEP	0.002 (0.000005% of ref pop (or 0.00005% of SE MU)	**Negligible**	0.002 (0.000005% of ref pop (or 0.00005% of SE MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			(DEP density of 0.24/km^2)		(DEP density of 0.24/km^2)	
		SEP	0.002 (0.000005% of ref pop (or 0.00005% of SE MU) (SEP density of 0.21/km^2)	**Negligible**	0.002 (0.000005% of ref pop (or 0.00004% of SE MU) (SEP density of 0.21/km^2)	**Negligible**

PTS from Cumulative Exposure

262. 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 12-33**).

263. 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 12.2** for further details).

264. 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.

265. 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 12-38**.

266. The magnitude of the potential impact without any mitigation is assessed as low to medium for harbour porpoise, low for bottlenose dolphin (however, this is likely to be an overestimation as the maximum impact area was rounded to a precautionary 0.1km^2 for maximum impact ranges of 100m or less, whereas the maximum area is actually less than 0.05km^2), negligible for white-beaked dolphin, low for minke whale, negligible to low for grey seal and harbour seal (**Table 12-38**).

267. 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 maximum impact range for SEL_{cum} at each location and between locations (**Table 12-33**). For example, for harbour porpoise at DEP for maximum monopile hammer energy of 5,500kJ the impact range is 4-4.9km and at SEP is 3.4-4.1km. 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 (**Table 12-33**), with impact ranges for harbour porpoise at DEP of 2.1-3km and at SEP of 1.5-2.2km.

Table 12-38: Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile without mitigation, based on worst-case

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa²s) Impulsive	DEP	100 (0.03% of NS MU) (DEP density of 1.64/km²) 54 (0.02% of NS MU) (SCANS-III density of 0.888/km²)	**Low to Medium**	21 (0.0006% of NS MU) (DEP density of 1.64/km²) 12 (0.003% of NS MU) (SCANS-III density of 0.888/km²)	**Low**
		SEP	25 (0.007% of NS MU) (DEP density of 0.58/km²) 38 (0.01% of NS MU) (SCANS-III	**Low to Medium**	5 (0.001% of NS MU) (DEP density of 0.58/km²) 8 (0.002% of NS MU) (SCANS-III	**Low**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			density of 0.888/km²)		density of 0.888/km²)	
Bottlenose dolphin (HF)	SEL_{cum} Weighted (185 dB re 1 µPa²s) Impulsive	DEP	0.003 (0.0002%; 0.002% of CES MU) (SCANS-III density of 0.03/km²)	**Low**	0.003 (0.0002%; 0.002% of CES MU) (SCANS-III density of 0.03/km²)	**Low**
		SEP	0.003 (0.0002%; 0.002% of CES MU) (SCANS-III density of 0.03/km²)	**Low**	0.003 (0.0002%; 0.002% of CES MU) (SCANS-III density of 0.03/km²)	**Low**
White-beaked dolphin (HF)	SEL_{cum} Weighted (185 dB re 1 µPa²s)	DEP	0.0006 (0.000004% of CGNS MU) (DEP and SEP	**Negligible**	0.0006 (0.000004% of CGNS MU) (DEP and SEP	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
	Impulsive		density of $0.006/km^2$)		density of $0.006/km^2$)	
		SEP	0.0006 (0.000004% of CGNS MU) (DEP and SEP density of $0.006/km^2$)	**Negligible**	0.0006 (0.000004% of CGNS MU) (DEP and SEP density of $0.006/km^2$)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (185 dB re 1 $\mu Pa^2 s$) Impulsive	DEP	1.5 (0.006% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Low**	0.33 (0.001% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Low**
		SEP	0.92 (0.004% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Low**	0.18 (0.0008% of CGNS MU) (SCANS-III density of $0.01/km^2$)	**Low**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)	SEL_{cum} Weighted (185 dB re 1 µPa^{2}s) Impulsive	DEP	0.13 (0.0005% of ref pop (or 0.002% of SE MU) (DEP density of 0.09/km^2)	**Negligible (low)**	0.009 (0.00004% of ref pop (or 0.0001% of SE MU) (DEP density of 0.09/km^2)	**Negligible (negligible)**
		SEP	0.39 (0.002% of ref pop (or 0.005% of SE MU) (SEP density of 0.47/km^2)	**Low (low)**	0.05 (0.0002% of ref pop (or 0.0006% of SE MU) (SEP density of 0.47/km^2)	**Negligible (negligible)**
Harbor seal (PW)	SEL_{cum} Weighted (185 dB re 1 µPa^{2}s) Impulsive	DEP	0.3 (0.0007% of ref pop (or 0.007% of SE MU) (DEP density of 0.24/km^2)	**Negligible (low)**	0.02 (0.00005% of ref pop (or 0.0005% of SE MU) (DEP density of 0.24/km^2)	**Negligible (negligible)**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
		SEP	0.2 (0.0004% of ref pop (or 0.004% of SE MU) (SEP density of 0.21/km^2)	**Negligible (low)**	0.02 (0.00005% of ref pop (or 0.0004% of SE MU) (SEP density of 0.21/km^2)	**Negligible (negligible)**

12.6.1.3.3.2 Temporary Auditory Injury (TTS) and Fleeing Response

268. Temporary auditory injury is often defined as a Temporary Threshold Shift (TTS), in that following exposure to high noise levels there is a threshold shift in the marine mammal's hearing which returns to normal once sound exposure has ceased, resulting in a temporary change in hearing sensitivity of the marine mammal.

269. 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}). As outlined in **Section 12.6.1.1.1**, a fleeing response is assumed to occur at the same noise levels as TTS.

270. All marine mammal species are assessed as having medium sensitivity to TTS / fleeing response (**Table 12-29**).

271. The underwater noise modelling results for the maximum predicted ranges (and areas) for TTS and fleeing response in marine mammals are presented in **Table 12-34**.

TTS from Single Strike at Maximum Hammer Energy

272. 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 12-34**).

273. 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 12-39**.

274. 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, with 1% or less of the relevant reference populations anticipated to be exposed to any temporary effect (**Table 12-39**).

275. The MMMP for piling (**Section 12.3.4**) would also reduce the risk of TTS, as the mitigation to reduce the risk of PTS will move animals away from the piling location and will therefore also reduce the number of animals in the predicted impact area for TTS.

Table 12-39: Maximum number of individuals (and % of reference population) that could be at risk of temporary auditory injury (TTS) from single strike of monopile or pin-pile at maximum hammer energy without mitigation, based on worst-case

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)	Monopile = SPL_{peak} Unweighted (196 dB re 1 µPa) Impulsive Pin-pile = SEL_{ss} Weighted (140 dB re 1 $\mu Pa^2 s$) Impulsive	DEP	9.02 (0.003% of NS MU) (DEP density of 1.64/km^2) 4.88 (0.001% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	6.72 (0.002% of NS MU) (DEP density of 1.64/km^2) 3.64 (0.001% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
		SEP	2.68 (0.0008% of NS MU) (SEP density of 0.58/km^2) 4.17 (0.001% of NS MU) (SCANS-III	**Negligible**	2.05 (0.0006% of NS MU) (DEP density of 0.58/km^2) 3.20 (0.0009% of NS MU) (SCANS-III	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			density of 0.888/km^2)		density of 0.888/km^2)	
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (224 dB re 1 µPa) Impulsive	DEP	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**
		SEP	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**	0.0003 (0.00002%; 0.0002% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted	DEP	0.00006 (0.0000004% of CGNS MU) (DEP and SEP	**Negligible**	0.00006 (0.0000004% of CGNS MU) (DEP and SEP	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
	(224 dB re 1 µPa) Impulsive		density of 0.006/km^2)		density of 0.006/km^2)	
		SEP	0.00006 (0.0000004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**	0.00006 (0.0000004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (168 dB re 1 µPa^{2}s) Impulsive	DEP	0.30 (0.001% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	0.21 (0.0009% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
		SEP	0.22 (0.0009% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	0.16 (0.0007% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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_{ss} Weighted (170 dB re 1 µPa²s) Impulsive	DEP	0.01 (0.00005% of ref pop (or 0.0001% of SE MU) (DEP density of 0.09/km²)	**Negligible**	0.01 (0.00004% of ref pop (or 0.0001% of SE MU) (DEP density of 0.09/km²)	**Negligible**
		SEP	0.05 (0.0002% of ref pop (or 0.0006% of SE MU) (SEP density of 0.47/km²)	**Negligible**	0.04 (0.0002% of ref pop (or 0.0005% of SE MU) (SEP density of 0.47/km²)	**Negligible**
Harbor seal (PW)	SEL_{ss} Weighted (170 dB re 1 µPa²s) Impulsive	DEP	0.03 (0.00007% of ref pop (or 0.0006% of SE MU) (DEP density of 0.24/km²)	**Negligible**	0.03 (0.00006% of ref pop (or 0.0005% of SE MU) (DEP density of 0.24/km²)	**Negligible**
		SEP	0.02 (0.00005% of ref pop (or	**Negligible**	0.02 (0.00004% of ref pop (or	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			0.0005% of SE MU) (SEP density of 0.21/km^2)		0.0004% of SE MU) (SEP density of 0.21/km^2)	

TTS from Cumulative Exposure

276. 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 12-34**).

277. 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 12-40**.

278. 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 reference population (**Table 12-40**).

279. 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 12-40: Maximum number of individuals (and % of reference population) that could be at risk of temporary auditory injury (TTS) from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile without mitigation, based on worst-case

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa^{2}s) Impulsive	DEP	1,230 (0.36% of NS MU) (DEP density of 1.64/km^2) 666 (0.19% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	722 (0.21% of NS MU) (DEP density of 1.64/km^2) 391 (0.11% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
		SEP	302 (0.09% of NS MU) (SEP density of 0.58/km^2) 471 (0.14% of NS MU) (SCANS-III	**Negligible**	171 (0.05% of NS MU) (DEP density of 0.58/km^2) 266 (0.08% of NS MU) (SCANS-III	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			density of 0.888/km^2)		density of 0.888/km^2)	
Bottlenose dolphin (HF)	SEL_{cum} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP	0.01 (0.0007%; 0.007% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**	0.003 (0.0002%; 0.002% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**
		SEP	0.01 (0.0005%; 0.005% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**	0.003 (0.0002%; 0.002% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**
White-beaked dolphin (HF)	SEL_{cum} Weighted (170 dB re 1 µPa^{2}s)	DEP	0.003 (0.00002% of CGNS MU) (DEP and SEP	**Negligible**	0.0006 (0.000004% of CGNS MU) (DEP and SEP	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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		density of 0.006/km^2)		density of 0.006/km^2)	
		SEP	0.002 (0.00001% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**	0.0006 (0.000004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (168 dB re 1 μPa^{2}s) Impulsive	DEP	11 (0.05% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	6 (0.03% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
		SEP	7 (0.03% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	4 (0.02% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa^{2}s) Impulsive	DEP	20 (0.08% of ref pop (or 0.24% of SE MU) (DEP density of 0.09/km^2)	**Negligible (negligible)**	8 (0.03% of ref pop (or 0.10% of SE MU) (DEP density of 0.09/km^2)	**Negligible (negligible)**
		SEP	66 (0.27% of ref pop (or 0.80% of SE MU) (SEP density of 0.47/km^2)	**Negligible (negligible)**	26 (0.11% of ref pop (or 0.32% of SE MU) (SEP density of 0.47/km^2)	**Negligible (negligible)**
Harbor seal (PW)	SEL_{cum} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP	53 (0.11% of ref pop (or 1.06% of SE MU) (DEP density of 0.24/km^2)	**Negligible (low)**	22 (0.05% of ref pop (or 0.44% of SE MU) (DEP density of 0.24/km^2)	**Negligible (negligible)**
		SEP	29 (0.06% of ref pop (or 0.59% of SE MU) (SEP density of 0.21/km^2)	**Negligible (negligible)**	12 (0.02% of ref pop (or 0.23% of SE MU) (SEP density of 0.21/km^2)	**Negligible (negligible)**

12.6.1.3.4 Impact Significance

280. For PTS, taking into account high marine mammal sensitivity (**Section 12.6.1.3.1**) and the potential magnitude of the effect (i.e. number of individuals as a percentage of the reference population; **Table 12-36**, **Table 12-37** and **Table 12-38**), 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 12-41**). For PTS from cumulative exposure without mitigation, the impact significance has been assessed as moderate to major for harbour porpoise, moderate for bottlenose dolphin, minor for white-beaked dolphin, moderate for minke whale, moderate to minor for grey seal and minor (moderate) for harbour seal (**Table 12-41**).

281. For TTS, taking into account medium marine mammal sensitivity (**Section 12.6.1.3.1**) and the potential magnitude of the effect (**Table 12-39** and **Table 12-40**), 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 12-42**). For PTS 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 12-42**).

12.6.1.3.5 Mitigation

282. The MMMP for piling (**Section 12.3.4**) 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 SNCBs 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 submitted with the DCO application.

283. Mitigation to reduce the risk of instantaneous PTS from the first strike of the soft-start would include activation of ADDs prior to the soft-start commencing. For a maximum impact range of 0.29km (**Table 12-33**), based on a swimming speed of 1.5m/s, the ADDs would be activated for 10 minutes to ensure marine mammals had moved beyond the maximum predicted impact range (distance of 0.9km for 10 minute ADD activation).

284. Mitigation to reduce the risk of instantaneous PTS from a single strike of monopile or pin-pile with maximum hammer energy would include establishing a mitigation zone for the maximum potential impact range of at least 0.57km (**Table 12-33**), activation of ADDs prior to the soft-start commencing for 10 minutes, soft-start for at least 20 minutes followed by ramp-up (**Table 12-30**). The 10 minute ADD activation (0.9km) and 20 minute soft-start (1.8km), would allow marine mammals to move at least 2.7km, based on a swimming speed of 1.5m/s. This would ensure marine mammals had moved beyond the maximum predicted impact range.

285. 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.

286. Mitigation to reduce the risk of PTS from cumulative exposure during installation of monopile would include establishing a mitigation zone for the maximum potential impact range (up to 8.3km for minke whale and up to 4.9km for harbour porpoise; **Table 12-33**), such as increasing the activation of ADDs prior to the soft-start to 55 minutes which would ensure harbour porpoise, dolphin species and seals were 4.95km from the location based on a swimming speed of 1.5m/s and minke whale were 10.73km based on a swimming speed of 3.25m/s. Development of the MMMP prior to construction will also consider other mitigation methods based on the latest information and requirements.

287. It is also important to note that Brandt *et al*. (2018) found that at seven German offshore windfarms 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.

12.6.1.3.6 Residual Impact Significance

288. The residual impact of the potential risk of PTS at either DEP or SEP to marine mammals as a result of underwater noise during piling will be reduced to a negligible magnitude with the proposed mitigation (**Section 12.6.1.3.4**). Therefore, with high sensitivity, the potential impact significance for any permanent auditory injury will be minor adverse for all species (**Table 12-41**).

289. The residual impact of the potential risk of TTS at either DEP or SEP to marine mammals as a result of underwater noise during piling, taking into account the MMMP for piling, would be minor adverse for all species (**Table 12-42**).

Table 12-41: Assessment of impact significance for PTS in marine mammals from underwater noise during piling

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	PTS from single strike of starting hammer energy	DEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP		Low to Medium	Moderate to Major		**Minor adverse**
		SEP		Low to Medium	Moderate to Major		**Minor adverse**
Bottlenose dolphin	PTS from single strike of starting hammer energy	DEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP		Low	Moderate		**Minor adverse**
		SEP		Low	Moderate		**Minor adverse**
White-beaked dolphin	PTS from single strike of starting hammer energy	DEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	PTS from single strike of maximum hammer energy	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
Minke whale	PTS from single strike of starting hammer energy	DEP	High	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP		Low	Moderate		**Minor adverse**
		SEP		Low	Moderate		**Minor adverse**
Grey seal	PTS from single strike of starting hammer energy	DEP	High	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
		DEP		Negligible	Minor		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	PTS during piling from cumulative exposure	SEP		Low to Negligible	Moderate to Minor		**Minor adverse**
Harbour seal	PTS from single strike of starting hammer energy	DEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible (low)	Minor		**Minor adverse**

Table 12-42: Assessment of impact significance for TTS in marine mammals from underwater noise during piling

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	TTS from single strike of maximum hammer energy	DEP	Medium	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	TTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
		DEP	Medium	Negligible	Minor		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Bottlenose dolphin	TTS from single strike of maximum hammer energy	SEP		Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
	TTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
White-beaked dolphin	TTS from single strike of maximum hammer energy	DEP	Medium	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	TTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
Minke whale	TTS from single strike of maximum hammer energy	DEP	Medium	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	TTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
Grey seal	TTS from single strike of maximum hammer energy	DEP	Medium	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
		DEP		Negligible	Minor		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	TTS during piling from cumulative exposure	SEP		Negligible	Minor		**Minor adverse**
Harbour seal	TTS from single strike of maximum hammer energy	DEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	TTS during piling from cumulative exposure	DEP		Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.1.3.7 Impact Assessment for DEP and SEP Together

290. As outlined in **Section 12.3.3.2**, there is the potential that DEP and SEP could be constructed concurrently.

291. The closest distance between DEP and SEP is 10.7km for DEP south site and 11km for DEP north site.

12.6.1.3.7.1 Permanent Auditory Injury (PTS)

292. 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 12-33**). Therefore, there would be no overlap between the two projects and the assessments (**Sections 12.6.1.1.3.1** and **12.6.1.1.6**) and mitigation (**Section 12.6.1.1.4**) for the DEP and SEP in isolation are appropriate. However, 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 DEP and SEP together, if they are developed concurrently (**Table 12-43**).

293. The magnitude of the potential impact for instantaneous PTS from the first strike of the soft-start without any mitigation at DEP and SEP together 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 12-43**).

294. 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 12-33**). Therefore, there would be no overlap between the two projects and the assessments (**Sections 12.6.1.1.3.1** and **12.6.1.1.6**) and mitigation (**Section 12.6.1.1.4**) for the DEP and SEP in isolation are appropriate. However, 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 DEP and SEP together, if they are developed concurrently (**Table 12-44**).

295. The magnitude of the potential impact for instantaneous PTS from single strike of the maximum hammer energy without any mitigation at DEP and SEP together 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 12-44**).

296. 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 12-33**). Therefore, there would be no overlap between the two projects and the assessments (**Sections 12.6.1.1.3.1** and **12.6.1.1.6**) and mitigation (**Section 12.6.1.1.4**) for the DEP and SEP in isolation are appropriate. However, 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 DEP and SEP together, if they are developed concurrently (**Table 12-45**).

297. The magnitude of the potential impact for cumulative PTS without any mitigation for the installation of monopiles at DEP and SEP together is assessed as medium for harbour porpoise, negligible for bottlenose dolphin and white-beaked dolphin, low for minke whale, grey seal and harbour seal (**Table 12-45**).

Table 12-43: Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from first strike of soft-start for monopile or pin-pile without mitigation, based on worst-case for DEP and SEP together

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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 1 µPa) Impulsive	DEP & SEP	0.57 (0.0002% of NS MU) 0.44 (0.0001% of NS MU)	**Negligible**	0.1 (0.00003% of NS MU) 0.08 (0.00002% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP & SEP	0.0006 (0.00003%; 0.0003% of CES MU)	**Negligible**	0.0006 (0.00003%; 0.0003% of CES MU)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP & SEP	0.0001 (0.0000008% of CGNS MU)	**Negligible**	0.0001 (0.0000008% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with starting hammer energy of 1,000kJ (worst-case)		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)
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1 μPa^2s) Impulsive	DEP & SEP	0.002 (0.000009% of CGNS MU)	**Negligible**	0.0004 (0.000002% of CGNS MU)	**Negligible**
Grey seal (PW)	SPL_{peak} Unweighted (218 dB re 1 µPa) Impulsive	DEP & SEP	0.006 (0.00002% of ref pop (or 0.00007% of SE MU)	**Negligible**	0.006 (0.00002% of ref pop (or 0.00007% of SE MU)	**Negligible**
Harbor seal (PW)	SPL_{peak} Unweighted (218 dB re 1 µPa) Impulsive	DEP & SEP	0.005 (0.00001% of ref pop (or 0.00009% of SE MU)	**Negligible**	0.005 (0.00001% of ref pop (or 0.00009% of SE MU)	**Negligible**

Table 12-44: Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from single strike of monopile or pin-pile at maximum hammer energy without mitigation, based on worst-case for DEP and SEP together

Species	**Criteria and threshold (Southall *et al.*, 2019)**	**Location**	**Monopile with maximum hammer energy of 5,500kJ (worst-case)**		**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 1 µPa) Impulsive	DEP & SEP	2.11 (0.0006% of NS MU) 1.62 (0.0005% of NS MU)	**Negligible**	1.41 (0.0004% of NS MU) 1.07 (0.0003% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP & SEP	0.0006 (0.00003%; 0.0003% of CES MU)	**Negligible**	0.0006 (0.00003%; 0.0003% of CES MU)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted (230 dB re 1 µPa) Impulsive	DEP & SEP	0.0001 (0.0000008% of CGNS MU)	**Negligible**	0.0001 (0.0000008% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{ss} Weighted (183 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	0.009 (0.00004% of CGNS MU)	**Negligible**	0.005 (0.00002% of CGNS MU)	**Negligible**
Grey seal (PW)	SPL_{peak} Unweighted	DEP & SEP	0.006 (0.00002% of ref pop (or	**Negligible**	0.006 (0.00002% of ref pop (or	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
	(218 dB re 1 µPa) Impulsive		0.00007% of SE MU)		0.00007% of SE MU)	
Harbor seal (PW)	SPL_{peak} Unweighted (218 dB re 1 µPa) Impulsive	DEP & SEP	0.005 (0.00001% of ref pop (or 0.00009% of SE MU)	**Negligible**	0.005 (0.00001% of ref pop (or 0.00009% of SE MU)	**Negligible**

Table 12-45: Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile without mitigation, based on worst-case for DEP and SEP together

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa^{2}s) Impulsive	DEP & SEP	125 (0.04% of NS MU)	**Medium**	26 (0.008% of NS MU)	**Low**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
			92 (0.03% of NS MU)		19 (0.006% of NS MU)	
Bottlenose dolphin (HF)	SEL_{cum} Weighted (185 dB re 1 µPa²s) Impulsive	DEP & SEP	0.006 (0.0003%; 0.003% of CES MU)	**Negligible (low)**	0.006 (0.0003%; 0.003% of CES MU)	**Negligible (low)**
White-beaked dolphin (HF)	SEL_{cum} Weighted (185 dB re 1 µPa²s) Impulsive	DEP & SEP	0.001 (0.000008% of CGNS MU)	**Negligible**	0.001 (0.000008% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (185 dB re 1 µPa²s) Impulsive	DEP & SEP	2.42 (0.01% of CGNS MU)	**Low**	0.51 (0.002% of CGNS MU)	**Low**
Grey seal (PW)	SEL_{cum} Weighted (185 dB re 1 µPa²s) Impulsive	DEP & SEP	0.52 (0.002% of ref pop (or 0.006% of SE MU)	**Low**	0.06 (0.0002% of ref pop (or 0.0007% of SE MU)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)
Harbor seal (PW)	SEL_{cum} Weighted (185 dB re 1 µPa²s) Impulsive	DEP & SEP	0.5 (0.001% of ref pop (or 0.01% of SE MU)	**Low**	0.05 (0.0001% of ref pop (or 0.0009% of SE MU)	**Negligible**

12.6.1.3.7.2 Temporary Auditory Injury (TTS) and Fleeing Response

298. 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 12-34**). Therefore, there would be no overlap between the two projects and the assessments for the DEP and SEP in isolation are appropriate. However, 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 DEP and SEP together, if they are developed concurrently (**Table 12-46**).

299. 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 DEP and SEP together 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 12-46**).

300. 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 12-34**). Therefore, there could be overlap between the maximum potential impact ranges for the two projects, however, the 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 DEP and SEP together, if they are developed concurrently (**Table 12-47**).

301. The magnitude of the potential impact for cumulative TTS without any mitigation at DEP and SEP together is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale and negligible for grey seal and harbour seal (**Table 12-47**).

Table 12-46: Maximum number of individuals (and % of reference population) that could be at risk of temporary auditory injury (TTS) from single strike of monopile or pin-pile at maximum hammer energy without mitigation, based on worst-case for DEP and SEP together

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)	Monopile = SPL_{peak} Unweighted (196 dB re 1 µPa) Impulsive Pin-pile = SEL_{ss} Weighted (140 dB re 1 $\mu Pa^2 s$) Impulsive	DEP & SEP	11.70 (0.003% of NS MU) 9.06 (0.003% of NS MU)	**Negligible**	8.78 (0.003% of NS MU) 6.84 (0.002% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SPL_{peak} Unweighted (224 dB re 1 µPa) Impulsive	DEP & SEP	0.0006 (0.00003%; 0.0003% of CES MU)	**Negligible**	0.0006 (0.00003; 0.0003% of CES MU)	**Negligible**
White-beaked dolphin (HF)	SPL_{peak} Unweighted	DEP & SEP	0.0001 (0.0000008% of CGNS MU)	**Negligible**	0.0001 (0.0000008% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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)**
	(224 dB re 1 µPa) Impulsive					
Minke whale (LF)	SEL_{ss} Weighted (168 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	0.52 (0.002% of CGNS MU)	**Negligible**	0.37 (0.002% of CGNS MU)	**Negligible**
Grey seal (PW)	SEL_{ss} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	0.06 (0.0003% of ref pop (or 0.0008% of SE MU)	**Negligible**	0.05 (0.0002% of ref pop (or 0.0006% of SE MU)	**Negligible**
Harbor seal (PW)	SEL_{ss} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	0.05 (0.0001% of ref pop (or 0.001% of SE MU)	**Negligible**	0.05 (0.0001% of ref pop (or 0.0009% of SE MU)	**Negligible**

Table 12-47: Maximum number of individuals (and % of reference population) that could be at risk of temporary auditory injury (TTS) from cumulative exposure (SEL_{cum}) during installation of monopile or pin-pile without mitigation, based on worst-case for DEP and SEP together

Species	Criteria and threshold (Southall *et al.*, 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 µPa^{2}s) Impulsive	DEP & SEP	1,532 (0.44% of NS MU) 1,137 (0.33% of NS MU)	**Negligible**	893 (0.26% of NS MU) 657 (0.19% of NS MU)	**Negligible**
Bottlenose dolphin (HF)	SEL_{cum} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	0.02 (0.001%; 0.01% of CES MU)	**Negligible**	0.006 (0.0003%; 0.003% of CES MU)	**Negligible**
White-beaked dolphin (HF)	SEL_{cum} Weighted (170 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	0.005 (0.00003% of CGNS MU)	**Negligible**	0.001 (0.000008% of CGNS MU)	**Negligible**
Minke whale (LF)	SEL_{cum} Weighted (168 dB re 1 µPa^{2}s) Impulsive	DEP & SEP	18 (0.08% of CGNS MU)	**Negligible**	10 (0.04% of CGNS MU)	**Negligible**

Species	Criteria and threshold (Southall *et al*., 2019)	Location	Monopile with maximum hammer energy of 5,500kJ (worst-case)		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 1 $\mu Pa^2 s$) Impulsive	DEP & SEP	86 (0.36% of ref pop (or 1.04% of SE MU)	**Negligible (low)**	34 (0.14% of ref pop (or 0.41% of SE MU)	**Negligible**
Harbor seal (PW)	SEL_{cum} Weighted (170 dB re 1 $\mu Pa^2 s$) Impulsive	DEP & SEP	82 (0.18% of ref pop (or 1.66% of SE MU)	**Negligible (low)**	33 (0.07% of ref pop (or 0.67% of SE MU)	**Negligible**

12.6.1.3.7.3 Impact Significance

Table 12-48 and **Table 12-49**

302. *Table 12-49* summarises the assessment of the impact significance for PTS and TTS, respectively, based on maximum number of marine mammals that could be impacted as a result of underwater noise during piling for DEP and SEP together, if they are developed concurrently.

12.6.1.3.7.4 Mitigation

303. There would be no further mitigation required for DEP and SEP together than the proposed mitigation for DEP and SEP alone, as outlined in **Section 12.6.1.3.4**.

12.6.1.3.7.5 Impact Significance

304. Taking into account the proposed mitigation for DEP and SEP alone, the residual impact would be **minor adverse** (not significant).

Table 12-48: Assessment of impact significance for PTS in marine mammals from underwater noise during piling for DEP and SEP together

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	PTS from single strike of starting hammer energy	DEP & SEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP & SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP & SEP		Medium to Low	Major to Moderate		**Minor adverse**
Bottlenose dolphin	PTS from single strike of starting hammer energy	DEP & SEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP & SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**
White-beaked dolphin	PTS from single strike of starting hammer energy	DEP & SEP	High	Negligible	Minor	MMMP (Section 12.6.1.3.4)	**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP & SEP		Negligible	Minor		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	PTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**
Minke whale	PTS from single strike of starting hammer energy	DEP & SEP	High	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP & SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP & SEP		Low	Moderate		**Minor adverse**
Grey seal	PTS from single strike of starting hammer energy	DEP & SEP	High	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	PTS from single strike of maximum hammer energy	DEP & SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP & SEP		Low to Negligible	Moderate to Minor		**Minor adverse**
Harbour seal	PTS from single strike of starting hammer energy	DEP & SEP	High	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	PTS from single strike of maximum hammer energy	DEP & SEP		Negligible	Minor		**Minor adverse**
	PTS during piling from cumulative exposure	DEP & SEP		Low to Negligible	Moderate to Minor		**Minor adverse**

Table 12-49: Assessment of impact significance for TTS in marine mammals from underwater noise during piling for DEP and SEP together

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	TTS from single strike of maximum hammer energy	DEP & SEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**
Bottlenose dolphin	TTS from single strike of maximum hammer energy	DEP & SEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
White-beaked dolphin	TTS from single strike of maximum hammer energy	DEP & SEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**
Minke whale	TTS from single strike of maximum hammer energy	DEP & SEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**
Grey seal	TTS from single strike of maximum hammer energy	DEP & SEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**
	TTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**
Harbour seal	TTS from single strike of maximum hammer energy	DEP & SEP	Medium	Negligible	Minor	MMMP (**Section 12.6.1.3.4**)	**Minor adverse**

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	TTS during piling from cumulative exposure	DEP & SEP		Negligible	Minor		**Minor adverse**

12.6.1.4 Impact 4: Disturbance and Behavioural Impacts from Underwater Noise Associated with Piling Activities

305. 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.

306. 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 12-34**, with the estimated number and percentage of reference populations in **Section 12.6.1.3.3.2** providing an indication of possible fleeing response.

12.6.1.4.1 Sensitivity

307. All marine mammal species are assessed as having medium sensitivity disturbance (**Table 12-29**).

12.6.1.4.2 Magnitude for DEP or SEP in Isolation

12.6.1.4.2.1 Disturbance During ADD Activation

308. 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.

309. As outlined in **Section 12.6.1.3.4**, mitigation to reduce the risk of instantaneous PTS from the first strike of the soft-start could include activation of ADDs for at least 10 minutes prior to the soft-start commencing.

310. During the 10 minute ADD activation 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.

311. 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 temporary disturbed (**Table 12-50**).

312. If ADDs were required as mitigation to reduce the risk of PTS from cumulative exposure during installation of monopile, up to 4.9km for harbour porpoise and up to 8.3km for minke whale, as outlined in **Section 12.6.1.3.4**, there is the potential, as a worst-case scenario, that ADDs could be activated for up to 55 minutes prior to the soft-start. During the 55 minute ADD activation harbour porpoise, dolphin species and seals move 4.95km from the location based on a swimming speed of 1.5m/s, resulting in a potential disturbance area of up to 77km^2 and minke whale 10.73km based on a swimming speed of 3.25m/s, resulting in a potential disturbance area of up to 362km^2. However, it is important to note, that the development of the MMMP prior to construction will also consider other mitigation methods based on the latest information and requirements.

313. 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 temporary disturbed (**Table 12-50**).

314. If ADDs were required as mitigation to reduce the risk of PTS from cumulative exposure during installation of pin-piles, up to 2.3km for harbour porpoise and up to 3.8km for minke whale (**Table 12-22**), there is the potential, as a worst-case scenario, that ADDs could be activated for up to 30 minutes prior to the soft-start. During the 30 minute ADD activation harbour porpoise, dolphin species and seals move 2.7km from the location based on a swimming speed of 1.5m/s, resulting in a potential disturbance area of up to $23km^2$ and minke whale up to 5.85km based on a swimming speed of 3.25m/s, resulting in a potential disturbance area of up to $108km^2$. The magnitude of impact would be negligible for all marine mammal species (**Table 12-50**).

315. Maximum total ADD activation time to install all piles, based on worst-case scenarios:

- DEP:
  - 32 monopiles = 5.4 hours for 10 minute ADD activation prior to each soft-start (29.4 hours for 55 minute ADD activation); or
  - 128 pin-piles, however, anticipated 4 pin-piles for jacket foundation of each WTG to be installed in sequence, therefore ADDs only activated per foundation (32 foundations) = 5.4 hours for 10 minute ADD activation (16 hours for 30 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 (1 hour for 30 minute activation).
- SEP:
  i. 24 monopiles = 4 hours for 10 minute ADD activation prior to each soft-start (22 hours for 55 minute ADD activation); or
  ii. 96 pin-piles, however, anticipated 4 pin-piles for jacket foundation of each WTG to be installed in sequence, therefore ADDs only activated per foundation (24 foundations) = 4 hours for 10 minute ADD activation (12 hours of 30 minute ADD activation); and
  iii. 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 (1 hour for 30 minute activation).

Table 12-50: Maximum number of individuals (and % of reference population) that could be at disturbed during ADD activation

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 30 minute ADD activation		Disturbance from 55 minute ADD activation	
		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)
Harbour porpoise	DEP	4.17 (0.0012% of NS MU) (DEP density of 1.64/km^2) 2.26 (0.0007% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	38 (0.01% of NS MU) (DEP density of 1.64/km^2) 20 (0.006% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	126 (0.04% of NS MU) (DEP density of 1.64/km^2) 68 (0.02% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	SEP	1.45 (0.0004% of NS MU) (SEP density of 0.58/km^2) 2.26 (0.0007% of NS MU) (SCANS-III	**Negligible**	13 (0.004% of NS MU) (SEP density of 0.58/km^2) 20 (0.006% of NS MU) (SCANS-III	**Negligible**	44 (0.01% of NS MU) (SEP density of 0.58/km^2) 68 (0.02% of NS MU) (SCANS-III	**Negligible**

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 30 minute ADD activation		Disturbance from 55 minute ADD activation	
		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)
		density of 0.888/km²)		density of 0.888/km²)		density of 0.888/km²)	
Bottlenose dolphin	DEP	0.08 (0.004%; 0.04% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**	0.7 (0.04%; 0.4% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**	2.3 (0.12%; 1.2% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible (low)**
	SEP	0.08 (0.004%; 0.04% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**	0.7 (0.04%; 0.4% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible**	2.3 (0.12%; 1.2% of CES MU) (SCANS-III density of 0.03/km²)	**Negligible (low)**
White-beaked dolphin	DEP	0.02 (0.0001% of CGNS MU) (DEP and SEP density of 0.006/km²)	**Negligible**	0.1 (0.0009% of CGNS MU) (DEP and SEP density of 0.006/km²)	**Negligible**	0.5 (0.003% of CGNS MU) (DEP and SEP density of 0.006/km²)	**Negligible**

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 30 minute ADD activation		Disturbance from 55 minute ADD activation	
		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)
	SEP	0.02 (0.0001% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**	0.1 (0.0009% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**	0.5 (0.003% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
Minke whale	DEP	0.12 (0.001% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	1.1 (0.005% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	3.6 (0.015% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	SEP	0.12 (0.001% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	1.1 (0.005% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	3.6 (0.015% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
Grey seal	DEP	0.23 (0.0009% of ref pop (or 0.003% of SE MU)	**Negligible**	2.1 (0.009% of ref pop (or 0.03% of SE MU)	**Negligible**	6.9 (0.03% of ref pop (or 0.08% of SE MU)	**Negligible**

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 30 minute ADD activation		Disturbance from 55 minute ADD activation	
		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)
		(DEP density of 0.09/km^2)		(DEP density of 0.09/km^2)		(DEP density of 0.09/km^2)	
	SEP	1.19 (0.005% of ref pop (or 0.01% of SE MU) (SEP density of 0.47/km^2)	**Negligible**	10.8 (0.04% of ref pop (or 0.13% of SE MU) (SEP density of 0.47/km^2)	**Negligible**	36.2 (0.15% of ref pop (or 0.44% of SE MU) (SEP density of 0.47/km^2)	**Negligible**
Harbor seal	DEP	0.61 (0.001% of ref pop (or 0.01% of SE MU) (DEP density of 0.24/km^2)	**Negligible**	5.5 (0.01% of ref pop (or 0.11% of SE MU) (DEP density of 0.24/km^2)	**Negligible**	18.5 (0.04% of ref pop (or 0.37% of SE MU) (DEP density of 0.24/km^2)	**Negligible**
	SEP	0.53 (0.001% of ref pop (or 0.01% of SE MU) (SEP density of 0.21/km^2)	**Negligible**	4.8 (0.01% of ref pop (or 0.10% of SE MU) (SEP density of 0.21/km^2)	**Negligible**	16.2 (0.03% of ref pop (or 0.33% of SE MU) (SEP density of 0.21/km^2)	**Negligible**

12.6.1.4.2.2 Disturbance of Marine Mammals from Piling Activities

316. 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 previously completed 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 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 through this study were mostly undertaken with noise abatement systems in order to reduce disturbance impacts on harbour porpoise.

317. 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 of harbour porpoise, however, this was not the case.

318. 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.

319. Analysis of the Cetacean Porpoise Detector (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.

320. 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).

321. 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.

322. 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).

323. 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^{2}s at the first location, during the first 24 hours following piling, increasing to 60.0dB re 1 1µPa^{2}s during the middle of the campaign, and to 70.9dB re 1 µPa^{2}s 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^{2}s at the first location, during the first 24 hours following piling, increasing to 150.0dB re 1 1µPa^{2}s during the middle of the campaign, and to 160.4dB re 1 µPa^{2}s by the end of the piling activities (Graham *et al*., 2019).

324. 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).

325. 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).

12.6.1.4.2.3 Disturbance / Displacement of Harbour Porpoise based on EDRs for Piling

326. 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 Southern North Sea SAC (JNCC *et al*., 2020). DEP and SEP are located approximately 14km and 25.6km, respectively, from the Southern North Sea SAC, therefore this approach has been used for the EIA as well as the assessments for the HRA.

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

328. 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 DEP and SEP is presented in **Table 12-51**.

329. The magnitude of the potential impact is assessed as low for monopile at DEP based on site specific density, with 1% of reference population anticipated to be affected and negligible for monopile at SEP or pin-pile at DEP or SEP, with 1% or less of the relevant reference populations anticipated to be temporary disturbed (**Table 12-51**).

330. Further assessments in relation to the Southern North Sea SAC are provided in the information for the HRA.

Table 12-51: Maximum number of harbour porpoise (and % of reference population) that could be at disturbed during piling based on EDRs

Species	Location	26km EDR (2,124km²) for monopile		15km EDR (707km²) 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	DEP	3,483 (1.01% of NS MU) (DEP density of 1.64/km²) 1,886 (0.55% of NS MU) (SCANS-III density of 0.888/km²)	**Low to Negligible**	1,159 (0.34% of NS MU) (DEP 1.64.58/km²) 628 (0.18% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**
	SEP	1,211 (0.35% of NS MU) (SEP density of 0.58/km²) 1,886 (0.55% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**	403 (0.12% of NS MU) (SEP density of 0.58/km²) 628 (0.18% of NS MU) (SCANS-III density of 0.888/km²)	**Negligible**

12.6.1.4.2.4 Possible Behavioural Response in Harbour Porpoise

331. 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).
332. The sensitivity of harbour porpoise to this type of effect is considered to be medium.
333. Based on the unweighted Lucke *et al*. (2009) criteria (unweighted SEL of 145 dB re 1 μPa²s), 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 12-35**).

334. 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).

335. The study of harbour porpoise at Horns Rev (Brandt *et al*., 2011), showed 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, at which approximately 50% could respond at the maximum predicted level as suggested by the dose-response curve in Thompson *et al*. (2013).

336. The estimated number of harbour porpoise, based on 100%, 75% and 50% of all individuals that could potentially exhibit a possible behavioural response as a result of a single strike of the maximum monopile and pin-pile hammer energy, based on the Lucke *et al*. (2009) unweighted criteria (unweighted SEL of 145 dB re 1 μPa^2s) and 50% of the harbour porpoise in the maximum predicted area responding (**Table 12-52**). The magnitude of the potential effect is assessed as negligible with less than 1% of the reference population anticipated to respond.

Table 12-52: 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 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)	DEP	2,296 (0.66% of NS MU) (DEP density of 1.64/km^2) 1,243 (0.36% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	1,722 (0.50% of NS MU) (DEP density of 1.64/km^2) 932 (0.27% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	861 (0.25% of NS MU) (DEP density of 1.64/km^2) 466 (0.13% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	SEP	798 (0.23% of NS MU) (SEP density of 0.58/km^2) 1,242 (0.36% of NS MU) (SCANS-III	**Negligible**	599 (0.17% of NS MU) (SEP density of 0.58/km^2) 932 (0.27% of NS MU) (SCANS-III	**Negligible**	299 (0.09% of NS MU) (SEP density of 0.58/km^2) 466 (0.13% of NS MU) (SCANS-III	**Negligible**

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)
		density of 0.888/km^2)		density of 0.888/km^2)		density of 0.888/km^2)	
Possible behavioural response of harbour porpoise - single strike of the maximum pin-pile hammer energy (3,000kJ)	DEP	1,804 (0.18% of NS MU) (DEP density of 1.64/km^2) 977 (0.28% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	1,353 (0.39% of NS MU) (DEP density of 1.64/km^2) 733 (0.21% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	677 (0.20% of NS MU) (DEP density of 1.64/km^2) 366 (0.11% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	SEP	627 (0.18% of NS MU) (SEP density of 0.58/km^2) 977 (0.28% of NS MU) (SCANS-III	**Negligible**	470 (0.14% of NS MU) (SEP density of 0.58/km^2) 733 (0.21% of NS MU) (SCANS-III	**Negligible**	235 (0.07% of NS MU) (SEP density of 0.58/km^2) 366 (0.11% of NS MU) (SCANS-III	**Negligible**

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)
		density of 0.888/km^2)		density of 0.888/km^2)		density of 0.888/km^2)	

12.6.1.4.2.5 Duration of Piling

337. The total duration of the installation campaign for the wind turbines is expected to be a maximum of 12 months for each project. This will include transit of the foundation components in batches to the site(s) and foundation installation, including any piling.

338. 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.

339. **Table 12-53** 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 12-53: Maximum duration of piling at DEP and SEP, 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
DEP	Up to 32 x 14MW WTG; or Up to 17 x 26MW WTG	Up to 32 monopiles or up to 17 monopiles	4 hours including soft-start and ramp-up (Table 12-30)	Up to 128 hours (5.4 days) for 32 monopiles; or up to 68 hours (2.8 days) for 17 monopiles	5.4 hours for 10 minute ADD activation (up to 29.4 hours for 55 minutes) for 32 monopiles	Up to 134 hours (6 days) with 10 minute ADD activation for 32 monopiles (up to 158 hours (up to 7 days) with 55 minute ADD activation)
		Up to 128 pin-piles for jackets; or up to 68 pin-piles for jackets	3 hours including soft-start and ramp-up (Table 12-30)	Up to 384 hours (16 days) for 128 pin-piles; or up to 204 hours (8.5 days) for 68 pin-piles	5.4 hours for 10 minute ADD activation (up to 16 hours for 30 minute ADD activation)	Up to 390 hours (17 days) with 10 minute ADD activation for 32 foundations (up to 400 hours (17 days) with 30 minute ADD activation)
	One substation	8 pin-piles	3 hours including soft-start and ramp-up (Table 12-30)	24 hours (one day) for 8 pin-piles	20 minutes for 10 minute ADD activation (up to 1 hour for 30 minute activation)	Up to 25 hours with 10 minute ADD activation (up to 25.5 hours with 30 minute ADD activation)
	Piling of up to 32 monopiles and one substation (including soft-start, ramp-up and ADD activation) = up to 159 hours (7 days) with 10 minute activation (183.5 hours (8 days) with 55 and 30 minute ADD activation); or					

Site	Parameter	Number of piles	Maximum active piling time per pile	Total piling time	ADD activation	Total duration
	Piling of up to 128 pin-piles and one substation (including soft-start, ramp-up and ADD activation) = up to 415 hours (18 days) with 10 minute ADD activation (826 hours (35 days) with 30 minute ADD activation)					
SEP	Up to 24 x 14MW WTG; or Up to 13 x 26MW WTG	Up to 24 or 13 monopiles	4 hours including soft-start and ramp-up (**Table 12-30**)	Up to 96 hours (4 days) for 24 monopiles; or up to 52 hours (2.2 days) for 13 monopiles	4 hours for 10 minute ADD activation (up to 22 hours for 55 minute ADD activation)	Up to 102 hours (5 days) with 10 minute ADD activation for 24 monopiles (up to 118 hours (5 days) with 55 minute ADD activation)
		Up to 96 pin-piles for jackets; or 52 pin-piles for jackets	3 hours including soft-start and ramp-up (**Table 12-30**)	Up to 288 hours (12 days) for 96 pin-piles; or up to 156 hours (6.5 days) for 52 pin-piles	4 hours for 10 minute ADD activation (up to 12 hours of 30 minute ADD activation)	Up to 292 hours (13 days) with 10 minute ADD activation for 24 foundations (up to 300 hours (13 days) with 30 minute ADD activation)
	One substation	8 pin-piles	3 hours including soft-start and ramp-up (**Table 12-30**)	24 hours (one day) for 8 pin-piles	20 minutes for 10 minute ADD activation (up to 1 hour for 30 minute activation)	Up to 25 hours with 10 minute ADD activation (up to 25.5 hours with 30 minute ADD activation)
	Piling of up to 24 monopiles and one substation (including soft-start, ramp-up and ADD activation) = up to 127 hours (6 days) with 10 minute activation (143.5 hours (6 days) with 55 and 30 minute ADD activation); or					

Site	Parameter	Number of piles	Maximum active piling time per pile	Total piling time	ADD activation	Total duration
	Piling of up to 96 pin-piles and one substation (including soft-start, ramp-up and ADD activation) = up to 317 hours (14 days) with 10 minute ADD activation (326 hours (14 days) with 30 minute ADD activation)					

340. 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 the Dudgeon Offshore Wind Farm (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 (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).

341. 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).

342. 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.

343. 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.

344. 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.

345. 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 windfarm construction noise on the North Sea harbour porpoise population, based on the acoustic monitoring of harbour porpoise during construction of the Dutch Gemini offshore windfarm. Local population densities around the Gemini windfarm 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 windfarm, 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).

346. 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 windfarm. Underwater noise from offshore windfarm construction noise only influenced population dynamics in the North Sea when simulated animals were assumed to respond at distances exceeding 20–50km from the windfarms. 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.

12.6.1.4.3 Impact Significance and Residual Impact

12.6.1.4.3.1 Impact Significance for Disturbance During Proposed ADD Activation

347. Taking into account the medium sensitivity (**Table 12-29**) 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 12-54**).

348. The use of ADDs as mitigation to reduce the risk of auditory injury (PTS) to marine mammals will be developed during the developed of 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.

349. The assessment of impact significance takes into account the duration of ADD activation for the DEP and SEP projects, as outlined in **Section 12.6.1.4.2.5**.

Table 12-54: Assessment of impact significance for disturbance from ADD activation

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

Species	Impact	Location	Sensitivity	Magnitude	Significance
		SEP		Negligible	**Minor adverse**

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

350. Taking into account the medium sensitivity (**Table 12-29**) 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 12-55**).

351. The assessment of impact significance takes into account the duration of active piling for the DEP and SEP projects, as outlined in **Section 12.6.1.4.2.5**.

352. Further assessments in relation to the Southern North Sea SAC are provided in the information for the HRA.

353. The Southern North Sea SAC SIP will be developed (as outlined in **Section 12.3.4.2**) to set out the approach to deliver any project mitigation or management measures in relation to the disturbance of harbour porpoise.

Table 12-55: 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	DEP	Medium	Low to Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	15km EDR for pin-pile	DEP	Medium	Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.1.4.3.3 Impact Significance and Residual Impact for Possible Behavioural Response of Harbour Porpoise

354. 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 induvial in maximum area responding (**Table 12-56**).

355. The assessment of impact significance takes into account the duration of active piling for the DEP and SEP projects, as outlined in **Section 12.6.1.4.2.5**.

Table 12-56: 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	DEP	Medium	Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Possible behavioural response – 23km for pin-pile	DEP	Medium	Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.1.4.4 Impact Assessment for DEP and SEP Together

356. As outlined in **Section 12.3.3.2**, there is the potential that DEP and SEP could be constructed concurrently.

357. The closest distance between DEP and SEP is 10.7km for DEP south site and 11km for DEP north site.

12.6.1.4.4.1 Disturbance During ADD Activation

358. 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.

359. The maximum predicted impact range during 10 minute ADD activation is up to 0.9km for harbour porpoise, bottlenose dolphin, white-beaked dolphin, grey seal and harbour seal and up to 1.95km for minke whale. Therefore, there would be no overlap between the two projects and the assessments for the DEP and SEP in isolation are appropriate. However, 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 DEP and SEP together, if they are developed concurrently and ADDs were activated at both sites at the same time (**Table 12-57**).

360. 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 temporary disturbed (**Table 12-57**).

361. The maximum predicted impact range during 55 minute ADD activation is up to 4.95km for harbour porpoise, bottlenose dolphin, white-beaked dolphin, grey seal and harbour seal and up to 10.73km for minke whale. Therefore, there could be overlap between the maximum potential impact range for minke whale, however, the 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 DEP and SEP together, if they are developed concurrently and ADDs were activated at both sites at the same time (**Table 12-57**).

362. 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 temporary disturbed (**Table 12-57**).

363. If ADDs were required as mitigation to reduce the risk of PTS from cumulative exposure during installation of pin-piles, there is the potential, as a worst-case scenario, that ADDs could be activated for up to 30 minutes prior to the soft-start. The magnitude of impact would be negligible for all marine mammal species (**Table 12-57**).

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

- DEP & SEP:
    i. 56 monopiles = up to 10 hours for 10 minute ADD activation prior to each soft-start (52 hours for 55 minute ADD activation); or
    ii. 224 pin-piles, however, anticipated 4 pin-piles for jacket foundation of each WTG to be installed in sequence, therefore ADDs only activated per foundation (56 foundations) = 10 hours for 10 minute ADD activation (28 hours for 30 minute ADD activation); and
    iii. 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 (2 hours for 30 minute activation).

Table 12-57: Maximum number of individuals (and % of reference population) that could be at disturbed during ADD activation at DEP and SEP together

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 30 minute ADD activation		Disturbance from 55 minute ADD activation	
		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)
Harbour porpoise	DEP & SEP	5.61 (0.002% of NS MU) 4.51 (0.001% of NS MU)	**Negligible**	51 (0.015% of NS MU) 41 (0.01% of NS MU)	**Negligible**	170 (0.05% of NS MU) 137 (0.04% of NS MU)	**Negligible**
Bottlenose dolphin	DEP & SEP	0.15 (0.008%; 0.08% of CES MU)	**Negligible**	1.4 (0.07%; 0.7% of CES MU)	**Negligible**	4.6 (0.24%; 2.4% of CES MU)	**Negligible (low)**
White-beaked dolphin	DEP & SEP	0.03 (0.0002% of CGNS MU)	**Negligible**	0.3 (0.005% of CGNS MU)	**Negligible**	0.9 (0.006% of CGNS MU)	**Negligible**
Minke whale	DEP & SEP	0.24 (0.001% of CGNS MU)	**Negligible**	2.2 (0.009% of CGNS MU)	**Negligible**	7.2 (0.03% of CGNS MU)	**Negligible**
Grey seal	DEP & SEP	1.42 (0.006% of ref pop (or	**Negligible**	13 (0.05% of ref pop (or	**Negligible**	43.1 (0.18% of ref pop (or	**Negligible**

Species	Location	Disturbance from 10 minute ADD activation		Disturbance from 30 minute ADD activation		Disturbance from 55 minute ADD activation	
		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)
		0.02% of SE MU)		0.16% of SE MU)		0.53% of SE MU)	
Harbor seal	DEP & SEP	1.14 (0.002% of ref pop (or 0.02% of SE MU)	**Negligible**	10.4 (0.02% of ref pop (or 0.2% of SE MU)	**Negligible**	34.7 (0.07% of ref pop (or 0.7% of SE MU)	**Negligible**

12.6.1.4.4.2 Disturbance / Displacement of Harbour Porpoise based on EDRs for Piling

365. There could be overlap between the maximum potential impact range based on 26km EDR for monopiles and 15km EDR for pin-piles, 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 DEP and SEP together, if they are developed concurrently and piling was undertaken at both sites at the same time.

366. 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 DEP and SEP together based on EDRs is presented in **Table 12-58**.

367. The magnitude of the potential impact is assessed as low for monopiles and both DEP and SEP and negligible for pin-piles and DEP and SEP (**Table 12-58**).

368. Further assessments in relation to the Southern North Sea SAC are provided in the information for the HRA.

Table 12-58: Maximum number of harbour porpoise (and % of reference population) that could be at disturbed during piling based on EDRs at DEP and SEP together

Species	Location	26km EDR ($2,124km^2$) for monopile		15km EDR (707km2) 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	DEP & SEP	4,694 (1.36% of NS MU) 3,772 (1.09% of NS MU)	**Low**	1,562 (0.45% of NS MU) 1,256 (0.36% of NS MU)	**Negligible**

12.6.1.4.4.3 Possible Behavioural Response in Harbour Porpoise

369. There could be overlap between the maximum potential impact ranges, with 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 12-35**). 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 DEP and SEP together, if they are developed concurrently and piling was undertaken at both sites at the same time.

370. 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 DEP and SEP together based on the Lucke *et al*. (2009) criteria (unweighted SEL of 145 dB re 1 $\mu Pa^2 s$) is presented in **Table 12-59**.

371. The magnitude of the potential impact is assessed as negligible for harbour porpoise (**Table 12-59**).

Table 12-59: 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 impact) at DEP and SEP together

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)	DEP & SEP	3,094 (0.90% of NS MU) 2,486 (0.72% of NS MU)	**Negligible**	2,321 (0.67% of NS MU) 1,865 (0.54% of NS MU)	**Negligible**	1,160 (0.34% of NS MU) 932 (0.27% of NS MU)	**Negligible**
Possible behavioural response of harbour porpoise - single strike of the maximum pin-pile hammer energy (3,000kJ)	DEP & SEP	2,431 (0.70% of NS MU) 1,954 (0.57% of NS MU)	**Negligible**	1,823 (0.53% of NS MU) 1,465 (0.42% of NS MU)	**Negligible**	912 (0.26% of NS MU) 733 (0.21% of NS MU)	**Negligible**

12.6.1.4.4.4 Duration of Piling

372. Based on assessment in **Table 12-53**, if DEP and SEP were constructed sequentially the maximum duration of piling, based on worst-case scenarios, including soft-start, ramp-up and ADD activation would be:

- DEP & SEP sequentially
    i. Piling of 56 monopiles and two substations (including soft-start, ramp-up and ADD activation) = up to 286 hours (12 days) with 10 minute activation (327 hours (14 days) with 55 and 30 minute ADD activation); or
    ii. Piling of 224 pin-piles and two substation (including soft-start, ramp-up and ADD activation) = 732 hours (31 days) with 10 minute ADD activation (1,152 hours (48 days) with 30 minute ADD activation).

373. However, if DEP and SEP 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 alone (e.g. 2 x 24 monopiles installed at the same time at both DEP and SEP plus additional 8 monopiles at DEP alone = 32 monopiles; or 2 x 96 pin-piles installed at the same time at both DEP and SEP plus additional 32 pin-piles at DEP alone = 128 pin-piles) plus the two substations:

- DEP & SEP concurrently
    i. Piling of 56 monopiles (2 x 24 monopiles concurrently installed) and two substations (including soft-start, ramp-up and ADD activation) = up to 184 hours (8 days) with 10 minute activation (209 hours (9 days) with 55 and 30 minute ADD activation); or
    ii. Piling of 224 pin-piles (2 x 96 concurrently installed) and two substations (including soft-start, ramp-up and ADD activation) = 440 hours (19 days) with 10 minute ADD activation (851.5 hours (36 days) with 30 minute ADD activation).

12.6.1.4.4.5 Impact Significance and Residual Impact

Impact Significance for Disturbance During Proposed ADD Activation

374. Taking into account the medium sensitivity (**Table 12-29**) 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 DEP and SEP together (**Table 12-60**).

375. The assessment of impact significance takes into account the duration of ADD activation for the DEP and SEP projects together.

376. The use of ADDs as mitigation to reduce the risk of auditory injury (PTS) to marine mammals will be developed during the developed of 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 12-60: Assessment of impact significance for disturbance from ADD activation at DEP and SEP together

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

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

377. Taking into account the medium sensitivity (**Table 12-29**) 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 12-61**).

378. The assessment of impact significance takes into account the duration of piling for the DEP and SEP projects together, as outlined in **Section 12.6.1.4.4.4**.

379. Further assessments in relation to the Southern North Sea SAC are provided in the information for the HRA.

380. The Southern North Sea SAC SIP will be developed (as outlined in **Section 12.3.4.2**) to set out the approach to deliver any project mitigation or management measures in relation to the disturbance of harbour porpoise.

Table 12-61: Assessment of impact significance for disturbance of harbour porpoise during pilling based on EDRs for DEP and SEP together

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	26km EDR for monopile	DEP & SEP	Medium	Negligible to Low	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
	15km EDR for pin-pile	DEP & SEP	Medium	Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**

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

381. 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^2s) has been assessed as minor adverse (not significant), based on 100%, 75% or 50% of all induvial in maximum area responding for DEP and SEP together (**Table 12-62**).

382. The assessment of impact significance takes into account the duration of active piling for the DEP and SEP projects, as outlined in **Section 12.6.1.4.4.4**.

Table 12-62: Assessment of impact significance for possible behavioural response of harbour porpoise during pilling at DEP and SEP together based on Lucke et al. (2009) criteria

Species	Impact	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Harbour porpoise	Possible behavioural response - 25km for monopile	DEP & SEP	Medium	Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
				Negligible	Minor		**Minor adverse**
	Possible behavioural response – 23km for pin-pile	DEP & SEP	Medium	Negligible	Minor	SIP (**Section 12.3.4.2**)	**Minor adverse**
				Negligible	Minor		**Minor adverse**

12.6.1.5 Impact 5: Impacts from Underwater Noise Associated with Other Construction Activities

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

384. 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.

385. 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).

386. 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.

387. 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 dredger (TSHD) dredgers 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).

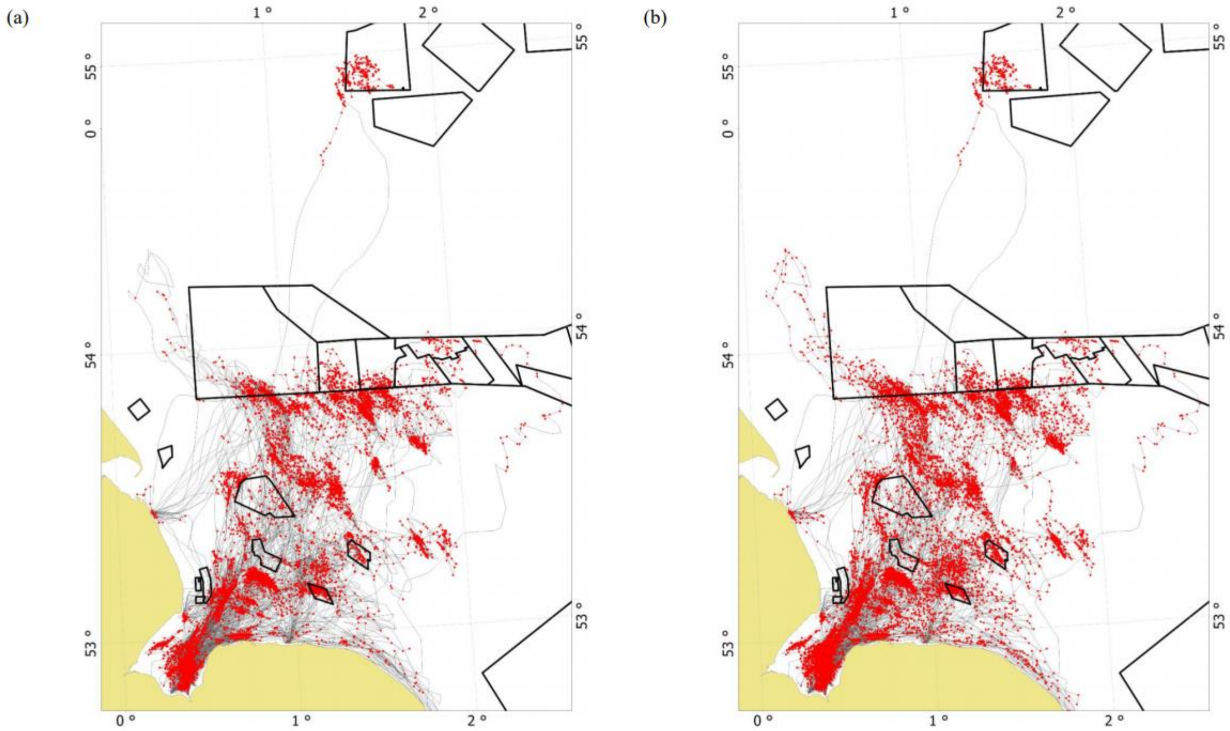
388. Reviews of published sources of underwater noise during dredging activity (e.g. Thomsen *et al*., 2006; Theobald *et al*., 2011; Todd *et al*., 2014), indicate that the sound levels that marine mammals may be exposed to during dredging activities are usually below auditory injury thresholds (PTS) 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 hearing loss (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).

389. 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).

390. 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 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).

391. 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 southern North Sea. The results of this study show foraging activity of harbour seal off the coast off Norfolk, and at DEP and SEP (**Plate 12-4**: 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, at the time of tagging (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 12-4: The tracks (grey) and estimated foraging locations (red) of tagged harbour seals in geo- (a) and hydro- (b) space (Russell, 2016b).



12.6.1.5.1 Sensitivity of Marine Mammals

392. The sensitivity of marine mammals to 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 12-29**). Marine mammals within the potential disturbance area are considered to have limited capacity to avoid such effects (**Table 12-8**), 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.

12.6.1.5.2 Underwater Noise Modelling

393. 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 DEP and SEP (see **Appendix 12.2** for further information). The activities that were assessed include:

- Cable laying (estimated sound source of 171dB re 1µPs @1m (RMS));
- Trenching (estimated sound source of 172dB re 1µPs @1m (RMS)): plough trenching may be required during the export cable installation;
- Rock placement (estimated sound source of 172dB re 1µPs @1m (RMS)): this is potentially required during offshore cable installation and scour protection;
- Drilling (estimated sound source of 169dB re 1µPs @1m (RMS)): drilling of the foundations may need to be undertaken in the case of impact piling refusal; and
- Dredging (estimated sound source of 186dB re 1µPs @1m (RMS)): a TSHD may be required for the export cable, array cable and interconnector cable installation.

394. For SEL_{cum} calculations, the duration the noise is also considered, with all sources operating for a worst case 12 hours in any given 24-hour period for non-impulsive noise.

395. 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 12.2** for further information).

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

12.6.1.5.2.1 Results

397. The results of the underwater noise modelling (**Table 12-63**) indicate that any marine mammal would have to be less than 100m (precautionary maximum range) from the continuous noise source for 12 hours in a 24 hour period, to be exposed to noise levels that could induce PTS or TTS / fleeing response based on the Southall *et al*. (2019) non-impulsive thresholds and criteria for SEL_{cum}. With the exception of harbour porpoise and the predicted impact ranges for TTS / fleeing response of 1km for rock placement and 0.2km for dredging.

12.6.1.5.3 Magnitude for DEP or SEP in Isolation

398. 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, other than piling (**Table 12-63**).

399. It is important to note that permanent auditory injury (PTS) is unlikely to occur in marine mammals, as the modelling indicates that the marine mammal would have to remain less than 100m for 12 hours in any given 24-hour period for any potential risk of permanent auditory injury (PTS) (**Table 12-63**). Therefore, permanent auditory injury (PTS) as a result of construction activity, other than piling, is highly unlikely and has not been further assessed.

400. Similarly, there is unlikely to be any significant risk of any temporary change in hearing sensitivity (TTS), as again the modelling indicates that the marine mammal would have to remain less than 100m for 12 hours in any given 24-hour period. With exception of harbour porpoise which would have to remain 1km or less than 200m during rock placement or dredging for 12 hours in any given 24-hour period to be at risk of TTS (**Table 12-63**). Therefore, TTS as a result of construction activity, other than piling, is highly unlikely.

401. 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 12-63**, with the estimated number and percentage of reference populations in **Table 12-64** providing an indication of possible fleeing response.

402. The magnitude of the potential impact for any temporary change in hearing sensitivity (TTS) / fleeing response 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 12-64**).

403. 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 has also been undertaken. The magnitude of the potential impact of temporary auditory impacts (TTS) / fleeing response 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 12-64**).

404. The potential 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 DEP and SEP and would be limited to only part of the overall construction period and area at any one time.

405. 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 activities other than piling noise will be both localised and temporary. Therefore, there is unlikely to be the potential for any significant impact on marine mammals.

Table 12-63: Predicted impact ranges (and areas) for PTS and TTS / fleeing response from cumulative exposure of other construction activities based on Southall et al. (2019) thresholds and criteria

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Cable laying	Trenching	Rock placement	Drilling	Dredging
Harbour porpoise (VHF)	Auditory injury (PTS)	SEL_{cum} Weighted (173 dB re 1 µPa^{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)
	TTS / fleeing response	SEL_{cum} Weighted (153 dB re 1 µPa^{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)**
Bottlenose dolphin and white-beaked dolphin (HF)	Auditory injury (PTS)	SEL_{cum} Weighted (198 dB re 1 µPa^{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)
	TTS / fleeing response	SEL_{cum} Weighted (178 dB re 1 µPa^{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)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Cable laying	Trenching	Rock placement	Drilling	Dredging
Minke whale (LF)	Auditory injury (PTS)	SEL_{cum} Weighted (199 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)
	TTS / fleeing response	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)
Grey and harbor seal (PW)	Auditory injury (PTS)	SEL_{cum} Weighted (201 dB re 1 $\mu Pa^2 s$) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)
	TTS / fleeing response	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)

Table 12-64: 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 DEP or SEP

Potential Impact	Species	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)
TTS / fleeing response from cumulative SEL, based on 12 hour exposure, for: - Cable laying - Trenching - Drilling	Harbour porpoise (VHF)	DEP or SEP	0.03 (0.000009% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 0.03 (0.000008% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**	3.5 (0.001% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 3 (0.0009% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
TTS / fleeing response from cumulative SEL, based on 12 hour exposure, for: - Rock placement	Harbour porpoise (VHF)	DEP or SEP	3.3 (0.001% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 2.8 (0.0008% of NS MU)	**Negligible**		

Potential Impact	Species	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)
			(SCANS-III density of 0.888/km^2)			
TTS / fleeing response from cumulative SEL, based on 12 hour exposure, for: - Dredging	Harbour porpoise (VHF)	DEP or SEP	0.14 (0.00004% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 0.12 (0.00003% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**		
TTS / fleeing response from cumulative SEL, based on 12 hour exposure, for:	Bottlenose dolphin (HF)	DEP or SEP	0.0009 (0.00005%; 0.0005% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**	0.005 (0.0002%; 0.002% of CES MU) (SCANS-III	**Negligible**

Potential Impact	Species	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)
- Cable laying - Trenching - Rock placement - Drilling - Dredging					density of 0.03/km^2)	
	White-beaked dolphin (HF)	DEP or SEP	0.0002 (0.000001% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**	0.0009 (0.000006% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
TTS / fleeing response from cumulative SEL, based on 12 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging	Minke whale (LF)	DEP or SEP	0.0003 (0.000001% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**	0.002 (0.000006% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
TTS / fleeing response from cumulative SEL,	Grey seal (PW)	DEP or SEP	0.01 (0.00004% of ref pop (or 0.0001% of SE MU)	**Negligible**	0.05 (0.0002% of ref pop (or 0.0006% of SE	**Negligible**

Potential Impact	Species	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 12 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging			(DEP, SEP & cable export area density of 0.35/km^2)		MU) (DEP, SEP & cable export area density of 0.35/km^2)	
	Harbor seal (PW)	DEP or SEP	0.006 (0.00001% of ref pop (or 0.0001% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible**	0.03 (0.00006% of ref pop (or 0.0006% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible**

12.6.1.5.3.1 Duration of Other Construction Activities

406. 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 5 Project Description**.

407. The duration of offshore export cable installation and trenching activities is expected to take approximately 60 day and 50 days for DEP and SEP export cables, respectively (**Table 12-2**).

12.6.1.5.4 Impact Significance

408. Taking into account the marine mammal sensitivity to TTS / fleeing response (**Table 12-29**) and the potential magnitude of the impact, as assessed in **Table 12-64**, the impact significance for TTS / fleeing response for construction activities other than piling at either DEP or SEP has been assessed as **minor adverse** (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-65**).

Table 12-65: Assessment of impact significance for TTS / fleeing response for underwater noise from construction activities other than piling

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS / fleeing response from cumulative SEL during other construction activities	Harbour porpoise	DEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Bottlenose dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Minke whale	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Grey seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Harbour seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.1.5.5 Mitigation

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

12.6.1.5.6 Impact Assessment for DEP and SEP Together

410. 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 DEP and SEP together, if they are developed concurrently (**Table 12-66**).

411. The magnitude of the potential impact for TTS / fleeing response during construction activities other than piling at DEP and SEP together is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-66**).

Table 12-66: 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 DEP and SEP together

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude (temporary impact)
TTS / fleeing response from cumulative SEL, based on 12 hour exposure, for: - Cable laying - Trenching - Rock placement - Drilling - Dredging	Harbour porpoise (VHF)	DEP & SEP	7 (0.002% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 6 (0.002% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	Bottlenose dolphin (HF)	DEP & SEP	0.009 (0.0005%; 0.005% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for TTS for all activities at the same time	Magnitude (temporary impact)
	White-beaked dolphin (HF)	DEP & SEP	0.002 (0.00001% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	Minke whale (LF)	DEP & SEP	0.003 (0.00001% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	Grey seal (PW)	DEP & SEP	0.11 (0.0004% of ref pop (or 0.001% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Negligible**
	Harbor seal (PW)	DEP & SEP	0.06 (0.0001% of ref pop (or 0.001% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible**

12.6.1.5.6.1 Duration of Other Construction Activities

412. 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 DEP and SEP together. However, construction activities would not be underway constantly throughout this period.

413. The duration of offshore export cable installation and trenching activities is expected to take approximately 110 days for DEP and SEP together.

12.6.1.5.6.2 Impact Significance

414. Taking into account the medium sensitivity to TTS / fleeing response (**Table 12-29**) and the potential magnitude of the impact, as assessed in **Table 12-66**, the impact significance for PTS and TTS / fleeing response for construction activities other than piling at DEP and SEP together has been assessed as **minor adverse** (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-67**).

Table 12-67: Assessment of impact significance for TTS / fleeing response from construction activities other than piling at DEP and SEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS / fleeing response from cumulative SEL during other construction activities	Harbour porpoise	DEP & SEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
	Bottlenose dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Minke whale	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Grey seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Harbour seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**

12.6.1.5.6.3 Mitigation

415. No mitigation is required or proposed for underwater noise from construction activities, other than piling, as the risk of any impacts is negligible.

12.6.1.6 Impact 6: Impacts from Underwater Noise and Disturbance Associated with Construction Vessels

416. During the construction phase there will be an increase in the number of vessels, this is estimated to be up to 16 vessels on DEP or SEP site including export cable route at any one time. The number, type and size of vessels will vary depending on the activities taking place at any one time.

417. 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 DEP and SEP sites and offshore cable corridor area.

418. 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 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.

419. As outlined in **Section 12.6.1.3.4**, Brandt *et al*. (2018) found that at seven German offshore windfarms 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).

420. 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).

421. **Chapter 15 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.

422. Shipping and Navigation data indicate 14 existing main routes within the study area, with four routes crossing the DEP wind farm site and 10 the cable corridor. The number of vessels on these main vessel routes could be up to 75 vessels per day (see **Chapter 15 Shipping and Navigation**).

423. As described within the **Appendix 15.1 Navigational Risk Assessment**, there is an existing relatively high level of vessel traffic within the navigational study area (DEP and SEP plus 10km buffer), including area close to the coastline. In summer, an average of 79 vessels were recorded per day within the study area, and in winter an average of 87 vessels were recorded.

424. 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 15 Shipping and Navigation**).

425. 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.

426. Trigg *et al*. (2020) found the predicted exposure of grey seals to shipping noise did not exceed thresholds for temporary threshold shift.

427. 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.

12.6.1.6.1 Sensitivity of Marine Mammals

428. The sensitivity of marine mammals to temporary auditory effects (TTS) / fleeing response is considered to be medium (see **Section 12.6.1.3.1**).

12.6.1.6.2 Underwater Noise Modelling

429. Underwater noise modelling was undertaken to assess the impact ranges of vessels 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; using measured sound source data scaled to relevant parameters for DEP and SEP (see **Appendix 12.2** 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).

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

431. 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 12.2** for further information).

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

12.6.1.6.2.1 Results

433. The results of the underwater noise modelling (**Table 12-68**) 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 / fleeing response based on the Southall *et al*. (2019) thresholds and criteria.

Table 12-68: Predicted impact ranges (and areas) for PTS and TTS / fleeing response from cumulative exposure of construction vessels based on Southall et al. (2019) thresholds and criteria

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Large vessel	Medium vessel
Harbour porpoise (VHF)	Auditory injury (PTS)	SEL_{cum} Weighted (173 dB re 1 µPa^{2}s) Non-impulsive	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)

Species	Impact	Criteria and threshold (Southall *et al.*, 2019)	Large vessel	Medium vessel
	TTS / fleeing response	SEL_{cum} Weighted (153 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
Bottlenose dolphin and white-beaked dolphin (HF)	Auditory injury (PTS)	SEL_{cum} Weighted (198 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
	TTS / fleeing response	SEL_{cum} Weighted (178 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
Minke whale (LF)	Auditory injury (PTS)	SEL_{cum} Weighted (199 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
	TTS / fleeing response	SEL_{cum} Weighted (179 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
Grey and harbor seal (PW)	Auditory injury (PTS)	SEL_{cum} Weighted (201 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
	TTS / fleeing response	SEL_{cum} Weighted (181 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)

12.6.1.6.3 *Magnitude for DEP or SEP in Isolation*

434. Permanent auditory injury (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 (**Table 12-68**). Therefore, PTS as a result of underwater noise from construction vessels is highly unlikely and has not been assessed further.

435. The number of marine mammals that could be impacted from any temporary auditory impacts (TTS) / fleeing response 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 12-68**) and for up to 16 vessels at each site, including the cable corridor area (0.48km^2; **Table 12-69**).

436. 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 12-69**).

437. 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 12-68**, with the estimated number and percentage of reference populations in **Table 12-69** providing an indication of possible fleeing response.

438. 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.

Table 12-69: Maximum number of individuals (and % of reference population) that could be impacted as a result of underwater noise associated with all construction vessels at DEP or SEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude (temporary impact)
TTS / fleeing response from cumulative SEL, based on 24 hour exposure for large or medium vessels	Harbour porpoise (VHF)	DEP or SEP	0.5 (0.0001% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 0.43 (0.0001% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude (temporary impact)
	Bottlenose dolphin (HF)	DEP or SEP	0.01 (0.001%; 0.01% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**
	White-beaked dolphin (HF)	DEP or SEP	0.003 (0.00002% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	Minke whale (LF)	DEP or SEP	0.005 (0.00002% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	Grey seal (PW)	DEP or SEP	0.17 (0.0007% of ref pop (or 0.002% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Negligible**
	Harbor seal (PW)	DEP or SEP	0.09 (0.0002% of ref pop (or 0.002% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible**

12.6.1.6.3.1 Duration of Construction Vessels

439. 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 DEP or SEP site, including cable corridor area, for two years.

12.6.1.6.4 Impact Significance

440. Taking into account the marine mammal sensitivity to TTS / fleeing response (**Table 12-29**) and the potential magnitude of the impact, as assessed in **Table 12-69**, the impact significance for TTS / fleeing response for underwater noise from construction vessels at either DEP or SEP has been assessed as minor adverse (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-70**).

Table 12-70: Assessment of impact significance for TTS / fleeing response for underwater noise from construction vessels

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS / fleeing response from cumulative SEL for construction vessels	Harbour porpoise	DEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Bottlenose dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Minke whale	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Grey seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Harbour seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.1.6.5 Mitigation

441. No mitigation is required or proposed for underwater noise from construction vessels, as the risk of any impact is negligible.

12.6.1.6.6 Impact Assessment for DEP and SEP Together

442. 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 DEP and SEP together, if they are developed concurrently (**Table 12-71**). The assessment is based on up to 25 vessels on both sites at the same time (an area of 0.75km^2).

443. The magnitude of the potential impact for TTS / fleeing response for underwater noise from construction vessels at DEP and SEP together is assessed as negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-71**).

Table 12-71: Maximum number of individuals (and % of reference population) that could be impacted as a result of underwater noise associated with all construction vessels at DEP and SEP together

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude (temporary impact)
TTS / fleeing response from cumulative SEL, based on 24 hour exposure, for large or medium vessels	Harbour porpoise (VHF)	DEP & SEP	0.79 (0.0002% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 0.67 (0.0002% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	Bottlenose dolphin (HF)	DEP & SEP	0.02 (0.001%: 0.01% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible**
	White-beaked dolphin (HF)	DEP & SEP	0.005 (0.00003% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	Minke whale (LF)	DEP & SEP	0.008 (0.00003% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	Grey seal (PW)	DEP & SEP	0.26 (0.001% of ref pop (or 0.003% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Negligible**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population) for all vessels	Magnitude (temporary impact)
	Harbor seal (PW)	DEP & SEP	0.14 (0.0003% of ref pop (or 0.003% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible**

12.6.1.6.6.1 Duration of Construction Vessels

444. 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 DEP and SEP together, including cable corridor areas, for four years.

12.6.1.6.6.2 Impact Significance

445. Taking into account the medium sensitivity to TTS / fleeing response (**Table 12-29**) and the potential magnitude of the impact, as assessed in **Table 12-71**, the impact significance for TTS / fleeing response for underwater noise from construction vessels at DEP and SEP together has been assessed as **minor adverse** (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-72**).

Table 12-72: Assessment of impact significance for TTS / fleeing response for underwater noise from construction vessels at DEP and SEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS / fleeing response from cumulative SEL for construction vessels	Harbour porpoise	DEP & SEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
	Bottlenose dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Minke whale	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Grey seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Harbour seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**

12.6.1.6.6.3 Mitigation

446. No mitigation is required or proposed for underwater noise from construction vessels, as the risk of any impact is negligible.

12.6.1.7 Impact 7: Barrier Effects from Underwater Noise during Construction

447. 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, DEP and SEP, including the export cable route are not located on any known migration routes for marine mammals.

12.6.1.7.1 Sensitivity of Marine Mammals

448. Telemetry studies (see **Appendix 12.1**) and the relatively low seal at sea usage (Russell *et al*., 2017; see **Appendix 12.1**) in and around DEP and SEP do not indicate any regular seal foraging routes through the site.

449. **Plate 12-4** in **Section 12.6.1.5** indicates that harbour seal will still undertake foraging activity during wind farm construction activities, based on study by Russell (2016b).

450. Marine mammals are assessed as having medium sensitivity to any barrier effect as a result of disturbance or displacement from underwater noise (**Table 12-29**).

12.6.1.7.2 Magnitude for DEP or SEP in Isolation

451. The worst-case scenario in relation to barrier effects as a result of underwater noise is based on the maximum spatial and temporal (i.e. longest duration) scenarios.

452. The spatial worst-case is the maximum area over which potential disturbance could occur at any one time. This would be the potential disturbance of harbour porpoise based on 26km EDR for a single monopile installation at DEP or SEP as assessed in **Section 12.6.1.4.2.3**. DEP and SEP are located 13.6km and 24.8km from the coast, respectively, therefore any other construction activities, including vessels, in the export cable route would be within the 26km EDR.

453. DEP has an area of 103.5km^2, with an estimated export cable area of approximately 19.23km^2. SEP has an area of 92.6km^2, with an estimated export cable area of approximately 24.6km^2. Therefore, the 2,124km^2 area for the 26km EDR at DEP would cover the DEP plus export cable area and the 2,124km^2 area for the 26km EDR at SEP would cover SEP plus export cable area.

454. As a result, there would be no additional disturbance of harbour porpoise from construction noise sources at DEP or SEP in addition to the 26km EDR. This would include ADD activation which would also be within the 26km EDR (**Table 12-73**).

455. For the other marine mammal species, for which there are no EDRs and it is not applicable to use the 26km EDR for harbour porpoise, the potential barrier effects has been based on the maximum potential disturbance from piling at the same time as other potential construction activities, including vessels, in the export cable route.

456. For bottlenose dolphin and white-beaked dolphin this has been based on the total area of DEP plus export cable route (114.33km^2) and SEP plus export cable route (117.2km^2) as these areas area greater than the maximum impact area for 55 minute ADD activation (77km^2), plus maximum TTS / fleeing response SEL_{cum} areas for piling (0.44km^2 for DEP and 0.33km^2 for SEP), plus all other construction activities (0.15km^2 at DEP or SEP) and all vessels (0.48km^2 for DEP or SEP), with unlikely total area of up to 79km^2 for DEP or SEP, as most of these areas would overlap and would not be additive (**Table 12-73**).

457. For minke whale, potential barrier effects from underwater noise have been based on the maximum TTS / fleeing response SEL_{cum} range and area for piling (25km with an area of 1,100km^2 at DEP and 20km with an area of 720km^2 at SEP), as outlined above for harbour porpoise 26km EDR this range and area would include the DEP or SEP sites plus export cable routes and therefore all activities and noise sources within the area, including ADD activation and other construction activities, including vessels, in the export cable route (**Table 12-73**).

458. For grey seal and harbour seal, the potential for barrier effects has been based on the unlikely worst-case scenario for the maximum impact area for 55 minute ADD activation (77km^2), plus maximum TTS / fleeing response SEL_{cum} areas for piling (220km^2 for DEP and 140km^2 for SEP), plus all other construction activities (0.15km^2 at DEP or SEP) and all vessels (0.48km^2 for DEP or SEP), with unlikely total area of up to 298km^2 for DEP or 218km^2 SEP, as most of these areas would overlap and would not be additive (**Table 12-73**).

459. The areas have been based on the maximum worst-case impact areas for monopiles without mitigation.

460. The maximum duration of for any barrier effects would the maximum piling at DEP and SEP, based on worst-case scenarios, including soft-start, ramp-up and ADD activation, as assessed in **Table 12-53**.

461. 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 12-73**).

Table 12-73: Potential barrier effects from underwater noise during construction at DEP or SEP

Species	Location	Barrier Effect	Maximum area at any one time	Maximum duration for piling	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Harbour porpoise	DEP including export cable route	26km EDR	2,124km^2	Up to 35 days	2,230 (0.65% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 1,886 (0.55% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	SEP including export cable route	26km EDR	2,124km^2	Up to 14 days	2,230 (0.65% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 1,886 (0.55% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
Bottlenose dolphin	DEP including export cable route	Area of DEP and export cable route	122.73km^2	Up to 35 days	3.68 (0.19%; 1.89% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**
	SEP including export cable route	Area of DEP and export cable route	117.2km^2	Up to 14 days	3.52 (0.18%;1.80% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**

Species	Location	Barrier Effect	Maximum area at any one time	Maximum duration for piling	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
White-beaked dolphin	DEP including export cable route	Area of DEP and export cable route	122.73km^2	Up to 35 days	0.74 (0.005% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	SEP including export cable route	Area of DEP and export cable route	117.2km^2	Up to 14 days	0.70 (0.004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
Minke whale	DEP including export cable route	Maximum TTS / fleeing response SEL_{cum} range (25km)	1,100km^2	Up to 35 days	11 (0.05% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	SEP including export cable route	Maximum TTS / fleeing response SEL_{cum} range (20km)	720km^2	Up to 14 days	7.2 (0.03% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
Grey seal	DEP including export cable route	Maximum TTS / fleeing response SEL_{cum} for	298km^2	Up to 35 days	104 (0.43% of ref pop (or 1.27% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Negligible (low)**

Species	Location	Barrier Effect	Maximum area at any one time	Maximum duration for piling	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
		piling, ADDs, all other construction activities and all vessels.				
	SEP including export cable route	Maximum TTS / fleeing response SEL_{cum} for piling, ADDs, all other construction activities and all vessels.	218km^2	Up to 14 days	76 (0.32% of ref pop (or 0.93% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Negligible (negligible)**
Harbour seal	DEP including export cable route	Maximum TTS / fleeing response SEL_{cum} for piling, ADDs, all other	298km^2	Up to 35 days	57 (0.12% of ref pop (or 1.14% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible (low)**

Species	Location	Barrier Effect	Maximum area at any one time	Maximum duration for piling	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
		construction activities and all vessels.				
	SEP including export cable route	Maximum TTS / fleeing response SEL_{cum} for piling, ADDs, all other construction activities and all vessels.	218km^2	Up to 14 days	41 (0.09% of ref pop (or 0.83% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible (negligible)**

12.6.1.7.3 Impact Significance

462. Taking into account the medium marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-73**, the impact significance for any potential barrier effects at either DEP or SEP 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 12-74**).

Table 12-74: Assessment of impact significance for any potential barrier effects from underwater noise during construction at DEP or SEP

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

12.6.1.7.4 Mitigation

463. The Southern North Sea SAC SIP will be developed (as outlined in **Section 12.3.4.2**) to set out the approach to deliver any project mitigation or management measures in relation to the significant disturbance of harbour porpoise.

464. 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.

12.6.1.7.5 Impact Assessment for DEP and SEP Together

465. 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 as a result of potential barrier effects from underwater noise if are developed DEP and SEP together concurrently (**Table 12-76**).

466. The magnitude of impact for any potential temporary barrier effects, based on worst-case, for DEP and SEP together is assessed as low for harbour porpoise, negligible for bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-76**).

12.6.1.7.5.1 Impact Significance

467. Taking into account the marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-76**, the impact significance for any potential barrier effects as a result of underwater noise during concurrent construction at DEP and SEP together has been assessed as minor adverse (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-75**).

12.6.1.7.5.2 Mitigation

468. As outlined in **Section 12.6.1.7.4** for DEP or SEP alone.

Table 12-75: Assessment of impact significance for any potential barrier effects from underwater noise during construction at DEP and SEP together

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

Table 12-76: Potential barrier effects from underwater noise during construction at DEP and SEP together

Species	Location	Barrier Effect	Maximum area at any one time	Maximum duration for piling	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Harbour porpoise	DEP & SEP including export cable routes	26km EDR x 2	4,248km^2	Up to 49 days	4,460 (1.29% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 3,772 (1.09% of NS MU) (SCANS-III density of 0.888/km^2)	**Low**
Bottlenose dolphin	DEP & SEP including export cable routes	Area of DEP & SEP and export cable routes	239.93km^2	Up to 49 days	7.20 (0.37%; 3.69% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**
White-beaked dolphin	DEP & SEP including export cable routes	Area of DEP & SEP and export cable routes	239.93km^2	Up to 49 days	1.44 (0.005% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
Minke whale	DEP & SEP including export cable routes	Maximum TTS / fleeing response SEL_{cum} range (25km + 20km))	1,820km^2	Up to 49 days	18.2 (0.08% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
Grey seal	DEP & SEP including	Maximum TTS / fleeing response SEL_{cum} for piling,	516km^2	Up to 49 days	181 (0.75% of ref pop (or 2.20% of SE MU)	**Negligible (low)**

Species	Location	Barrier Effect	Maximum area at any one time	Maximum duration for piling	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
	export cable routes	ADDs, all other construction activities and all vessels.			(DEP, SEP & cable export area density of 0.35/km^2)	
Harbour seal	DEP & SEP including export cable routes	Maximum TTS / fleeing response SEL_{cum} for piling, ADDs, all other construction activities and all vessels.	516km^2	Up to 49 days	98 (0.21% of ref pop (or 1.98% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Negligible (low)**

12.6.1.8 Impact 8: Increased Risk of Collision with Vessels during Construction

469. During the offshore construction phase of DEP and SEP there will be an increase in vessel traffic within the offshore development area and to and from the windfarm site. 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.

12.6.1.8.1 Sensitivity of Marine Mammals

470. Marine mammals in and around DEP and SEP and in the wider Southern North Sea area would typically be habituated to the presence of vessels (given the existing levels of marine traffic, see **Chapter 15 Shipping and Navigation**) and would be able to detect and avoid vessels. Therefore, the sensitivity of marine mammals to collision risk with vessels during construction is considered to be low.

12.6.1.8.2 Magnitude for DEP or SEP in Isolation

471. The approximate number of vessels on site at any one time during construction is estimated to be 16 vessels at DEP or SEP, 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 12-2**).

472. As outlined in **Chapter 15 Shipping and Navigation**, the baseline conditions indicate an already relatively high level of shipping activity in and around DEP, SEP and the export corridor routes. Shipping and Navigation data indicate 14 existing main routes within the study area, with four routes crossing the DEP wind farm site and 10 the cable corridor. The number of vessels on these main vessel routes could be up to 75 vessels per day.

473. As described within the **Appendix 15.1 Navigational Risk Assessment**, there is an existing relatively high level of vessel traffic within the navigational study area (DEP and SEP plus 10km buffer), including area close to the coastline. In summer, an average of 79 vessels were recorded per day within the study area, and in winter an average of 87 vessels were recorded.

474. In total, for the construction of either DEP or SEP, the daily construction vessels trips, represents very small increase of 1% compared to average daily vessels (n=79, in summer) currently within the DEP and SEP vessel and navigation study area, or an increase of 0.95% compared to the average daily vessels present in winter (n=87).

475. 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 out-with recognised vessel routes, can pose an increased risk of vessel collision to marine mammals.

476. 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).

477. Harbour porpoise are small and highly mobile and given their responses to vessel noise (e.g. Thomsen *et al*., 2006; Evans *et al*., 1993; 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.

478. Of the 274 reported harbour porpoise strandings in 2015 (latest UK Cetacean Stranding's Investigation Programme (CSIP) Report currently available), 53 were investigated at post mortem (27 were conducted in England, 13 in Scotland and 13 in Wales). A cause of death was established in 51 examined individuals (approximately 96% of examined cases). Of these, four (8%) had died from physical trauma of unknown cause, which could have been vessel strikes (CSIP, 2015). 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).

479. There is currently limited information on the collision risk of marine mammals in the Southern North Sea area.

480. Although the risk of collision is likely to be low, as a precautionary worse-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 DEP, SEP and export cable areas potentially being at increased collision risk (**Table 12-77**). This has been based on the percentage of harbour porpoise post mortem examinations in the ASCOBANS area with evidence of interaction with vessels.

481. This is a highly precautionary assumption, as it is unlikely that marine mammals present in the DEP, SEP and export cable areas would be at increased collision risk with vessels during construction, considering the minimal number of vessel movements compared to the existing number vessel movements in the area and that vessels within the wind farm 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 (**Section 12.6.1.5.6.3**), there should be no potential for increased collision risk with construction vessels.

482. The potential for increased collision risk with construction vessels based on precautionary worst-case scenario has been assessed as low for harbour porpoise and bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, low for grey seal and for harbour seal (**Table 12-77**).

483. However, as previously outlined, taking into account the disturbance from vessels the actual risk is likely to be very low or negligible.

Table 12-77: 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 DEP or SEP and export cable routes

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	**Magnitude (permanent impact)**
Harbour porpoise	DEP and export cable area (122.73km^2)	6.4 (0.002% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 5.4 (0.002% of NS MU) (SCANS-III density of 0.888/km^2)	**Low**
	SEP and export cable area (117.2km^2)	6.2 (0.002% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 5.2 (0.002% of NS MU) (SCANS-III density of 0.888/km^2)	**Low**
Bottlenose dolphin	DEP and export cable area (122.73km^2)	0.18 (0.009%; 0.09% of CES MU) (SCANS-III density of 0.03/km^2)	**Low (medium)**
	SEP and export cable area (117.2km^2)	0.18 (0.009%; 0.09% of CES MU) (SCANS-III density of 0.03/km^2)	**Low (medium)**
White-beaked dolphin	DEP and export cable area (122.73km^2)	0.04 (0.0002% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	SEP and export cable area (117.2km^2)	0.04 (0.0002% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	Magnitude (permanent impact)
Minke whale	DEP and export cable area (122.73km^2)	0.06 (0.0003% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	SEP and export cable area (117.2km^2)	0.06 (0.0003% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
Grey seal	DEP and export cable area (122.73km^2)	2.1 (0.009% of ref pop (or 0.03% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Low (medium)**
	SEP and export cable area (117.2km^2)	2.1 (0.009% of ref pop (or 0.03% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Low (medium)**
Harbor seal	DEP and export cable area (122.73km^2)	1.2 (0.002% of ref pop (or 0.02% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Low (medium)**
	SEP and export cable area (117.2km^2)	1.1 (0.002% of ref pop (or 0.02% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Low (medium)**

12.6.1.8.3 Impact Significance

484. Taking into account the low marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-77**, the impact significance for any potential increased collision risk as a result of vessels during construction at either DEP or SEP 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 12-78**).

Table 12-78: Assessment of impact significance for any increased collision risk with vessels during construction at DEP or SEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Increased collision risk	Harbour porpoise	DEP	Low	Low	Minor	No further mitigation proposed other than good practice.	**Negligible**
		SEP		Low	Minor		**Negligible**
	Bottlenose dolphin	DEP	Low	Low	Minor		**Negligible**
		SEP		Low	Minor		**Negligible**
	White-beaked dolphin	DEP	Low	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Minke whale	DEP	Low	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Grey seal	DEP	Low	Low	Minor		**Negligible**
		SEP		Low	Minor		**Negligible**
	Harbour seal	DEP	Low	Low	Minor		**Negligible**
		SEP		Low	Minor		**Negligible**

12.6.1.8.4 Mitigation

485. 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 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.

12.6.1.8.5 Residual Impact

486. The residual impact, taking into account good practice to reduce any risk of collisions with marine mammals, would be negligible at either DEP or SEP for all marine mammals. There have been no known reported incidents of marine mammal collisions with offshore wind farm vessels.

12.6.1.8.6 Impact Assessment for DEP and SEP Together

487. As a precautionary worst-case the number of marine mammals that could be at increased risk of collision with construction vessels, if DEP and SEP are constructed concurrently has been based on the estimated maximum number of DEP and SEP alone (**Table 12-79**).

488. The potential for increased collision risk with construction vessels based on precautionary worst-case scenario has been assessed as low for harbour porpoise, medium of bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, medium (medium) for grey seal and low (medium) for harbour seal (**Table 12-79**).

489. 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 DEP and SEP. 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 risk of bottlenose dolphin is likely to be a lot less than in the worst-case assessment.

490. In addition, as previously outlined, taking into account the disturbance from vessels the actual risk is likely to be very low or negligible.

Table 12-79: 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 DEP and SEP and export cable routes

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	Magnitude (permanent impact)
Harbour porpoise	DEP & SEP and export cable areas (239.93km^2)	12.6 (0.004% of NS MU) (DEP, SEP & cable export area density of 1.05/km^2) 10.7 (0.003% of NS MU) (SCANS-III density of 0.888/km^2)	**Low**
Bottlenose dolphin	DEP & SEP and export cable areas (239.93km^2)	0.36 (0.02%; 0.18% of CES MU) (SCANS-III density of 0.03/km^2)	**Medium**
White-beaked dolphin	DEP & SEP and export cable areas (239.93km^2)	0.07 (0.0005% of CGNS MU)	**Negligible**

Species	Location	5% Vessel Collision Risk	
		Maximum number of individuals (% of reference population)	Magnitude (permanent impact)
		(DEP and SEP density of 0.006/km^2)	
Minke whale	DEP & SEP and export cable areas (239.93km^2)	0.12 (0.0005% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
Grey seal	DEP & SEP and export cable areas (239.93km^2)	4.2 (0.02% of ref pop (or 0.05% of SE MU) (DEP, SEP & cable export area density of 0.35/km^2)	**Medium (medium)**
Harbor seal	DEP & SEP and export cable areas (239.93km^2)	2.3 (0.005% of ref pop (or 0.05% of SE MU) (DEP, SEP & cable export area density of 0.19/km^2)	**Low (medium)**

12.6.1.8.6.1 Impact Significance

491. Taking into account the low marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-79**, the impact significance for any potential increased collision risk as a result of vessels during construction of DEP and SEP together 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 12-80**).

Table 12-80: Assessment of impact significance for any increased collision risk with vessels during construction at DEP and SEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Increased collision risk	Harbour porpoise	DEP & SEP	Low	Low	Minor	No further mitigation proposed other than good practice.	**Negligible**
	Bottlenose dolphin	DEP & SEP	Low	Medium	Minor		**Negligible**
	White-beaked dolphin	DEP & SEP	Low	Negligible	Negligible		**Negligible**
	Minke whale	DEP & SEP	Low	Negligible	Negligible		**Negligible**

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Grey seal	DEP & SEP	Low	Medium	Minor		**Negligible**
	Harbour seal	DEP & SEP	Low	Low	Minor		**Negligible**

12.6.1.8.6.2 Mitigation

492. As outlined in **Section 12.6.1.8.4**.

12.6.1.8.7 Residual Impact

493. The residual impact, taking into account good practice to reduce any risk of collisions with marine mammals, would be negligible for all marine mammals.

12.6.1.9 Impact 9: Disturbance at Seal Haul-Out Sites

494. 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 12.5.5**). For harbour seal, the pupping season is between June and July (see **Section 12.5.6**).

495. Disturbance from vessel transits to and from DEP and SEP also has the potential to disturb seals at haul-out sites, depending on the route and proximity to the haul-out sites.

496. The Blakeney Point haul-out site is located closest to the proposed DEP and SEP sites, 12km from the nearest Project boundary (including export cable corridors and landfall locations). As outlined in **Sections 12.5.5** and **12.5.6**, the Blakeney Point haul-out site has significant number of both grey seal and harbour seal. Other haul-out sites are further from the proposed DEP and SEP sites 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 DEP and SEP project and the nearest known seal haul-out sites; there is very little potential for any direct disturbance as a result of construction activities.

497. The construction port(s) to be used for DEP and SEP is not yet known and could be located on the east coast of England. 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.

498. There is an existing relatively high level of vessel traffic within the navigational study area (DEP and SEP plus 10km buffer), including close to the coastline. In summer, an average of 79 vessels were recorded per day within the study area, and in winter an average of 87 vessels were recorded (**Appendix 15.1 Navigational Risk Assessment**). High density navigation routes[1] 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.

12.6.1.9.1 Sensitivity of Seals

499. 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.

500. 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.

501. 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).

502. 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).

503. 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).

[1] https://explore-marine-plans.marineservices.org.uk/ [accessed 24/02/2021]

504. 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).

505. 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.

506. 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.

507. 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.

12.6.1.9.2 Magnitude for DEP or SEP in Isolation

508. DEP and SEP are located 12km at closest point to any seal haul-out site (**Sections 11.5.5** and **12.5.6**), there is therefore no potential for any direct disturbance as a result of construction activities within either DEP or SEP (including landfall and the export cable corridor).

509. 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.

510. Vessel movements to DEP and SEP from the chosen construction port(s) would use direct 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.

511. 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.

512. In total, for the construction of either DEP or SEP, up to 21 construction vessels may be on the site at any one time, representing an increase of 27% compared to average daily vessels (n=79, in summer) currently within the DEP and SEP vessel and navigation study area, or an increase of 24% compared to the average daily vessels present in winter (n=87). This represents a relatively significant increase in the current number of vessels in the area.

513. 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.

12.6.1.9.2.1 Impact Significance

514. Taking into account the negligible to low sensitivity, and the potential magnitude of negligible for the temporary impact, the impact significance for disturbance at seal haul-out sites during construction of DEP or SEP has been assessed as negligible to minor adverse (not significant) for both grey seal and harbour seal (**Table 12-81**).

Table 12-81: 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	DEP	Low to Medium	Negligible	Negligible to minor	No further mitigation proposed other than good practice.	**Negligible to Minor adverse**
		SEP		Negligible	Negligible to minor		**Negligible to Minor adverse**
	Harbour seal	DEP	Low to Medium	Negligible	Negligible to minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to minor		**Negligible to Minor adverse**

12.6.1.9.2.2 Mitigation

515. 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.

12.6.1.9.3 Impact Assessment for DEP and SEP Together

516. The impacts for DEP and SEP together would be the same as those assessed for DEP and SEP separately, as both the number of construction vessels at the site at any one time, and the vessel transit routes would remain the same.

12.6.1.10 Impact 10: Changes to Prey Availability

517. As outlined in **Chapter 11 Fish and Shellfish Ecology**, the potential impacts on fish species during construction can result from:

- Physical disturbance and temporary loss of seabed habitat;
- Increased suspended sediment concentrations and sediment re-deposition;
- Re-mobilisation of contaminated sediment; and

- Underwater noise.

518. Any impacts on prey species has the potential to affect marine mammals.

12.6.1.10.1 Sensitivity of Marine Mammals

519. As outlined in **Appendix 12.1**, the diet of the 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 its 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.

520. Bottlenose dolphin and white-beaked dolphin are opportunistic feeders, feeding on wide range of prey species and have large foraging ranges (see **Appendix 12.1**) and are therefore considered to have low sensitivity to changes in prey resources.

521. 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 12.1**). Therefore, minke whale are considered to have a low to medium sensitivity to changes in prey resource.

522. 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 12.1**). Grey seal and harbour seal are therefore considered to have low sensitivity to changes in prey resources.

12.6.1.10.2 Magnitude for DEP or SEP in Isolation

12.6.1.10.2.1 Physical Disturbance and Temporary Habitat Loss

523. During construction, activities such as foundation installation (for wind turbines and offshore platforms), 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 seabed habitat (see **Chapter 10 Benthic Ecology**) and fish species (see **Chapter 11 Fish and Shellfish Ecology**).

524. During construction the maximum area of seabed habitat that could be disturbed is as follows:

- DEP in isolation = up to 1.93km^2 (1.87% of DEP area[2])
- SEP in isolation = up to 0.53km^2 (0.57% of SEP area)
- DEP and SEP together = 2.47km^2 (1.26% of DEP and SEP area)

[2] Note this is as a percentage of the wind farm area only.

525. 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.

526. The magnitude of effect of physical disturbance to seabed habitat during construction has been assessed as low for DEP and SEP in **Chapter 10 Benthic Ecology**. In **Chapter 11 Fish and Shellfish Ecology** the magnitude of physical disturbance during construction activities for the either DEP or SEP is considered to be negligible, based on the availability of similar suitable habitat both in the offshore development areas and in the wider context of the southern North Sea together with the intermittent and reversible nature of the effect. The impact significance for fish species is assessed as minor adverse.

527. Therefore, any potential changes to prey availability as a result of physical disturbance and temporary habitat loss is assessed as negligible for marine mammals.

528. Temporary habitat loss during construction has not been assessed as a direct impact on marine mammals as any impacts of habitat loss would be as a result of any changes in prey availability.

12.6.1.10.2.2 Increased Suspended Sediments and Sediment Deposition

529. Construction activities such as seabed preparation, foundation installation, drilling operations and cable installation may lead to the potential for increased suspended sediment concentrations (SSC) in the water column and subsequent sediment re-deposition. Activities such as seabed disturbances from jack-up vessels and placement of cable protection are not expected to increase the suspended sediment concentrations to the extent to which it would cause an impact to benthic or fish receptors.

530. 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 SSC and low changes in seabed level when the sediments are deposited. In **Chapter 10 Benthic Ecology**, the impact magnitude is considered to be low at DEP and SEP. Similarly, the magnitude of effect in **Chapter 11 Fish and Shellfish Ecology** is also assessed as low at DEP and SEP. The impact significance for fish species is assessed as minor adverse.

531. Therefore, any potential changes to prey availability as a result of increased suspended sediment concentrations and sediment deposition is assessed as negligible for marine mammals.

12.6.1.10.2.3 Re-mobilisation of Contaminated Sediment

532. The data and analysis in **Chapter 9 Marine Water and Sediment Quality** indicates that levels of contaminants within the DEP and SEP project areas are very low and do not contain elevated levels to cause concern, therefore the magnitude of the effect is negligible / no impact.

533. Therefore, any potential changes to prey availability as a result of re-mobilisation of contaminated sediments is assessed as negligible for marine mammals.

12.6.1.10.2.4 Underwater noise

534. Potential sources of underwater noise and vibration during construction include UXO clearance, piling, increased vessel traffic, seabed 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.

535. 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.

536. Underwater noise modelling (**Appendix 12.2**), 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).

537. The underwater noise modelling results (**Appendix 12.2**) indicates that fish species in which the swim bladder is involved in hearing are the most sensitive to the impact of underwater noise.

538. **Table 12-82** summarises the maximum impact ranges for fish species during UXO clearance. With a maximum impact range of up to 810m, this is considerably less than the 13km impact range for harbour porpoise, based on the unweighted SPL_{peak} criteria (**Table 12-22**). Therefore, there would be no additional impacts as result of any changes in prey availability during UXO clearance than the direct impacts to marine mammals as a result of underwater noise assessed in **Sections 12.6.1.1** and **12.6.1.2**.

539. Any potential changes to prey availability as a result of UXO clearance is assessed as negligible for marine mammals.

Table 12-82: Summary of the impact ranges for UXO detonation using the unweighted SPL_{peak} explosion noise criteria from Popper et al. (2014) for fish species

Potential Impact	25kg	55kg	120kg	240kg	525kg
234 dB (Mortality and potential mortal injury)	170m	230m	290m	370m	490m
229 dB (Mortality and potential mortal injury)	290m	380m	490m	620m	810m

540. **Table 12-83** summarises some of the maximum impact ranges and areas for fish species, further details are provided in **Appendix 12.2** and **Chapter 11 Fish and Shellfish Ecology**.

541. The maximum predicted cumulative impact range for TTS of 19km for fish species based on stationary model (**Appendix 12.2**), is the same as TTS SEL_{cum} range for harbour porpoise, less 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 12-34**). However, it is important to note 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.

542. Therefore, modelling assuming a fleeing animal in response to noise, especially fish with a swim bladder involved in hearing, is more realistic and therefore 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 fleeing response.

543. The maximum predicted cumulative impact range for TTS of 12km for fish species based on the fleeing response model (**Table 12-83**), is the less that TTS SEL_{cum} range 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 12-34**).

544. Piling duration would be the same as assessed from marine mammals in **Table 12-53**.

Table 12-83: Predicted maximum impact ranges (and areas) for monopile and pin-pile maximum hammer energies for fish species

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 SEL_{cum} Fleeing model	DEP SE	0.3km (0.16km^2)	<0.1km (<0.1km^2)
			SEP E	0.2km (0.16km^2)	<0.1km (<0.1km^2)
	Recoverable injury	203 dB SEL_{cum} Fleeing model	DEP SE	0.9km (<0.1km^2)	0.2km (<0.1km^2)
			SEP E	0.6km (1.1km^2)	0.2km (<0.1km^2)
	TTS	>186 dB SEL_{cum}	DEP SE	**12km (330km^2)**	7.8km (130km^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	SEP E	9.6km ($210km^2$)	5.7km ($75km^2$)

545. 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 ($330km^2$ at DEP and $210km^2$ at SEP). 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.

546. 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, minke whale, grey seal and harbour seal (**Table 12-84**).

547. 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 12-84: Maximum number of individuals (and % of reference population) that could be impacted as a result of changes in prey availability during construction at DEP or SEP

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Changes in prey availability	Harbour porpoise	DEP	541 (0.16% of NS MU) (DEP density of $1.64/km^2$) 293 (0.08% of NS MU) (SCANS-III density of $0.888/km^2$)	**Negligible**
		SEP	120 (0.03% of NS MU) (DEP density of $0.58/km^2$)	**Negligible**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
			186 (0.05% of NS MU) (SCANS-III density of 0.888/km^2)	
	Bottlenose dolphin	DEP	10 (0.5%; 5% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**
		SEP	6 (0.3%; 3% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**
	White-beaked dolphin	DEP	2 (0.01% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
		SEP	1 (0.01% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	Minke whale	DEP	3 (0.01% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
		SEP	2 (0.01% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	Grey seal	DEP	30 (0.12% of ref pop (or 0.36% of	**Negligible (negligible)**

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
			SE MU) (DEP density of 0.09/km^2)	
		SEP	99 (0.41% of ref pop (or 1.2% of SE MU) (SEP density of 0.47/km^2)	**Negligible (low)**
	Harbor seal	DEP	79 (0.17% of ref pop (or 1.6% of SE MU) (DEP density of 0.24/km^2)	**Negligible (low)**
		SEP	44 (0.09% of ref pop (or 0.89% of SE MU) (SEP density of 0.21/km^2)	**Negligible (negligible)**

548. 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 12.2**), which is less than the precited impact ranges for marine mammals (**Table 12-63**).

549. Therefore, any potential changes to prey availability as a result of other construction activities and vessels is assessed as negligible for marine mammals.

12.6.1.10.3 Impact Significance

550. Taking into account the marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-84**, the impact significance for any potential changes in prey availability as a result of underwater noise during piling at DEP or SEP 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 12-85**).

Table 12-85: Assessment of impact significance for any potential changes in prey availability during construction at DEP or SEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Change in prey availability	Harbour porpoise	DEP	Low to Medium	Negligible	Negligible to Minor	No mitigation	**Negligible to Minor adverse**

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
during piling		SEP		Negligible	Negligible to Minor	required for prey. However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	**Negligible to Minor adverse**
	Bottlenose dolphin	DEP	Low	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	White-beaked dolphin	DEP	Low	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Minke whale	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Grey seal	DEP	Low	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Harbour seal	DEP	Low	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**

12.6.1.10.4 Mitigation

551. Mitigation 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.

12.6.1.10.5 Impact Assessment for DEP and SEP Together

552. 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 as a result of potential changes in prey availability from underwater noise during piling if are developed DEP and SEP together concurrently (**Table 12-86**).

553. The magnitude of impact for any potential temporary changes in prey availability, based on worst-case, for DEP and SEP together is assessed as negligible for harbour porpoise, medium for bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, negligible (low) for grey seal and negligible (low) for harbour seal (**Table 12-86**).

Table 12-86: Maximum number of individuals (and % of reference population) that could be impacted as a result of changes in prey availability during construction at DEP and SEP together

Potential Impact	Species	Location	Maximum number of individuals (% of reference population)	Magnitude (temporary impact)
Changes in prey availability	Harbour porpoise	DEP & SEP	311 (0.09% of NS MU) (DEP density of 0.58/km^2) 480 (0.14% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	Bottlenose dolphin	DEP & SEP	16 (0.83%; 8% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (medium)**
	White-beaked dolphin	DEP & SEP	3 (0.02% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	Minke whale	DEP & SEP	5 (0.02% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	Grey seal	DEP & SEP	128 (0.53% of ref pop (or 1.57% of SE MU) (DEP density of 0.09/km^2)	**Negligible (low)**
	Harbor seal	DEP & SEP	123 (0.26% of ref pop (or 2.49% of SE MU) (DEP density of 0.24/km^2)	**Negligible (low)**

12.6.1.10.5.1 Impact Significance

554. Taking into account the marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-86**, the impact significance for any potential changes in prey availability as a result of underwater noise during concurrent piling at DEP and SEP together 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 12-87**).

Table 12-87: Assessment of impact significance for any potential changes in prey availability during construction at DEP and SEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Change in prey availability during piling	Harbour porpoise	DEP & SEP	Low to Medium	Negligible	Negligible to Minor	No mitigation required for prey. However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	**Negligible to Minor adverse**
	Bottlenose dolphin	DEP & SEP	Low	Negligible	Negligible		**Negligible**
	White-beaked dolphin	DEP & SEP	Low	Negligible	Negligible		**Negligible**
	Minke whale	DEP & SEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Grey seal	DEP & SEP	Low	Negligible	Negligible		**Negligible**
	Harbour seal	DEP & SEP	Low	Negligible	Negligible		**Negligible (minor adverse)**

12.6.1.10.5.2 Mitigation

555. As for DEP and SEP alone, mitigation 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.

12.6.1.11 Impact 11: Changes to Water Quality

556. As outlined in **Chapter 9 Marine Water and Sediment Quality** potential changes in water quality during construction are:

- Deterioration in water quality due to an increase in suspended sediment through seabed preparation;
- 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 during construction activities.

12.6.1.11.1 Sensitivity of Marine Mammals

557. 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).

558. 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.

559. 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 potential indirect impacts via prey species, as assessed in **Section 12.6.1.10.2.3**. Therefore, marine mammals have negligible sensitivity to any direct impacts from contaminated sediment during construction activities.

12.6.1.11.2 Magnitude for DEP or SEP in Isolation

560. The magnitude for the potential changes in water quality has been based on the assessments in **Chapter 9 Marine Water and Sediment Quality** (**Table 12-88**).

Table 12-88: Magnitude of potential changes in water quality during construction at DEP or SEP, based on assessments in Chapter 9 Marine Water and Sediment Quality

Potential Impact	Location	Magnitude (temporary impact)
Deterioration in water quality due to an increase in suspended sediment through seabed preparation	DEP or SEP	**Negligible**
Deterioration in water quality due to an increase in suspended sediment associated with drill arisings for foundation installation of piled foundations	DEP or SEP	**Negligible**
Deterioration in water quality due to an increase in suspended sediment during export cable installation	DEP or SEP	**Negligible**
Deterioration in water quality due to an increase in suspended sediment during offshore cable installation (infield and interlink cables)	DEP or SEP	**Negligible**
Deterioration in water quality due to the release of contaminated sediment during construction activities	DEP or SEP	**Negligible**

12.6.1.11.3 Impact Significance

561. Taking into account the negligible marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-88**, the impact significance for any potential changes in water quality during construction at DEP or SEP 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 12-78**).

Table 12-89: Assessment of impact significance for any changes in water quality during construction at DEP or SEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Changes in water quality	Harbour porpoise	DEP	Negligible	Negligible	Negligible	No further mitigation proposed other than embedded mitigation.	**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Bottlenose dolphin	DEP	Negligible	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	White-beaked dolphin	DEP	Negligible	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Minke whale	DEP	Negligible	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Grey seal	DEP	Negligible	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**
	Harbour seal	DEP	Negligible	Negligible	Negligible		**Negligible**
		SEP		Negligible	Negligible		**Negligible**

12.6.1.11.4 Mitigation

562. No mitigation is required or proposed, other than the embedded mitigation outlined in **Table 12-3**.

12.6.1.11.5 Impact Assessment for DEP and SEP Together

563. The impacts for DEP and SEP together would be the same as those assessed for DEP and SEP separately, with a **negligible** magnitude and impact significance.

12.6.1.12 Overall Impacts During Construction

12.6.1.12.1 Potential Overall Effects During UXO clearance

564. It is not anticipated that piling or any other construction activities will be undertaken during UXO clearance at DEP, SEP or the export cable routes. Therefore, the assessments for UXO clearance in **Section 12.6.1.1** and **12.6.1.2** represent the overall worst-case scenario. However, if this was to change this would be assessed as part of the separate Marine Licence for UXO clearance.

12.6.1.12.2 Potential Overall Effects During Pilling

565. The assessment of potential barrier effects in **Section 12.6.1.6.6.3** represents the worst-case scenario for underwater noise, based on the maximum potential area for piling, other construction activities and vessels at DEP, SEP and the export cable routes.

566. For harbour porpoise and minke whale, there would be no further additional impacts as any potential changes in prey availability would be within the maximum impact area assessed for potential barrier effects.

567. For bottlenose dolphin and white-beaked dolphin, the assessment of the potential changes in prey represents the worst- case (maximum area of potential impacts) during piling. There would be no further additional impacts as any potential barrier effects from underwater noise would be within the maximum impact area assessed for any changes in prey availability during piling.

568. For grey and harbour seal at DEP the maximum area assessed for any potential changes in prey availability during piling represents the worst-case and at SEP any potential barrier effects from underwater noise represents the worst-case.

12.6.1.12.3 Potential Overall Effects During Other Construction Activities

569. 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.

12.6.2 Potential Impacts during Operation

570. The potential impacts during Operation and Maintenance (O&M) 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.

12.6.2.1 Impact 1: Impacts from Underwater Noise Associated with Operational Wind Turbines

571. The operational turbines will operate nearly continuously, except for occasional shutdowns for maintenance or severe weather. The DEP and SEP design life is 35 years. Therefore, there is concern that underwater noise from operational turbines could contribute a consistent, long duration of sound to the marine environment.

572. 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).

573. 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 seabed (Tougaard *et al*., 2009a). 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).

574. Measurements made at three different wind turbines in Denmark and Sweden at ranges between 14 and 40 meters 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).

575. As outlined in **Appendix 12.2**, 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.

12.6.2.1.1 Sensitivity of Marine Mammals

576. Currently available data indicates that there is no lasting disturbance or exclusion of harbour porpoise or seals around windfarm 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).

577. Monitoring was carried out at the Horns Rev and Nysted windfarms 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 windfarm 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 windfarms studied, following two years of operation.

578. 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 windfarm 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).

579. Both harbour porpoise and seals have been shown to forage within operational windfarm sites (e.g. Lindeboom *et al*., 2011; Russell *et al*., 2014), indicating no restriction to movements in operational offshore windfarm sites.

580. 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).

581. As a precautionary approach, harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, 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.

582. The sensitivity of marine mammals to any temporary auditory effect (TTS) / fleeing response is considered to be medium.

12.6.2.1.2 Underwater Noise Modelling

583. Underwater noise modelling was undertaken to assess the potential impact ranges for operational wind turbines (see **Appendix 12.2**). The predicted source levels used in the modelling for the turbine sizes that could be installed at DEP and SEP are:

- 14MW = 157.1 dB re 1 µPa (SPL_{RMS}) @ 1 m; and
- 26MW = 173.8 dB re 1 µPa (SPL_{RMS}) @ 1 m.

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

12.6.2.1.2.1 Results

585. The results of the underwater noise modelling (**Table 12-90**) 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 / fleeing response based on the Southall *et al*. (2019) non-impulsive thresholds and criteria for SEL_{cum}.

Table 12-90: Predicted impact ranges (and areas) for PTS and TTS / fleeing response from cumulative exposure of operational turbines, based on Southall et al. (2019) thresholds and criteria

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Operational WTG (14 MW)	Operational WTG (26 MW)
Harbour porpoise	Auditory injury (PTS)	SEL_{cum} Weighted	<0.1km (<0.03km^2)	<0.1km (<0.03km^2)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Operational WTG (14 MW)	Operational WTG (26 MW)
(VHF)		(173 dB re 1 μPa²s) Non-impulsive		
	TTS / fleeing response	SEL_{cum} Weighted (153 dB re 1 μPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
Bottlenose dolphin and white-beaked dolphin (HF)	Auditory injury (PTS)	SEL_{cum} Weighted (198 dB re 1 μPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
	TTS / fleeing response	SEL_{cum} Weighted (178 dB re 1 μPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
Minke whale (LF)	Auditory injury (PTS)	SEL_{cum} Weighted (199 dB re 1 μPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
	TTS / fleeing response	SEL_{cum} Weighted (179 dB re 1 μPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)
Grey and harbor seal (PW)	Auditory injury (PTS)	SEL_{cum} Weighted (201 dB re 1 μPa²s)	<0.1km (<0.03km²)	<0.1km (<0.03km²)

Species	Impact	Criteria and threshold (Southall *et al*., 2019)	Operational WTG (14 MW)	Operational WTG (26 MW)
		Non-impulsive		
	TTS / fleeing response	SEL_{cum} Weighted (181 dB re 1 µPa²s) Non-impulsive	<0.1km (<0.03km²)	<0.1km (<0.03km²)

12.6.2.1.3 Magnitude for DEP or SEP in Isolation

586. It is important to note that permanent auditory injury (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 permanent auditory injury (PTS) (**Table 12-90**). Therefore, permanent auditory injury (PTS) as a result of operational wind turbine noise, is highly unlikely and has not been assessed further.

587. Similarly, there is unlikely to be any significant risk of any temporary change in hearing sensitivity (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 12-90**). Therefore, TTS as a result of operational wind turbine noise, is also highly unlikely.

588. 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 12-90**, with the estimated number and percentage of reference populations in **Table 12-91** providing an indication of possible fleeing response / displacement.

589. The magnitude of the potential impact for any temporary change in hearing sensitivity (TTS) / fleeing response as a result of underwater noise from all operational wind turbines at each site (32 at DEP and 24 at SEP) is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale grey seal and harbour seal (**Table 12-91**), with less than 0.01% of the reference populations exposed to any long term impact (see **Table 12-10**).

590. The indicative separation distance between turbines (inter-row) and between turbines in rows (in-row) would be a minimum of 0.99km (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 12-91: 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 DEP or SEP

Species	Location	14MW or 26MW Operational Turbines	
		Maximum number of individuals (% of reference population)	**Magnitude (long-term impact)**
Harbour porpoise	DEP (up to 32 WTGs)	1.57 (0.0005% of NS MU) (DEP density of 1.64/km^2) 0.85 (0.0002% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
	SEP (up to 24 WTGs)	0.41 (0.0001% of NS MU) (SEP density of 0.58/km^2) 0.64 (0.0002% of NS MU) (SCANS-III density of 0.888/km^2)	**Negligible**
Bottlenose dolphin	DEP (up to 32 WTGs)	0.03 (0.0015%; 0.015% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**
	SEP (up to 24 WTGs)	0.02 (0.0011%; 0.011% of CES MU) (SCANS-III density of 0.03/km^2)	**Negligible (low)**
White-beaked dolphin	DEP (up to 32 WTGs)	0.006 (0.00004% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**
	SEP (up to 24 WTGs)	0.004 (0.00003% of CGNS MU) (DEP and SEP density of 0.006/km^2)	**Negligible**

Species	Location	14MW or 26MW Operational Turbines	
		Maximum number of individuals (% of reference population)	Magnitude (long-term impact)
Minke whale	DEP (up to 32 WTGs)	0.01 (0.00004% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
	SEP (up to 24 WTGs)	0.007 (0.00003% of CGNS MU) (SCANS-III density of 0.01/km^2)	**Negligible**
Grey seal	DEP (up to 32 WTGs)	0.09 (0.0004% of ref pop (or 0.001% of SE MU) (DEP density of 0.09/km^2)	**Negligible**
	SEP (up to 24 WTGs)	0.34 (0.001% of ref pop (or 0.004% of SE MU) (SEP density of 0.47/km^2)	**Negligible**
Harbor seal	DEP (up to 32 WTGs)	0.23 (0.0005% of ref pop (or 0.005% of SE MU) (DEP density of 0.24/km^2)	**Negligible**
	SEP (up to 24 WTGs)	0.15 (0.0003% of ref pop (or 0.003% of SE MU) (SEP density of 0.21/km^2)	**Negligible**

12.6.2.1.4 Impact Significance

591. Taking into account low to medium sensitivity and the potential magnitude of the potential long-term impact (**Table 12-91**), the impact significance for any displacement as a result of underwater noise from operational turbines has been assessed as negligible to minor adverse (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal (**Table 12-92**).

Table 12-92 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	DEP	Low to Medium	Negligible	Negligible to Minor	No mitigation required	**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Bottlenose dolphin	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	White-beaked dolphin	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Minke whale	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Grey seal	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Harbour seal	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**

12.6.2.1.5 Mitigation

592. No mitigation is required or proposed.

12.6.2.1.6 Impact Assessment for DEP and SEP Together

593. The magnitude of the potential impact for any temporary change in hearing sensitivity (TTS) / fleeing response as a result of underwater noise from all operational wind turbines at DEP (32 WTGs) and SEP (24 WTGs) together is negligible for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale grey seal and harbour seal (**Table 12-93**).

Table 12-93: 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 DEP and SEP together

Species	Location	14MW or 26MW Operational Turbines	
		Maximum number of individuals (% of reference population)	Magnitude (long-term impact)
Harbour porpoise	DEP (up to 32 WTGs) & SEP (up to 24 WTGs)	1.98 (0.0006% of NS MU) 1.49 (0.0004% of NS MU)	**Negligible**
Bottlenose dolphin	DEP (up to 32 WTGs) & SEP (up to 24 WTGs)	0.05 (0.003%; 0.03% of CES MU)	**Negligible (low)**
White-beaked dolphin	DEP (up to 32 WTGs) & SEP (up to 24 WTGs)	0.01 (0.00006% of CGNS MU)	**Negligible**
Minke whale	DEP (32 WTGs) & SEP (24 WTGs)	0.02 (0.00007% of CGNS MU)	**Negligible**
Grey seal	DEP (32 WTGs) & SEP (24 WTGs)	0.42 (0.002% of ref pop (or 0.005% of SE MU)	**Negligible**
Harbor seal	DEP (32 WTGs) & SEP (24 WTGs)	0.38 (0.0008% of ref pop (or 0.008% of SE MU)	**Negligible**

12.6.2.1.6.1 Impact Significance

594. Taking into account low to medium sensitivity and the potential magnitude of the potential long-term impact (**Table 12-93**), the impact significance for any displacement as a result of underwater noise from operational turbines at DEP and SEP together has been assessed as negligible to minor adverse (not significant) for harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal and minor adverse (not significant) (**Table 12-94**).

Table 12-94: Assessment of impact significance for underwater noise from operational turbines at SEP and DEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Underwater noise from operational turbines	Harbour porpoise	DEP & SEP	Low to Medium	Negligible	Negligible to Minor	No mitigation required	**Negligible to Minor adverse**
	Bottlenose dolphin	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
	White-beaked dolphin	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Minke whale	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Grey seal	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Harbour seal	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**

12.6.2.1.6.2 Mitigation

595. No mitigation is required or proposed.

12.6.2.2 Impact 2: Impacts from Underwater Noise Associated with Operational and Maintenance Activities

12.6.2.2.1 Sensitivity of Marine Mammals

596. As outlined in **Section 12.6.1.5.1**, 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.

12.6.2.2.2 Magnitude for DEP or SEP in Isolation

597. 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 12-2** provides estimates (as outlined in **Chapter 5 Project Description**) for potential cable repairs and reburial.

598. As outlined in **Section 12.6.1.5**, 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 12 hours. Therefore, the only potential impact from underwater noise during maintenance activities is disturbance.

599. The impacts from additional cable laying and protection are temporary in nature and will be limited to relatively short periods during the operational 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 actually taking place.

600. Therefore, the underwater noise from maintenance activities are considered to be the same or less than those assessed for underwater noise from for other construction activities (including rock placement, trenching and cable laying) (**Section 12.6.1.5**).

601. The magnitude for all marine mammal species is assessed as negligible based on maximum impact areas for all activities (**Table 12-64**).

12.6.2.2.3 Impact Significance

602. 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 12-95**).

Table 12-95: Assessment of impact significance for underwater noise from maintenance activities

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Underwater noise from maintenance activities	Harbour porpoise	DEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Bottlenose dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Minke whale	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Grey seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Harbour seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.2.2.4 Mitigation

603. No mitigation is required or proposed for underwater noise for maintenance activities, such as rock placement, trenching and cable laying, as the risk of any impacts is negligible

12.6.2.2.5 Impact Assessment for DEP and SEP Together

604. The potential impacts for underwater noise during maintenance activities at SEP and DEP together would be the same or less than the assessment of the construction activities, other than piling, assessed in **Section 12.6.1.5.5**. 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 12-96**).

Table 12-96: Assessment of impact significance for underwater noise from maintenance activities at DEP and SEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Underwater noise from maintenance activities	Harbour porpoise	DEP & SEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
	Bottlenose dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Minke whale	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Grey seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Harbour seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**

12.6.2.3 Impact 3: Impacts from Underwater Noise and Disturbance Associated with Operation and Maintenance Vessels

12.6.2.3.1 Sensitivity of Marine Mammals

605. As outlined in **Section 12.6.1.6.1**, the sensitivity of marine mammals to vessel noise and presence is assessed as a precautionary medium.

12.6.2.3.2 Magnitude for DEP or SEP in Isolation

606. As outlined in **Section 12.6.1.5.6.3**, 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.

607. 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.

608. 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 7, which is considerably less than the 16 vessels that could be on site during construction. However, as a precautionary approach the assessment for construction has been used of the operational and maintenance assessment, as a worst-case scenario.

609. For the operation of either DEP or SEP, there could be up to 690 vessel trips per year (approximately 1.89 trips per day), representing an increase of up to 2.4%% compared to average daily vessels (n=79, in summer) currently within the DEP and SEP vessel and navigation study area, or an increase of up to 2.2% compared to the average daily vessels present in winter (n=87).

610. The magnitude for all marine mammal species is assessed as negligible based on maximum impact areas for all vessels (**Table 12-69**).

12.6.2.3.3 Impact Significance

611. Taking into account medium sensitivity and the potential magnitude of the temporary impact, the impact significance for disturbance from operational 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 12-97**).

Table 12-97: Assessment of impact significance for underwater noise from operation and maintenance vessels

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Underwater noise from O&M vessels	Harbour porpoise	DEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Bottlenose dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Minke whale	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**
	Grey seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Harbour seal	DEP	Medium	Negligible	Minor		**Minor adverse**
		SEP		Negligible	Minor		**Minor adverse**

12.6.2.3.4 *Mitigation*

612. No mitigation is required or proposed for underwater noise or disturbance from operational and maintenance vessels, as the risk of any impact is negligible.

12.6.2.3.5 *Impact Assessment for DEP and SEP Together*

613. The potential impacts for underwater noise from operational and maintenance vessels at SEP and DEP together would be less than the assessment for construction vessels in **Section 12.6.1.6.5**. However, the assessment for construction vessels has been used for the assessment for operational 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 12-98**).

Table 12-98: Assessment of impact significance for underwater noise from operation and maintenance vessels at DEP and SEP together

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
TTS / fleeing response from cumulative SEL for construction vessels	Harbour porpoise	DEP & SEP	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
	Bottlenose dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	White-beaked dolphin	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Minke whale	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Grey seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**
	Harbour seal	DEP & SEP	Medium	Negligible	Minor		**Minor adverse**

12.6.2.4 Impact 4: Barrier Effects from Underwater Noise during Operation and Maintenance

614. No barrier effects as a result of underwater noise during operation and maintenance are anticipated.

615. As assessed in **Section 12.6.2.1**, the magnitude for displacement (based on TTS / fleeing response) as a result of underwater noise from operational turbines has been assessed 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 DEP and SEP alone.

616. As outlined in **Section 12.6.2.1**, the indicative separation distance between turbines (inter-row) and between turbines in rows (in-row) would be a minimum of 0.99km (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 DEP and SEP.

617. As assessed in **Section 12.6.2.1.6.2**, the magnitude for disturbance (based on TTS / fleeing response) as a result of underwater noise from operational 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.

618. As assessed in **Section 12.6.2.3**, the magnitude for disturbance (based on TTS / fleeing response) as a result of underwater noise from operational and maintenance vessels is assessed as negligible for all marine mammal species based on maximum impact areas for all vessels, with a minor adverse impact significance.

619. Therefore, any potential barrier effects as a result of underwater noise during operation and maintenance has not been assessed further.

12.6.2.5 Impact 5: Increased Risk of Collision with Vessels during Operation

12.6.2.5.1 Sensitivity of Marine Mammals

620. As outlined in **Section 12.6.1.8.1**, marine mammals are considered to have a low sensitivity to the risk of a vessel strike.

12.6.2.5.2 Magnitude for DEP or SEP in Isolation

621. 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 7 at DEP or SEP, which is less than the 16 vessels that could be on site during construction. However, as a precautionary approach the assessment for construction has been used of the operational and maintenance assessment, as a worst-case scenario.

622. The potential for increased collision risk with construction or operational and maintenance vessels based on precautionary worst-case scenario has been assessed as low for harbour porpoise, medium of bottlenose dolphin, negligible for white-beaked dolphin, negligible for minke whale, low (medium) for grey seal and low (medium) for harbour seal (**Table 12-77**).

12.6.2.5.3 Impact Significance

623. Taking into account the low marine mammal sensitivity and the potential magnitude of the impact, as assessed in **Table 12-77**, 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 12-78**). 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.

12.6.2.5.4 Mitigation

624. As outlined in **Section 12.6.1.8.4**, 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 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.

12.6.2.5.5 Impact Assessment for DEP and SEP Together

625. As a precautionary approach, the assessment for the potential increased collision risk with operational and maintenance vessels at DEP and SEP together is the same as the assessment for the potential increased collision risk with construction vessels at DEP and SEP together in **Section 12.6.1.8.4**.

626. 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 12-80**).

12.6.2.6 Impact 6: Disturbance at Seal Haul-Out Sites

12.6.2.6.1 Sensitivity of Seals

627. 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 12.6.1.9.1**). 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.

12.6.2.6.2 Magnitude for DEP or SEP in Isolation

628. 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 cable route and at landfall site, or from vessels 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 likely to be negligible.

12.6.2.6.2.1 Impact Significance

629. 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 12-99**).

Table 12-99: 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	DEP	Low to Medium	Negligible	Negligible to Minor	No mitigation required	**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**
	Harbour seal	DEP	Low to Medium	Negligible	Negligible to Minor		**Negligible to Minor adverse**
		SEP		Negligible	Negligible to Minor		**Negligible to Minor adverse**

12.6.2.6.2.2 Mitigation

630. 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.

12.6.2.6.3 Impact Assessment for DEP and SEP Together

631. The impacts for DEP and SEP together would be the same as that presented for DEP and SEP separately, as both the number of construction vessels at the site at any one time, and the vessel transit routes would remain the same.

12.6.2.7 Impact 7: Changes to Prey Availability

632. As outlined in **Chapter 11 Fish and Shellfish Ecology**, the potential impacts on fish species during operation and maintenance can result from:

- Permanent loss or change of habitat;
- Physical disturbance / temporary loss of seabed habitat;
- Electromagnetic fields (EMF);
- Increased suspended sediment concentrations and sediment re-deposition; and
- Underwater noise.

633. Any impacts on prey species has the potential to affect marine mammals.

12.6.2.7.1 Sensitivity of Marine Mammals

634. As outlined in **Section 12.6.1.10.1**, 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.

12.6.2.7.2 Magnitude for DEP or SEP in Isolation

12.6.2.7.2.1 Permanent Loss or Change of Habitat

635. Habitat loss will occur during the lifetime of DEP and SEP as a result of structures installed on the seabed. 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.
636. As outlined in **Chapter 10 Benthic Ecology**, at DEP a worst-case scenario of 32 14MW GBS foundations (458,044m^2) and one OSP suction bucket foundation with four legs of 20m diameter (1,662m^2) is being considered. For the whole of DEP, the maximum footprint on the seabed from turbine and offshore OSP foundations and scour protection is 0.46km^2. Overall, this represents 0.44% of the DEP wind farm array area.
637. The worst-case scenario of cable protection for the DEP infield and interlink cables is rock berm protection, with a footprint of 0.013km^2 and up to thirteen crossings (0.027km^2), totalling 0.04km^2.
638. For a DEP in isolation scenario, up to 0.5km of the export cable will require protection (with a footprint of 0.0024km^2) and up to four crossings (0.008km^2).
639. Overall a permanent loss or change of habitat of 0.51km^2 is predicted at DEP.
640. In **Chapter 10 Benthic Ecology** this is considered to be a low magnitude in relation to the site and the wider region due to the presence of comparable subtidal sand and gravel habitats in and around DEP.
641. As outlined in **Chapter 10 Benthic Ecology**, the maximum footprint of hard substrate on the seabed within the SEP site causing permanent habitat loss is 0.36km^2. This represents 0.37% of the total seabed area within the SEP site.
642. The worst-case scenario of cable protection for the infield cables is rock berm protection, with a total footprint of 0.004km^2.
643. For SEP in isolation, up to 0.5km of the export cable will require protection (with a footprint of 0.0024km^2) and up to four crossings (0.0084km^2), totalling 0.0108m^2.
644. Overall a permanent loss or change of habitat of 0.36km^2 is predicted at SEP.
645. This is considered to be a low magnitude in relation to the site and the wider region due to the presence of comparable subtidal sand and gravel habitats in and around SEP.
646. In **Chapter 11 Fish and Shellfish Ecology**, the impact magnitude for fish species has been assessed as low.

12.6.2.7.2.2 Physical Disturbance / Temporary Loss of Seabed Habitat

647. Cable repairs and reburial could be required over the operational lifetime of DEP or SEP. Vessels used during the maintenance of the cables and wind turbines also have the potential to impact the seabed during the operational phase, for example, jack-up legs or multiple anchors.

648. However, as outlined in **Chapter 10 Benthic Ecology**, any impacts would be small in relation to the impacts during construction and in relation to the overall site and cable route areas. Any impacts would be temporary, on the scale of days to months.

649. In **Chapter 11 Fish and Shellfish Ecology**, the impact magnitude for fish species has been assessed as negligible.

12.6.2.7.2.3 Electromagnetic Fields (EMF)

650. 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.

651. 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 fish species is therefore considered to be low and the impact of EMFs of minor adverse significance (**Chapter 11 Fish and Shellfish Ecology**).

12.6.2.7.2.4 Increased Suspended Sediment Concentrations and Sediment Deposition

652. Increases in SSC within the water column and subsequent deposition onto the seabed may occur as a result of operation and maintenance activities.

653. As outlined in **Chapter 10 Benthic Ecology**, any increases in SSC are expected to cause localised and short-term increases in SSC at the point of discharge. Therefore, the impact of SSC and deposition during the operational phase is considered to be negligible.

654. In the **Chapter 11 Fish and Shellfish Ecology**, the impact magnitude for fish species has been assessed as negligible.

12.6.2.7.2.5 Underwater Noise during Operation and Maintenance

655. Sources of underwater noise during operation and maintenance include, operational wind turbines, maintenance activities, such as cable repairs, replacement and protection, and vessels.

656. Underwater noise modelling (**Appendix 12.2**), 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).

657. 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 12-100**).

658. The impact range for fish species (**Table 12-100**) are less than the predicted impact range for marine mammal species for operational turbines (**Table 12-91**), maintenance activities such as cable laying, trenching and rock placement (**Table 12-63**) and vessels (**Table 12-68**). 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.

12.6.2.7.3 Impact Significance

659. Taking into account the marine mammal sensitivity and the potential magnitude of the impact (negligible to low), the impact significance for any potential changes in prey availability during operation and maintenance at DEP or SEP 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 12-101**).

12.6.2.7.4 Mitigation

660. No mitigation is required or proposed for any potential impacts on prey species during operation and maintenance.

Table 12-100: Predicted maximum impact ranges for fish species during operation and maintenance

Species	Potential Impact	Criteria and threshold (Popper *et al*., 2014)	Operational WTGs (14MW or 26MW)	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

Table 12-101: Assessment of impact significance for any potential changes in prey availability during operation and maintenance at DEP or SEP

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Change in prey availability during O&M	Harbour porpoise	DEP or SEP	Low to Medium	Negligible to Low	Negligible to Minor	No mitigation required for prey.	**Negligible to Minor adverse**
	Bottlenose dolphin	DEP or SEP	Low	Negligible to Low	Negligible to Minor		**Negligible to Minor adverse**
	White-beaked dolphin	DEP or SEP	Low	Negligible to Low	Negligible to Minor		**Negligible to Minor adverse**
	Minke whale	DEP or SEP	Low to Medium	Negligible to Low	Negligible to Minor		**Negligible to Minor adverse**

Potential Impact	Species	Location	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Grey seal	DEP or SEP	Low	Negligible to Low	Negligible to Minor		**Negligible to Minor adverse**
	Harbour seal	DEP or SEP	Low	Negligible to Low	Negligible to Minor		**Negligible to Minor adverse**

12.6.2.7.5 Impact Assessment for DEP and SEP Together

661. The impacts for DEP and SEP together would be the same as the assessments for DEP and SEP separately.

662. As assessed in **Chapter 11 Fish and Shellfish Ecology** any potential impacts to fish species at DEP and SEP together during operation and maintenance would be negligible to low.

663. The impact significance for any potential changes in prey availability during operation and maintenance at DEP and SEP together 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.

12.6.2.8 Impact 8: Changes to Water Quality

664. As outlined in **Chapter 9 Marine Water and Sediment Quality** potential changes in waters quality during operation and maintenance are:

- Deterioration in water quality through an increase in suspended sediment due to scouring effects;
- Deterioration in water quality through an increase in suspended sediment due to cable repairs / reburial and maintenance vessel footprints; and
- Deterioration in water quality through the resuspension of contaminated sediment due to scouring effects and maintenance activities.

12.6.2.8.1 Sensitivity of Marine Mammals

665. As outlined in **Section 12.6.1.11.1**, marine mammals are considered to have negligible sensitivity to any changes in water quality.

12.6.2.8.2 Magnitude for DEP or SEP in Isolation

666. As assessed in **Chapter 9 Marine Water and Sediment Quality** any potential changes in waters quality at DEP or SEP during operation and maintenance would be negligible.

12.6.2.8.3 Impact Significance

667. 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 DEP or SEP has been assessed as negligible.

12.6.2.8.4 Mitigation

668. No mitigation is required or proposed, other than the embedded mitigation outlined in **Table 12-3**.

12.6.2.8.5 Impact Assessment for DEP and SEP Together

669. As assessed in **Chapter 9 Marine Water and Sediment Quality** any potential changes in waters quality at DEP and SEP together during operation and maintenance would be negligible.

670. 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 DEP and SEP together has been assessed as negligible.

12.6.2.9 Overall Impacts during Operation and Maintenance

671. 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.

672. Any potential impacts during operation and maintenance from underwater noise during maintenance activities, changes in prey availability or water quality would be localised, temporary and negligible.

12.6.3 Potential Impacts during Decommissioning

673. The potential impacts during decommissioning that will be assessed for marine mammals include:

- Physical injury, auditory injury and behavioural impacts resulting from the noise associated with foundation removal (e.g. cutting);
- Barrier effects as a result of underwater noise;
- Impacts resulting from the deployment of vessels:
  - Underwater noise and disturbance from vessels;
  - Vessel interaction (collision risk); and
  - Disturbance at seal haul-out sites.
- Changes to prey resource; and
- Changes to water quality.

674. Potential impacts on marine mammals associated with the 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 plan will be provided to the regulator prior to decommissioning that will give details of the techniques to be employed and any relevant mitigation measures required.

675. Decommissioning would most likely involve the removal of the accessible installed components comprising: all of the wind turbine components; part of the foundations (those above seabed level); and the sections of the array cables close to the offshore structures, as well as sections of the export cables. The process for removal of foundations is generally the reverse of the installation process. There would be no piling, and foundations may be cut to an appropriate level.

676. 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).

677. The potential impacts on marine mammals during decommissioning would be the same or less than those assessed for construction in **Section 12.6.1**.

12.7 Cumulative Impacts

678. As outlined in **Section 12.4.4**, the CIA considers plans or projects where the predicted impacts have the potential to interact with impacts from the proposed construction, operation and maintenance or decommissioning of the proposed DEP and SEP projects.

679. The plans and projects screened into the CIA are located in the relevant marine mammal reference population areas (as defined in **Table 12-19**). Full information on the CIA screening methods and projects screened into the CIA are provided in **Appendix 12.3**.

12.7.1 Identification of Potential Cumulative Impacts

680. The first step in the cumulative assessment is the identification of which impacts assessed for DEP and/or SEP have the potential for a cumulative impact with other plans, projects and activities (described as 'impact screening'). This information is set out in **Table 12-102** below, together with a consideration of the confidence in the data that is available to inform a detailed assessment and the associated rationale. Only potential impacts assessed as negligible or above are considered in the CIA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact).

681. **Table 12-102** identifies that the cumulative impacts taken forward for assessment are:

- Disturbance from underwater noise;
- Changes to prey resource availability; and
- Vessel collision risk.

Table 12-102: Potential cumulative impacts (impact screening)

Impact	Potential for Cumulative Impact	Rationale
Disturbance from underwater noise generating activities	Disturbance from pile driving noise	Cumulative increase in underwater noise from piling during construction at offshore developments has the potential to cause disturbance to marine mammals.
	Disturbance from other offshore wind farm construction activities	Cumulative increase underwater noise from non-piling activities, including vessel noise, cable installation works, dredging, seabed preparation, and rock placement.
	Disturbance from UXO clearance activities	UXO clearance has the potential to cause significant disturbance impacts to marine mammals, and therefore the potential for any such activities taking place at the same time as construction of DEP and SEP will be assessed.

Impact	Potential for Cumulative Impact	Rationale
	Disturbance from seismic surveys	Seismic surveys have the potential to cause significant disturbance impacts to marine mammals, and therefore the potential for any such surveys taking place at the same time as construction of DEP and SEP will be assessed.
Changes to prey resources	Changes to prey resource availability	Cumulative changes in fish abundance and distribution resulting from construction, operation and maintenance, and decommissioning of offshore developments may lead to a loss or changes in prey resources for marine mammals.
Vessel collision risk	Vessel collision risk.	Cumulative increase in vessel traffic arising from construction, operation and maintenance, and decommissioning of offshore developments may result in increased collision risk to marine mammals.

12.7.1.1 Disturbance from Underwater Noise

682. Auditory injury (PTS) could occur as a result of pile driving during offshore windfarm installation, pile driving during oil and gas platform installation, underwater explosives (used occasionally during the removal of underwater structures and UXO clearance) and seismic surveys (JNCC, 2010a, 2010b). However, if there is the potential for any auditory injury (PTS), suitable mitigation would be put in place to reduce any risk to marine mammals. Other activities such as dredging, drilling, rock placement, vessel activity, operational windfarms, oil and gas installations or wave and tidal sites will emit broadband noise in lower frequencies and auditory injury (PTS) from these activities is very unlikely. Therefore, the potential risk of any auditory injury (PTS) in marine mammals is not included in the CIA.

683. The CIA assessment determines the potential for disturbance to marine mammals from underwater noise sources during the offshore construction, operation, maintenance and decommissioning of DEP and SEP.

684. The approach to the assessment for cumulative disturbance from underwater noise during piling for harbour porpoise has been based on the approach for the assessment of disturbance in **Section 12.6.1.4**, and follows the current advice from the SNCBs on the assessment of impacts on the SNS harbour porpoise SAC.

685. 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 DEP and SEP for each species.

686. The potential disturbance from offshore windfarms during non-piling construction activities, such as vessel noise, seabed preparation, rock placement and cable installation, has been based on the worst-case maximum area modelled for DEP and SEP for all activities and vessels, this is a precautionary approach, as it is highly unlikely that all non-piling construction activities and vessels would be on each site at any one time.

687. Where a quantitative assessment has been possible, the potential magnitude of disturbance in the CIA has been based on the number of harbour porpoise, bottlenose dolphin, white-beaked dolphin and minke whale in the potential impact area using the latest SCANS-III or ObSERVE density estimates (Hammond *et al*., 2017; Rogan *et al*., 2018) for the area of the projects. The number of grey and harbour seal in the potential impact area has been estimated based on the latest seal at sea usage maps (Russell *et al.*, 2017) for the area of the projects.

688. 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.

12.7.1.2 Changes to Prey Resources

689. The cumulative assessment on potential changes to prey availability has assumed that any potential impacts on marine mammal prey species from underwater noise, including piling, would be the same or less than those for marine mammals. Therefore, there would be no additional cumulative impacts other than those assessed for marine mammals, i.e. if prey are disturbed from an area as a result of underwater noise, marine mammals will be disturbed from the same or greater area, therefore any changes to prey availability would not affect marine mammals as they would already be disturbed from the same area.

690. Any impacts on prey species are likely to be intermittent, temporary and highly localised, with potential for recovery following cessation of the disturbance activity. Any permanent loss or changes of prey habitat will typically represent a small percentage of the potential habitat in the surrounding area.

691. Therefore, any changes in prey resources has not been included or assessed further in the CIA.

12.7.1.3 Vessel Collision Risk

692. As outlined in **Section 12.6.1.8**, the increased collision risk even using a very precautionary approach the potential impact is negligible.

693. Vessel movements to and from any port will be incorporated within existing vessel routes and therefore there would be no increased collision risk as the increase in the number offshore wind farm vessels would be relatively small compared to the baseline levels of vessel movements in these areas.

694. Once on-site offshore wind farm vessels would be stationary or slow moving as they undertake the activity they are associated. Therefore, the risk of any increased collision risk for marine mammals would be negligible, if any.

695. Therefore, any increased collision risk with offshore wind farm vessels has not been included or assessed further in the CIA.

12.7.2 Other Plans, Projects and Activities

696. The second step in the cumulative assessment is the identification of the other plans, projects and activities that may result in cumulative impacts for inclusion in the CIA (described as 'project screening').

697. The types of plans and projects included in the CIA, and the approach to screening, are based on the current stage of the plan or project within the planning and development process (see **Appendix 12.3**). This approach allows for the different levels of 'uncertainty' to be taken into account in the CIA, as well as the quality of the data available (as outlined in **Section 12.4.4**).

12.7.2.1 Tier 1 Projects

698. Tier 1 projects are relevant operational projects, and therefore there is no potential for any overlap in the construction of these projects with the construction of DEP and SEP. Tier 1 projects are considered to part of the baseline if they were fully operational prior to the commencement of the aerial surveys in May 2018.

699. All tier 1 projects were considered part of the baseline and not included in the CIA (see **Appendix 12.3**).

12.7.2.2 Tier 2 Projects

700. Tier 2 projects are marine infrastructure projects currently under construction, and which are due to be commissioned prior to the construction of DEP and SEP, and therefore there is no potential for any overlap in the construction and piling of these projects with the construction and piling of DEP and SEP.

701. All tier 2 projects were screened out of the CIA (see **Appendix 12.3**).

12.7.2.3 Tier 3 Projects

702. Tier 3 projects are relevant marine infrastructure projects which have been consented, but for which construction has not yet commenced. Therefore, there is more certainty that these projects will be constructed compared to projects for which an application has not yet been determined. For tier 3 offshore windfarm projects there is also more information on when construction is likely to be undertaken and an assessment of the potential impacts during piling have been provided in the project ESs, which allows quantified assessment of the potential impacts of these projects in the CIA.

703. However, there is still significant uncertainty associated with these projects, for example, in terms of the scale of the final development that will be constructed, construction programme dates and the likely final impacts. In particular, offshore windfarm projects aim to get consent for a maximum design scenario, based on the worst-case parameters, and then these parameters are generally refined and reduced prior to construction.

704. Tier 3 offshore windfarms could have possible cumulative construction impacts. All other Tier 3 projects were screened out of the CIA (see **Appendix 12.3**).

12.7.2.4 Tier 4 Projects

705. Tier 4 projects are relevant marine infrastructure projects which have an application submitted to the appropriate regulatory body but that have not yet been determined, or projects that are consented but currently on hold due to judicial challenge or appeal process. There is increased uncertainty about these projects, especially where the projects are currently on-hold, as to when or if they could be constructed and what changes could be made to the scale of the developments.

706. Tier 4 offshore windfarms could have possible cumulative construction impacts. All other tier 4 plans and projects were screened out of the CIA (see **Appendix 12.3**).

12.7.2.5 Tier 5 Projects

707. Tier 5 projects are relevant marine infrastructure projects that the regulatory body are expecting to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects). For tier 5 projects there is a lot of uncertainty and not enough information to allow a robust assessment. However, as a very precautionary approach, the tier 5 UK offshore windfarm projects that we are currently aware of have been included in the CIA.

708. Tier 5 offshore windfarms could have possible cumulative construction impacts. All other tier 5 plans were screened out of the CIA (see **Appendix 12.3**).

12.7.3 Assessment of Cumulative Impacts

709. Having established the potential impacts from DEP and/or SEP with the potential for cumulative impacts with the other relevant plans, projects and activities, assessments have been conducted to determine the magnitude of any cumulative impact that may arise.

710. 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 impacts in 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.

711. 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.

712. 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.

713. 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 cumulative impact assessment.

714. 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).

715. The DEPONS model indicated the North Sea harbour porpoise population was not affected by the construction of 65 windfarms, as required to meet the EU renewable energy target (Nabe-Nielsen *et al.,* 2018). However, windfarm 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 windfarms were constructed in random order. Similarly, when windfarm 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.

12.7.3.1 Cumulative Impact 1: Underwater Noise Impacts during Construction from Offshore Wind Farm Piling

716. One of the greatest noise source of offshore wind farm construction is likely to result from pile driving (UXO is assessed in **Section 12.7.3.2**). This stage of the cumulative assessment for underwater noise considers the potential disturbance of marine mammals during piling for DEP and SEP, with the piling at other offshore windfarm projects screened into the CIA, where there is the potential for piling to be at the same time.

717. The UK offshore wind farms included in the initial screening for cumulative impact of offshore wind farm piling are UK offshore wind farms that are within tier 3, 4 and 5 at the time of writing, and European offshore wind farms that are at tier 3 or 4 at the time of writing. These projects are then further screened to determine whether they are within the relevant MUs of each species included within this assessment, and whether there is the potential for the piling periods of each of those projects to overlap with the piling periods of DEP and SEP; and therefore this screening process determines whether there is both spatial and temporal overlap of the piling of other offshore windfarms with the piling of DEP and SEP. Further details are provided in **Appendix 12.3**.

718. The potential piling period for DEP and SEP has been based on the widest likely range of offshore construction dates, dependent on the construction scenario, of between 2025 and 2032, as a very precautionary approach. It should be noted that while the projects included within the following assessment have the potential to overlap with DEP and SEP, they may not all have the potential to overlap with each other, partially considering the long offshore construction period of DEP and SEP, and this assessment is therefore considered to a worst-case.

719. The following cumulative assessment has been undertaken based on the most realistic worst-case scenario of the offshore windfarms that could be piling at the same time as DEP and SEP. This scenario is based on a precautionary approach using the maximum duration of piling periods where they are known, and the overall offshore construction periods where the piling periods are not known.

720. Once the screening was undertaken, further considerations of the realistic potential for piling of other offshore wind farms, at the same time as DEP and SEP, were identified and taken into account. 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. It has therefore been assumed that in these cases, there will be no overlap in the piling periods, unless further information is available (for example in the case of the East Anglia Hub); see **Appendix 12.3** for which projects have been screened in or out.

721. While it is considered that projects with the same developer will not be piled at the same time, it has been assessed that these projects could have overlapping construction windows, and therefore there is the potential for cumulative impact from other construction activities. All offshore wind farm projects with overlapping offshore construction windows with DEP and SEP have been included for the assessment of other construction activities, unless they have previously been included within the assessment for cumulative piling (i.e. all projects that have overlapping overall construction windows with DEP and SEP, but do not have overlapping piling periods, have been included in the other construction activities assessment).

722. The CIA has been based on a single piling event within DEP and/or SEP, with single piling occurring in the screened in offshore wind farms, as it is considered unlikely that all included offshore wind farms would be undertaking concurrent piling, and therefore an assessment for single piling only is considered more realistic, although still precautionary, approach.

12.7.3.1.1 Potential for Disturbance during Offshore Wind Farm Piling

723. The commitment to the mitigation measures agreed through the MMMP for piling as outlined above would reduce the risk of physical injury or permanent auditory injury (PTS) for all marine mammals. As such, DEP and SEP 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.

12.7.3.1.1.1 Sensitivity to Disturbance

724. As outlined in **Section 12.6.1.3.1**, 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.

12.7.3.1.1.2 Magnitude of Potential Disturbance

725. 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 DEP and SEP 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 DEP and SEP 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 DEP and SEP for TTS / fleeing response (weighted SEL_{cum}) of 9.7km from each piling location (220km^2 per project)

726. 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.

727. For each project, the number of harbour porpoise, white-beaked dolphin, minke whale, and bottlenose dolphin in the potential impact areas for single piling, has been estimated using the latest SCANS-III density estimates (Hammond *et al.* 2017) for the relevant survey block that each project is located within. As for the project alone calculations, for any project located within survey block O, the bottlenose dolphin density estimate for survey block R will be used instead, due to the recent change in distribution. See **Section 12.5.2** for more information.

728. The number of grey seal and harbour seal in the potential impact areas, for single and concurrent piling, has been estimated using the latest seal at sea usage maps to estimate densities (Russell *et al.,* 2017) for the relevant area that each project is located.

729. The conservative potential worst case scenario for offshore windfarms, in the harbour porpoise, white-beaked dolphin, minke whale, bottlenose dolphin, grey seal and harbour seal reference population areas, that could be piling at the same time as DEP and SEP, have been used to inform the assessment of the potential impact of cumulative piling (**Table 12-103** to **Table 12-107**).

730. For this 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 windfarm or between offshore windfarms. The maximum number of harbour porpoise that could potentially be temporarily disturbed is 16,809 individuals, which represents approximately 4.87% of the North Sea MU reference population (**Table 12-103**). Therefore, the potential magnitude of the temporary effect is assessed as low (between 1% and 5% of the reference population). However, this is very precautionary, as it is unlikely that all screened in projects could be piling at exactly the same time as piling at either the DEP or SEP site.

731. Piling at both DEP and SEP together has been included in the CIA as a worst-case scenario.

Table 12-103: Quantified CIA for the potential disturbance of harbour porpoise during single piling at the offshore windfarm projects which could be piling at the same time as DEP and SEP

Name of Project	SCANS-III Block	Harbour porpoise density	Number of individuals at risk of disturbance from single piling
DEP	O	0.888	1,886
SEP	O	0.888	1,886
Dogger Bank C	N	0.837	1,778
East Anglia Hub (ONE North or TWO)	L	0.607	1,289
ForthWind Demo Phase 1	R	0.599	1,272
Hornsea Project Four	O	0.888	1,886
Marr Bank (Seagreen Foxtrot Golf)	R	0.599	1,272
Norfolk Boreas	O	0.888	1,886
North Falls	L	0.607	1,289
Borkum Riffgrund III	N	0.837	1,778
Gode Wind 03	M	0.277	588
Total number of harbour porpoise at risk of disturbance			**16,809**
% of reference population			**4.87%**

732. Based on a single pile installation (0.44km^2) at each of the offshore windfarms with the potential for overlapping piling periods with DEP and SEP, the estimated maximum area of potential disturbance for bottlenose dolphin is 4.84km^2, without any overlap in the potential areas of disturbance at each windfarm or between offshore windfarms. The maximum number of bottlenose dolphin that could potentially be disturbed is 0.1 (0.005% of the reference population; **Table 12-104**). 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 12-104: Quantified CIA for the potential disturbance of bottlenose dolphin during single piling at offshore windfarm projects which could be piling at the same time as DEP and SEP

Name of Project	SCANS-III Block	Bottlenose dolphin density	Number of individuals at risk of disturbance from single piling
DEP	O	0.03	0.013
SEP	O	0.03	0.013
Dogger Bank C	N	0	0
East Anglia Hub (ONE North or TWO)	L	0	0
Hornsea Project Four	O	0.03	0.013
Marr Bank (Seagreen Foxtrot Golf)	R	0.03	0.013
Norfolk Boreas	O	0.03	0.013
North Falls	L	0	0
Borkum Riffgrund III	N	0	0
Gode Wind 03	M	0	0
Kattegatt Offshore	2	0	0
Total number of bottlenose dolphin at risk of disturbance			**0.1**
% of reference population			**0.005%**

733. Based on a single pile installation (0.44km^2) at each of the offshore windfarms with the potential for overlapping piling periods with DEP and SEP, the estimated maximum area of potential disturbance for white-beaked dolphin is 6.16km^2, without any overlap in the potential areas of disturbance at each windfarm or between offshore windfarms. The maximum number of white-beaked dolphin that could potentially be disturbed is 0.2 (0.001% of the reference population; **Table 12-105**). 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 12-105: Quantified CIA for the potential disturbance of white-beaked dolphin during single piling at offshore windfarm projects which could be piling at the same time as DEP and SEP

Name of Project	SCANS-III Block	White beaked dolphin density	Number of individuals at risk of disturbance from single piling
DEP	O	0.002	0.0009
SEP	O	0.002	0.0009
Awel y Mor	F	0	0
Dogger Bank C	N	0	0
East Anglia Hub (ONE North and TWO)	L	0	0
ForthWind Demo Phase 1	R	0.243	0.1
Hornsea Project Four	O	0.002	0.0009
Marr Bank (Seagreen Foxtrot Golf)	R	0.243	0.1
Norfolk Boreas	O	0.002	0.0009
North Falls	L	0	0
Borkum Riffgrund III	N	0	0
Gode Wind 03	M	0	0
Kattegatt Offshore	2	0	0
Total number of white-beaked dolphin at risk of disturbance			**0.2**
% of reference population			**0.001%**

734. Based on a single pile installation (1,100km^2) at each of the offshore windfarms with the potential for overlapping piling periods with DEP and SEP, the estimated maximum area of potential disturbance for minke whale is 14,300km^2, without any overlap in the potential areas of disturbance at each windfarm or between offshore windfarms. The maximum number of minke whale that could therefore be potentially temporarily disturbed is 571 individuals, which represents approximately 2.43% of the reference population (**Table 12-106**). 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 12-106: Quantified CIA for the potential disturbance of minke whale during single piling at offshore windfarm projects which could be piling at the same time as DEP and SEP

Name of Project	SCANS-III Block	Minke whale density	Number of individuals at risk of disturbance from single piling
DEP	O	0.01	11
SEP	O	0.01	11
Awel y Mor	F	0	0
Dogger Bank C	N	0.02	22
East Anglia Hub (ONE North or TWO)	L	0	0
ForthWind Demo Phase 1	R	0.039	43
Hornsea Project Four	O	0.01	11
Marr Bank (Seagreen Foxtrot Golf)	R	0.39	429
Norfolk Boreas	L / O	0.02	22
North Falls	L	0	0
Borkum Riffgrund III	N	0.02	22
Gode Wind 03	M	0	0
Kattegatt Offshore	2	0	0
Total number of minke whale at risk of disturbance			**571**
% of reference population			**2.43%**

735. Based on a single pile installation (220km^2) at each of the offshore wind farms with the potential for overlapping piling periods with DEP and SEP, the estimated maximum area of potential disturbance for both grey seal and harbour seal is 1,760km^2, without any overlap in the potential areas of disturbance at each windfarm or between offshore windfarms. The maximum number of grey seal and harbour seal that could potentially be disturbed is 270 (1.12% of the reference population) and 115 (0.48% of the reference population), respectively (**Table 12-107**). The potential magnitude for the cumulative impacts of concurrent piling is assessed as negligible for grey and harbour seal, with less than 1% of the reference population with the potential to be impacted.

Table 12-107: Quantified CIA for the potential disturbance of grey and harbour seal during single piling at offshore windfarm projects which could be piling at the same time as DEP and SEP

Name of Project	Grey seal density	Harbour seal density	Number of grey seal at risk of disturbance from single piling	Number of harbour seal at risk of disturbance from single piling
DEP	0.35	0.24	77	53
SEP	0.35	0.24	77	53
Dogger Bank C	0.13	0.00004	29	0.009
East Anglia Hub (ONE North or TWO)	0.0009	0.0004	0.2	0.09
Hornsea Project Four	0.14	0.04	31	9
Norfolk Boreas	0.0006	0.00006	0.1	0.01
North Falls	0.018	0.002	4	0.4
Total number of grey seal or harbour seal at risk of disturbance			**281**	**115**
% of reference population			**0.9%**	**0.48%**

736. The approach to the CIA, based on the potential for UK and EU windfarms to be piling during the same period as DEP and SEP, would allow for some of these sites not to be piling at the same time while others could be concurrent piling. This is considered to be the most realistic worst case scenario, as it is highly unlikely that the other windfarms would be concurrently piling at exactly the same time or even on the same day as piling at DEP and SEP.

737. Although the potential piling duration for DEP and SEP has been assessed based on a precautionary maximum duration for construction, the actual for active piling time which could disturb marine mammals is only a very small proportion of this time, of up to approximately 30 days, which less than 1% of the estimated construction period, based on the estimated maximum duration to install individual piles (**Table 12-2**).

738. 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 windfarm project construction periods. In addition, not all individuals would be displaced over the entire potential disturbance ranges 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%.

12.7.3.1.1.3 Mitigation

739. Each OWF project would have, if required, mitigation measures to reduce the risk of significant disturbance of marine mammals.

740. The implementation of the management measures for the SNS SAC, the potential impacts could 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.

12.7.3.1.1.4 Impact Significance of Potential Disturbance during Offshore Wind Farm Piling

741. If all included offshore windfarms were single piling at the same time as DEP and SEP, there is the potential for a negligible to low magnitude of impact (dependent on species), however, as outlined above, it is highly unlikely that all offshore windfarms could be piling at exactly the same time.

742. Therefore, taking into account the medium receptor sensitivity for all marine mammal species, the negligible to low potential magnitude, the overall cumulative impact assessment for disturbance to marine mammals from piling at offshore wind farms is minor adverse, prior to any mitigation measures being taken into account. This is deemed to be a conservative assessment based on the realistic worst-case scenario for offshore windfarms single piling at the same time as DEP and SEP (**Table 12-108**).

743. The approach to the CIA, based on all potential UK and EU offshore windfarms to be piling at the same time as DEP and SEP, would allow for some of these sites not to be piling at the same time while others could be concurrent piling.

744. The confidence that 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 taken. 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 12-108: Cumulative impact significance for disturbance to marine mammal from offshore windfarms piling during piling at DEP and SEP

Potential Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigations	Residual Impact
Cumulative impact of disturbance during single piling at the same time as piling at DEP and SEP	Harbour porpoise	Medium	Low	Minor	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance from cumulative offshore wind farm piling for all marine mammal species	**Minor adverse**
	Bottlenose dolphin		Negligible	Minor		**Minor adverse**
	White-beaked dolphin		Negligible	Minor		**Minor adverse**
	Minke whale		Low	Minor		**Minor adverse**
	Grey seal		Negligible	Minor		**Minor adverse**
	Harbour seal		Negligible	Minor		**Minor adverse**

12.7.3.2 Cumulative Impact 2: Underwater Noise Impacts from all other Noise Sources

745. During the construction period for DEP and SEP, there are other potential noise sources in addition to piling that could also disturb harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal, these sources are:

- UXO clearance;
- Seismic surveys; and
- Offshore windfarm operation and maintenance activities.

746. The CIA screening (**Appendix 12.3**) determined that it was highly unlikely that the following activities could contribute significantly to the cumulative effects of underwater noise, therefore they have not been assessed further or included in the CIA:

- Offshore windfarm non-piling construction activities;
- Tidal and wave developments (construction, operation and maintenance);
- Aggregate extraction and dredging;
- Offshore mining;
- Oil and gas projects, other than potential seismic surveys;
- Licenced disposal sites;
- Navigation and shipping operations;
- Subsea cables and pipelines; and
- Carbon capture projects.

12.7.3.2.1 Potential for Disturbance from UXO Clearance

12.7.3.2.1.1 Sensitivity to Disturbance

747. As outlined in **Section 12.6.1.1.1**, 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.

12.7.3.2.1.2 Magnitude of Potential Disturbance

748. As for piling, the commitment to the mitigation measures agreed through the MMMP for UXO clearance would result in no potential effects for physical injury or permanent auditory injury (PTS). As such, DEP and SEP would not contribute to any cumulative impacts for any physical injury or permanent auditory injury (PTS), therefore the CIA only considers potential disturbance effects.

749. This assessment has therefore been based on the potential for disturbance due to UXO clearance activities, cumulatively with the construction of DEP and SEP. The magnitude of the potential disturbance from UXO clearance has been estimated based on the following disturbance ranges for each marine mammal species:

- 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 DEP and SEP 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 DEP and SEP 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 DEP and SEP for TTS / fleeing response (unweighted SPL_{peak}) of 20km (1,256.6km^2)

750. However, as outlined in the BEIS (2020) Review of Consents (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).

751. It is also highly unlikely that more than one UXO detonation would occur at exactly the same time or on the same day as another UXO detonation, even if they had overlapping UXO clearance operation durations.

752. The SCANS-III harbour porpoise density estimate for the North Sea MU is 0.52/km^2, and the density estimates for bottlenose dolphin, white-beaked dolphin and minke whale across the entire SCANS-III aerial survey blocks are 0.016/km^2, 0.030/km^2 and 0.011/km^2, respectively (Hammond *et al.*, 2017). Without knowing the actual location for any UXO clearance, these density estimates have been used to estimate the potential number of individuals that could potentially be disturbed.

753. Without knowing the actual location for any UXO clearance the mean density estimates are based on the average seal at sea density estimates for the areas of the UK and EU offshore windfarms. This is 0.1 grey seal per km^2 and 0.02 harbour seal per km^2. This is based on the seal-at-sea maps (Russell *et al.*, 2017) and an average density based on a 50km buffer around all offshore windfarms (UK and EU) included within the CIA.

754. **Table 12-109** presents the cumulative impact assessment for one UXO clearance event occurring at the same time as piling at DEP or SEP (using the assessment for piling as the worst-case).

755. UXO clearance at DEP and SEP will be assessed as part of a separate Marine Licence.

Table 12-109: Quantified CIA for the potential disturbance of marine mammals for UXO clearance at the same time as piling at DEP or SEP

Species	Activity	Area of disturbance	Density estimate	Potential number at risk of disturbance (% of reference population)
Harbour porpoise	Piling at DEP or SEP, as the worst-case disturbance impact during construction	2,123.7km^2	0.888/km^2	1,886
	Disturbance from one UXO clearance operation in the North Sea area	2,123.7km^2	0.52/km^2	1,104
	Cumulative assessment for harbour porpoise			**2,990 (0.87%)**
Bottlenose dolphin	Piling at DEP or SEP, as the worst-case disturbance impact during construction	0.44km^2	0.03/km^2	0.01
	Disturbance from one UXO clearance operation in the North Sea area	5.3km^2	0.016/km^2	0.08
	Cumulative assessment for bottlenose dolphin			**0.1 (0.005%)**

Species	Activity	Area of disturbance	Density estimate	Potential number at risk of disturbance (% of reference population)
White-beaked dolphin	Piling at DEP or SEP, as the worst-case disturbance impact during construction	0.44km^2	0.006/km^2	0.003
	Disturbance from one UXO clearance operation in the North Sea area	5.3km^2	0.03/km^2	0.16
	Cumulative assessment for white-beaked dolphin			**0.2 (0.001%)**
Minke whale	Piling at DEP or SEP, as the worst-case disturbance impact during construction	1,100km^2	0.01/km^2	11
	Disturbance from one UXO clearance operation in the North Sea area	33,329.2km^2	0.011/km^2	367
	Cumulative assessment for minke whale			**378 (1.6%)**
Grey seal	Piling at DEP or SEP, as the worst-case disturbance impact during construction	220km^2	0.35/km^2	77
	Disturbance from one UXO clearance operation in the North Sea area	1,256.6km^2	0.1/km^2	126
	Cumulative assessment for grey seal			**203 (0.84%)**
Harbour seal	Piling at DEP or SEP, as the worst-case disturbance impact during construction	220km^2	0.24/km^2	53
	Disturbance from one UXO clearance operation in the North Sea area	1,256.6km^2	0.02/km^2	25
	Cumulative assessment for harbour seal			**78 (0.17%)**

756. As assessed in **Table 12-109**, the number of harbour porpoise that could potentially be disturbed during one UXO detonation during construction of DEP and SEP could be up to 2,990 harbour porpoise (0.87% of the NS MU reference population). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the temporary effect.

757. For bottlenose dolphin, the number of individuals that could be disturbed as a result of UXO detonation during the construction of DEP and SEP is 0.1 (0.05% of the relevant reference population) (**Table 12-109**). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the temporary effect.

758. For white-beaked dolphin, the number of individuals that could be disturbed as a result of UXO detonation during the construction of DEP and SEP is 0.2 (0.001% of the relevant reference population) (**Table 12-109**). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the temporary effect.

759. For minke whale, the number of individuals that could potentially be disturbed during one UXO detonation during the construction of DEP and SEP, could be 378 (1.6% of the CGNS MU reference population; **Table 12-109**). The potential magnitude of the temporary effect is therefore assessed as low, with between 1% and 5% of the reference population likely to be exposed to the effect.

760. For grey seal, the number of individuals that could potentially be disturbed during one UXO detonation during the construction of DEP and SEP could be up to 203 grey seal (0.84% of the reference population; **Table 12-109**). Therefore, the magnitude would be negligible, with less than 1% of the reference population likely to be exposed to the effect.

761. The number of harbour seal that could potentially be disturbed would be 78 (0.17% of the reference population; **Table 12-109**). 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.

12.7.3.2.2 Potential for Disturbance from Seismic Surveys

12.7.3.2.2.1 Sensitivity to Disturbance

762. As outlined in **Section 12.6.1.3.1**, 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.

12.7.3.2.2.2 Magnitude of Potential Disturbance

763. It is currently not possible to estimate the number of potential seismic surveys that could be undertaken at the same time as construction and potential piling activity at DEP and SEP.

764. The BEIS (2020) 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 southern North Sea at exactly the same time. It is therefore assumed, as a worst-case scenario, that there could potentially be up to two seismic surveys in the North Sea at any one time, alongside construction of DEP and SEP. To take into account the larger MU for both white-beaked dolphin and minke whale, it is assumed that up to three seismic surveys could be undertaken at the same time as construction at DEP and SEP.

765. This assessment has been based on the potential for disturbance due to seismic surveys undertaken at the same time as the construction of DEP and SEP. The magnitude of the potential disturbance from seismic surveys has been estimated based on the following disturbance ranges for each marine mammal species:

- Harbour porpoise
  - The potential impact area during seismic surveys, based on a radius of 12km from each piling location (452.4km^2 per project), following the current SNCB guidance for the assessment of impact to harbour porpoise in the SNS SAC
- Bottlenose dolphin and white-beaked dolphin and
  - There is little available information on the potential for disturbance from seismic surveys, however, observations of behavioural changes in common dolphins in the Irish Sea show a reduced vocalisation rate and / or exclusion within 1km of a 2D seismic survey (of 2,120 cu. in.) (Goold, 1996); a potential disturbance range of 1km (disturbance area of 3.1km^2) will therefore be applied to both white-beaked dolphin and bottlenose dolphin due to a lack of species-specific information.
- 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 of 1,600 cu. in.) (Macdonald *et al*., 1995); a potential disturbance range of 10km (disturbance area of 314.1km^2) will therefore be applied to minke whale due to a lack of species-specific information.
- 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 of 1,600 cu. in.) (Harris *et al*., 2001); a potential disturbance range of 3.6km (disturbance area of 40.7km^2) will therefore be applied to both grey seal and harbour seal due to a lack of species-specific information.

766. It should be noted that this assessment is based on the potential impacts for seismic surveys required by the oil and gas industry. The higher frequencies typically used for geophysical surveys for offshore windfarms generally fall outside the hearing frequencies of cetaceans and the sounds produced are likely to attenuate more quickly than the lower frequencies used in deeper waters (JNCC, 2017).

767. The densities for each marine mammal species used in the following assessment are set out above for the assessment of UXO clearance being undertaken at the same time as construction at DEP and SEP.

768. **Table 12-110** presents the cumulative impact assessment for either two or three (dependent on species) seismic surveys occurring at the same time as construction at DEP and SEP (using the assessment for piling as the worst-case).

Table 12-110: Quantified CIA for the potential disturbance of marine mammals for seismic surveys at the same time as construction of DEP or SEP

Species	Activity	Area of disturbance	Density estimate	Potential number at risk of disturbance (% of reference population)
Harbour porpoise	Piling at DEP or SEP, as the worst-case disturbance impact during construction	2,123.7km^2	0.888/km^2	1,886
	Disturbance from two seismic surveys in the North Sea area	904.8km^2	0.52/km^2	470
	Cumulative assessment for harbour porpoise			**2,356 (0.68%)**
Bottlenose dolphin	Piling at DEP or SEP, as the worst-case disturbance impact during construction	0.4km^2	0.03/km^2	0.01

Species	Activity	Area of disturbance	Density estimate	Potential number at risk of disturbance (% of reference population)
	Disturbance from two seismic surveys in the North Sea area	6.2km^2	0.016/km^2	0.1
	Cumulative assessment for bottlenose dolphin			**0.1 (0.005%)**
White-beaked dolphin	Piling at DEP or SEP, as the worst-case disturbance impact during construction	0.4km^2	0.006/km^2	0.002
	Disturbance from three seismic surveys in the North Sea area	9.3km^2	0.03/km^2	0.28
	Cumulative assessment for white-beaked dolphin			**0.3 (0.002%)**
Minke whale	Piling at DEP or SEP, as the worst-case disturbance impact during construction	1,100km^2	0.01/km^2	11
	Disturbance from three seismic surveys in the North Sea area	942.3km^2	0.011/km^2	10
	Cumulative assessment for minke whale			**21 (0.09%)**
Grey seal	Piling at DEP or SEP, as the worst-case disturbance impact during construction	220km^2	0.35/km^2	77
	Disturbance from two seismic	81.4km^2	0.1/km^2	8

Species	Activity	Area of disturbance	Density estimate	Potential number at risk of disturbance (% of reference population)
	surveys in the North Sea area			
	Cumulative assessment for grey seal			**85 (0.35%)**
Harbour seal	Piling at DEP or SEP, as the worst-case disturbance impact during construction	220km^2	0.24/km^2	53
	Disturbance from two seismic surveys in the North Sea area	81.4km^2	0.02/km^2	2
	Cumulative assessment for harbour seal			**55 (0.12%)**

769. As assessed in **Table 12-110**, the number of harbour porpoise that could potentially be disturbed during two seismic surveys cumulatively with the construction of DEP and SEP could be up to 2,356 harbour porpoise (0.68% of the NS MU reference population). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

770. For bottlenose dolphin, the number of individuals that could potentially be disturbed during two seismic surveys being undertaken cumulatively with the construction of DEP and SEP, could be 0.1 (0.06% of the GNS MU reference population; **Table 12-110**). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

771. For white-beaked dolphin, the number of individuals that could be disturbed as a result of three seismic surveys being undertaken during the construction of DEP and SEP is 0.3 (0.002% of the relevant reference population) (**Table 12-110**). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect for both species

772. For minke whale, the number of individuals that could be disturbed as a result of three seismic surveys being undertaken during the construction of DEP and SEP is 21 (0.09% of the relevant reference population) (**Table 12-110**). The potential magnitude of the temporary effect is therefore assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect for both species.

773. Two seismic surveys taking place at the same time as construction at DEP and SEP could potentially disturb up to 85 grey seal (0.35% of the reference population; **Table 12-110**). The number of harbour seal that could potentially be disturbed could be 55 (0.12% of the reference population; **Table 12-110**). Therefore, the potential magnitude of the temporary effect is assessed as negligible for grey and harbour seal, with less than 1% of the reference populations likely to be exposed to the effect.

12.7.3.2.3 Potential for Disturbance from other Offshore Wind Farm Construction Activities

12.7.3.2.3.1 Sensitivity to Disturbance

774. As outlined in **Section 12.6.1.3.1**, 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.

12.7.3.2.3.2 Magnitude of Potential Disturbance

775. During the construction of DEP and SEP, there is the potential to overlap with impacts from the non-piling construction activities at other offshore windfarms. Noise sources which could cause potential disturbance impacts during offshore windfarm construction activities, other than pile driving, can include vessels, seabed preparation, ploughing / jetting / pre-trenching or cutting for installation of cables and rock placement for protection of the cable.

776. There would be no additional cumulative impacts of underwater noise from other construction activities for those projects which also have overlapping piling with DEP and SEP, as the ranges for piling would be significantly greater than those from other construction noise sources, and therefore the assessment under the potential for cumulative impacts from piling activities represents the worst-case.

777. The potential impact ranges of these noise sources during offshore windfarm construction will be localised and significantly less than the ranges predicted for piling.

778. The CIA determined the UK and European offshore windfarms which could potentially have non-piling construction activities during the DEP and SEP construction period. The assessment includes all projects that could have non-piling construction activities during the DEP and SEP construction period.

779. The potential temporary disturbance during offshore windfarm construction activities, other than pile driving noise sources, has been based on worst-case areas used in assessments for DEP and SEP for all construction activities other than piling (area of 3.4km^2 for harbour porpoise and 0.15km^2 for all other species) and all construction vessels (0.63km^2) at each of the screened in offshore windfarm sites. Therefore, total offshore windfarm construction area for each site is 4km^2 for harbour porpoise and 0.8km^2 for all other marine mammal species. 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.

780. In addition, it is unlikely, as outlined for the cumulative impact assessment for piling, that developers would construct more than one offshore windfarm at a time as it is generally more efficient to develop one site and have it operational prior to constructing the next site. In addition, the UK government funding mechanism for offshore wind (Contracts for Difference auctions) also makes it more unlikely that developers would be constructing more than one windfarm concurrently.

781. For each project, the number of harbour porpoise, bottlenose dolphin, white-beaked dolphin and minke whale in the potential impact areas, has been estimated using the latest SCANS-III density estimates (Hammond *et al.,* 2017) for the relevant survey block that the project is located within. As for the project alone calculations, for any project located within survey block O, the bottlenose dolphin density estimate for survey block R will be used instead, due to the recent change in distribution.

782. The number of grey seal and harbour seal in the potential impact areas, has been estimated using the latest seal at sea usage maps to estimate densities (Russell *et al.* 2017) for the relevant area that the project is located.

783. The conservative potential worst case scenario for offshore windfarms, in the harbour porpoise, white-beaked dolphin, minke whale, bottlenose dolphin, grey seal and harbour seal reference population areas, that could be constructing at the same time as DEP and SEP, have been used to inform an assessment of the potential impact of cumulative piling (**Table 12-111** to **Table 12-115**).

784. In this potential worst case scenario, for all offshore wind farms that could be constructing at the same time as DEP and SEP, and based on the area of the wind farms, the maximum number of harbour porpoise that could potentially be temporarily disturbed approximately 1.1% of the North Sea MU reference population (**Table 12-111**). Therefore, the potential magnitude of the temporary effect is assessed as low.

Table 12-111: Quantified CIA for the potential disturbance of harbour porpoise during the construction (other than piling) at other offshore windfarm projects at the same time as construction at DEP and SEP

Name of Project	Area (km^2)	SCANS-III Block	Harbour porpoise density	Number of individuals at risk of disturbance
DEP	2,123.7km^2	O	0.888	1,886
SEP	2,123.7km^2	O	0.888	1,886
Berwick Bank	4	R	0.599	2
Dolphyn Project – commercial	4	R	0.599	2.4
Dolphyn Project - pre-commercial	4	R	0.599	2.4
East Anglia THREE	4	L	0.607	2
Five Estuaries	4	L	0.607	2
Hornsea Project Three	4	O	0.888	4
Kincardine - DOLPHYN demo	4	R	0.599	2.4

Name of Project	Area (km²)	SCANS-III Block	Harbour porpoise density	Number of individuals at risk of disturbance
Moray West	4	S	0.152	1
Norfolk Vanguard	4	L / O	0.888	4
Pentland	4	S	0.152	0.6
Rampion Extension	4	C	0.213	1
Sofia (formerly Dogger Bank Teesside B)	4	O / N	0.888	4
EnBW He Dreiht	4	M	0.277	1
Kaskasi	4	M	0.277	1.1
Borssele Site V - Leeghwater - Innovation Plot	4	L	0.607	2.4
Hollandse Kust Zuid Holland III and IV	4	N	0.837	3
TetraSpar Demo - Metcentre	4	V	0.137	0.55
Sotenas Offshore Park	4	1	1.33	5.3
Total number of harbour porpoise at risk of disturbance				**3,813**
% of reference population				**1.1%**

785. Based on all offshore wind farms with the potential for overlapping construction periods with DEP and SEP, the maximum number of bottlenose dolphin that could potentially be disturbed is 0.2 (0.01% of the reference population) (**Table 12-112**). Therefore, the potential magnitude of the temporary effect is assessed as negligible (less than 1% of the reference population).

Table 12-112: Quantified CIA for the potential disturbance of bottlenose dolphin during the construction (other than piling) at other offshore windfarm projects at the same time as construction at DEP and SEP

Name of Project	Area (km²)	SCANS-III Block	Bottlenose dolphin density	Number of individuals at risk of disturbance
DEP	0.44	O	0.03	0.013
SEP	0.44	O	0.03	0.013
Berwick Bank	0.8	R	0.599	0.02
Dolphyn Project – commercial	0.8	R	0.599	0.02
Dolphyn Project - pre-commercial	0.8	R	0.599	0.02
East Anglia THREE	0.8	L	0.607	0
Five Estuaries	0.8	L	0.607	0
Hornsea Project Three	0.8	O	0.888	0.02

Name of Project	Area (km^2)	SCANS-III Block	Bottlenose dolphin density	Number of individuals at risk of disturbance
Kincardine - DOLPHYN demo	0.8	R	0.599	0.02
Moray West	0.8	S	0.152	0.003
Norfolk Vanguard	0.8	L / O	0.888	0.02
Pentland	0.8	S	0.152	0.003
Rampion Extension	0.8	C	0.213	0
Sofia (formerly Dogger Bank Teesside B)	0.8	O / N	0.888	0.02
EnBW He Dreiht	0.8	M	0.277	0
Kaskasi	0.8	M	0.277	0
Borssele Site V - Leeghwater - Innovation Plot	0.8	L	0.607	0
Hollandse Kust Zuid Holland III and IV	0.8	N	0.837	0
TetraSpar Demo - Metcentre	0.8	V	0.137	0
Sotenas Offshore Park	0.8	1	1.33	0
Total number of bottlenose dolphin at risk of disturbance				**0.2**
% of reference population				**0.01%**

786. Based on all offshore wind farms with the potential for overlapping construction periods with DEP and SEP, the maximum number of white-beaked dolphin that could potentially be disturbed is 0.8 (0.005% of the reference population) (**Table 12-113**). Therefore, the potential magnitude of the temporary effect is assessed as negligible (less than 1% of the reference population).

Table 12-113: Quantified CIA for the potential disturbance of white-beaked dolphin during construction (other than piling) at other offshore windfarm projects at the same time as construction at DEP and SEP

Name of Project	Area (km^2)	SCANS-III Block	White-beaked dolphin density	Number of individuals at risk of disturbance
DEP	0.44	O	0.002	0.0009
SEP	0.44	O	0.002	0.0009
Berwick Bank	0.8	R	0.243	0.2
Dolphyn Project – commercial	0.8	R	0.243	0.2
Dolphyn Project - pre-commercial	0.8	R	0.243	0.2
East Anglia THREE	0.8	L	0	0

Name of Project	Area (km^2)	SCANS-III Block	White-beaked dolphin density	Number of individuals at risk of disturbance
Erebus (Commercial)	0.8	D	0	0
Erebus (Demonstration)	0.8	D	0	0
Five Estuaries	0.8	L	0	0
Hornsea Project Three	0.8	O	0.002	0.002
Kincardine - DOLPHYN demo	0.8	R	0.243	0.2
Moray West	0.8	S	0.021	0.02
Norfolk Vanguard	0.8	L / O	0.002	0.002
Pentland	0.8	S	0.021	0.02
Rampion Extension	0.8	C	0	0
Sofia (formerly Dogger Bank Teesside B)	0.8	O / N	0.002	0.002
Valorous	0.8	D	0	0
Wave Hub	0.8	D	0	0
EnBW He Dreiht	0.8	M	0	0
Kaskasi	0.8	M	0	0
Atlantic Marine Energy Test Site	0.8	Stratum 6	0	0
Borssele Site V - Leeghwater - Innovation Plot	0.8	L	0	0
Hollandse Kust Zuid Holland III and IV	0.8	N	0	0
TetraSpar Demo - Metcentre	0.8	V	0.007	0.006
Sotenas Offshore Park	0.8	1	0	0
Total number of white-beaked dolphin at risk of disturbance				**0.8**
% of reference population				**0.005%**

787. Based on the offshore wind farms that could be undergoing construction at the same time as DEP and SEP, the maximum number of minke whale that could be potentially temporarily disturbed is approximately 0.09% of the reference population (**Table 12-114**). 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 12-114: Quantified CIA for the potential disturbance of minke whale during the construction (other than piling) at other offshore windfarm projects at the same time as construction at DEP and SEP

Name of Project	Area (km^2)	SCANS-III Block	Minke whale density	Number of individuals at risk of disturbance
DEP	1,100km^2	O	0.01	11
SEP	1,100km^2	O	0.01	11
Berwick Bank	0.8	R	0.039	0.03
Dolphyn Project – commercial	0.8	R	0.039	0.03
Dolphyn Project - pre-commercial	0.8	R	0.039	0.03
East Anglia THREE	0.8	L	0	0
Erebus (Commercial)	0.8	D	0.011	0.009
Erebus (Demonstration)	0.8	D	0.011	0.009
Five Estuaries	0.8	L	0	0
Hornsea Project Three	0.8	O	0.01	0.008
Kincardine - DOLPHYN demo	0.8	R	0.039	0.03
Moray West	0.8	S	0.01	0.008
Norfolk Vanguard	0.8	L / O	0.01	0.008
Pentland	0.8	S	0.01	0.008
Rampion Extension	0.8	C	0.002	0.002
Sofia (formerly Dogger Bank Teesside B)	0.8	O / N	0.01	0.008
Valorous	0.8	D	0.011	0.009
Wave Hub	0.8	D	0.011	0.009
EnBW He Dreiht	0.8	M	0	0
Kaskasi	0.8	M	0	0
Atlantic Marine Energy Test Site	0.8	Stratum 6	0	0
Borssele Site V - Leeghwater - Innovation Plot	0.8	L	0	0
Hollandse Kust Zuid Holland III and IV	0.8	N	0.02	0.02
TetraSpar Demo - Metcentre	0.8	V	0.011	0.009
Sotenas Offshore Park	0.8	1	0	0
Total number of minke whale at risk of disturbance				**22.23**
% of reference population				**0.09%**

788. Based on the projects that could have construction overlapping with DEP and SEP, the maximum number of grey seal and harbour seal that could potentially be disturbed is 0.6% and 0.2% of the reference populations, respectively (**Table 12-115**). 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 12-115: Quantified CIA for the potential disturbance of grey seal and harbour seal during the construction (other than piling) at other offshore windfarm projects at the same time as construction at DEP and SEP

Name of Project	Area (km^2)	Grey seal density	Harbour seal density	Number of grey seal at risk of disturbance	Number of harbour seal at risk of disturbance
DEP	220	0.35	0.24	77	53
SEP	220	0.35	0.24	77	53
East Anglia THREE	0.8	0.0001	0.001	0.00008	0.0008
Five Estuaries	0.8	0.01	0.0007	0.008	0.0006
Hornsea Project Three	0.8	0.037	0.002	0.03	0.002
Norfolk Vanguard	0.8	0.001	0.00008	0.0008	0.00006
Sofia (formerly Dogger Bank Teesside B)	0.8	0.04	0.00004	0.03	0.00003
Total number of grey and harbour seal at risk of disturbance				**154**	**106**
% of reference population				**0.6%**	**0.2%**

789. 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 windfarm project construction periods. Therefore, this assessment is considered to be a precautionary worst-case.

12.7.3.3 Overall Cumulative Underwater Noise Impacts (Impacts 1 and 2)

12.7.3.3.1 Magnitude of Potential Disturbance from All Sources including Piling

790. **Table 12-116** provides a summary of the number of each marine mammal species that could be disturbed from all noise sources, including piling.

791. For harbour porpoise, up to 18,424 individuals (5.3% of the reference population) could be at risk of disturbance (**Table 12-116**). Therefore, for harbour porpoise, the potential magnitude is assessed as medium, with between 5% and 10% of the reference population potentially impacted.

792. For bottlenose dolphin, 0.5 individuals (0.25% of the reference population) could be at risk of disturbance (**Table 12-116**). Therefore, for bottlenose dolphin, the potential magnitude is assessed as negligible, with less than 1% of the reference population potentially impacted.

793. For white-beaked dolphin, up to 1.4 individuals (0.009% of the reference population) could be at risk of disturbance from all noise sources (**Table 12-116**). Therefore, for white-beaked dolphin, the potential magnitude is assessed as negligible, with less than 1% of the reference population potentially impacted.

794. For minke whale, up to 948 individuals (4% of the reference population) could be at potential risk of disturbance (**Table 12-116**). Therefore, for minke whale, the potential magnitude is assessed as low, with between 1% and 5% of the reference population potentially impacted.

795. For grey seal and harbour seal, up to 415 and 142 individuals (1.72% and 0.3% of the reference populations), respectively, could be potential at risk of disturbance (**Table 12-116**). Therefore, for grey seal, the potential magnitude is assessed as low, with between 1% and 5% of the reference population potentially impacted, and for harbour seal, the magnitude is assessed as negligible, with less than 1% of the reference population potentially impacted.

Table 12-116: Quantified CIA for the potential disturbance of marine mammals from all possible noise sources including piling during construction of DEP and SEP

Potential noise source	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
Offshore wind farm piling, including DEP & SEP	16,809	0.1	0.2	571	281	115
UXO clearance	1,104	0.08	0.16	367	126	25
Seismic surveys	470	0.1	0.28	10	8	2
Non-piling construction activities at other offshore wind farms	41	0.2	0.8	0.2	0.07	0.003
Total number potentially at risk of disturbance for all noise sources, including piling at DEP & SEP	**18,424**	**0.5**	**1.44**	**948**	**415**	**142**
% of reference population	**5.33**	**0.25**	**0.009**	**4.03**	**1.72**	**0.30**

796. If all included activities were being undertaken at the same time as piling at DEP and SEP, there is the potential for a negligible to medium magnitude of impact (dependent on species), however, as outlined above, it is highly unlikely that all these activities would be conducted at exactly the same time as piling at DEP and SEP. 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 would also reduce the potential disturbance of white-beaked dolphin, minke whale, bottlenose dolphin, as well as grey and harbour seal.

797. The assessment considers the overall cumulative impact of underwater noise associated with piling (**Impact 1**) and all other noise sources (**Impact 2**). There would be no additional cumulative impacts of noise from other construction activities for those projects which also have overlapping piling with piling at DEP and SEP, as the impact ranges for piling would be significantly greater than those impacts from other construction noise sources.

798. This assessment is based on highly conservative assumptions (e.g. that impact ranges do no overlap).

799. The contribution of DEP or SEP to the overall cumulative impact from underwater noise, during single pile installation would potentially be the disturbance of:

- Up to 1,886 harbour porpoise at each site, approximately 10% of the total 18,424 harbour porpoise that could be disturbed;
- Up to 0.03 bottlenose dolphin at each, approximately 6% of the total 0.5 bottlenose dolphin that could be disturbed;
- Up to 0.002 white-beaked dolphin at each site, approximately 0.1% of the total 1.4 white-beaked dolphin that could be disturbed;
- Up to 11 minke whale at each site, approximately 1% of the total 948 minke whale that could be disturbed;
- Up to 77 grey seal at each site, approximately 19% of the total of 415 grey seal that could be disturbed; and
- Up to 53 harbour seal at each site, approximately 37% of the total 142 harbour seal that could be disturbed.

12.7.3.3.2 Overall Impact Significance of Disturbance from All Noise Sources including Piling

800. Taking into account the medium receptor sensitivity for all marine mammal species, the negligible to medium potential magnitude of the cumulative impact, the overall cumulative impact assessment for disturbance to marine mammals from all other noise sources is minor to moderate adverse, prior to any mitigation measures, such as SIPs for harbour porpoise in the SNS SAC being taken into account (**Table 12-117**).

801. 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 windfarm sites.

Table 12-117: Overall cumulative impact significance for disturbance of marine mammals from all noise sources including piling during construction at DEP and SEP

Potential Impact	Species	Sensitivity	Magnitude	Impact Significance	Mitigation	Residual Impact
Overall cumulative impact of disturbance to marine mammals during construction of DEP and SEP	Harbour porpoise	Medium	Medium	Moderate	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance of harbor porpoise	**Minor adverse**
	Bottlenose dolphin		Negligible	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**

12.8 Transboundary Impacts

802. 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 12-118**). This approach has been taken through all of the assessments.

Table 12-118: 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 and Coastal East Scotland MU for bottlenose dolphin.

Country	Marine mammal species	Inclusion within assessments
	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 and Coastal East Scotland 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 and Coastal East Scotland MU for bottlenose dolphin.
	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	Grey seal and harbour seal	Not part of the grey seal and harbour seal reference population area, and therefore no potential for transboundary impacts.
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 and Coastal East Scotland MU for bottlenose dolphin.
	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	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
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 and Coastal East Scotland 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 and Coastal East Scotland MU for bottlenose dolphin.
	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	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 and Coastal East Scotland MU for bottlenose dolphin.
	Harbour porpoise	Part of the North Sea MU for harbour porpoise.
	Grey seal and harbour seal	Not part of the grey seal and harbour seal reference population area, and therefore no potential for transboundary impacts.

803. There is a significant level of marine development being undertaken, and being planned, by other countries (including Belgium, the Netherlands, Germany and Denmark) in the southern North Sea. Each of these countries have 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 DEP and SEP to impact marine mammals from other designated sites, this is assessed in the **draft Information for HRA Report**. The potential for transboundary impacts has been assessed with the other cumulative impacts, as based on the wide MU areas and EU wind farms, where relevant, are included in the CIA.

12.9 Inter-relationships

804. For marine mammals, potential inter-relationships between impact pathways are already covered as part of the marine mammal assessments provided above. **Table 12-119** provides a signposting to where these potential inter-relationship impacts have already been assessed.

Table 12-119: Marine Mammal inter-relationships

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Underwater noise from vessels	*Chapter 14: Shipping and Navigation*	**Section 12.6.1.5.6.3** for construction and **Section 12.6.2.3** 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 14: Shipping and Navigation*	**Section 12.6.1.8** for construction and **Section 12.6.2.5** for operation and maintenance	Increased vessel traffic associated with the projects could affect the level of collision risk for marine mammals.
Disturbance at seal haul-out sites	*Chapter 14: Shipping and Navigation*	**Section 12.6.1.8.6.2** for construction and **Section 12.6.2.6** for operation and maintenance	Increased vessel traffic associated with the projects could affect the level of disturbance at seal haul-out sites.
Changes to prey availability	*Chapter 10: Fish and Shellfish Ecology* and *Chapter 10 Benthic Ecology*	**Section 12.6.1.10** for construction and **Section 12.6.2.7** for operation and maintenance	Potential impacts on fish species could affect the prey resource for marine mammals.

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Changes to water quality	*Chapter 9 Marine Water and Sediment Quality*	**Section 12.6.1.10.5.2** for construction and **Section 12.6.2.8** 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.

12.10 Interactions

805. 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.

806. The areas of potential interaction between impacts are presented in **Table 12-120**. This provides a screening tool for which impacts have the potential to interact.

807. 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.

808. In **Table 12-121** the impacts are assessed relative to each development phase (assessment for construction, operation, 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.

809. 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 12-120: Interaction between impacts - screening of potential for interaction impacts

Potential Interaction between Impacts											
Construction											
	Impact 1	**Impact 2**	**Impact 3**	**Impact 4**	**Impact 5**	**Impact 6**	**Impact 7**	**Impact 8**	**Impact 9**	**Impact 10**	**Impact 11**
Impact 1: Physical and Auditory Injury from Underwater Noise Associated with UXO Clearance	-	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 2: Behavioural Impacts from Underwater Noise Associated with UXO Clearance	Yes	-	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 3: Auditory Injury from Underwater Noise Associated with Piling	Yes	Yes	-	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 4: Behavioural Impacts from Underwater Noise Associated with Piling Activities	Yes	Yes	Yes	-	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 5: Behavioural Impacts from Underwater Noise Associated with Other Construction Activities	Yes	Yes	Yes	Yes	-	Yes	Yes	No	Yes	Yes	Yes
Impact 6: Impacts from Underwater Noise Associated with Construction Vessels	Yes	Yes	Yes	Yes	Yes	-	Yes	No	Yes	Yes	Yes
Impact 7: Barrier Effects from Underwater Noise	Yes	Yes	Yes	Yes	Yes	Yes	-	No	Yes	Yes	Yes

Potential Interaction between Impacts											
Impact 8: Increased Risk of Collision with Vessels during Construction	No	No	No	No	No	No	No	-	No	No	No
	Impact 1	**Impact 2**	**Impact 3**	**Impact 4**	**Impact 5**	**Impact 6**	**Impact 7**	**Impact 8**	**Impact 9**	**Impact 10**	**Impact 11**
Impact 9: Disturbance at Seal Haul-Out Sites	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	-	Yes	Yes
Impact 10: Changes to Prey Availability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	-	Yes
Impact 11: Changes to Water Quality	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	-

Operation								
	Impact 1	**Impact 2**	**Impact 3**	**Impact 4**	**Impact 5**	**Impact 6**	**Impact 7**	**Impact 8**
Impact 1: Auditory Impacts from Underwater Noise Associated with Operational Wind Turbines	-	Yes	Yes	Yes	No	Yes	Yes	Yes
Impact 2: Impacts from Underwater Noise Associated with Other Operation and Maintenance Activities	Yes	-	Yes	Yes	No	Yes	Yes	Yes
Impact 3: Impacts from Underwater Noise Associated with Operation and Maintenance Vessels	Yes	Yes	-	Yes	No	Yes	Yes	Yes

Potential Interaction between Impacts								
Impact 4: Barrier Effects from Underwater Noise	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes
Impact 5: Increased Risk of Collision with Vessels during Operation	No	No	No	No	-	No	No	No
	Impact 1	**Impact 2**	**Impact 3**	**Impact 4**	**Impact 5**	**Impact 6**	**Impact 7**	**Impact 8**
Impact 6: Disturbance at Seal Haul-Out Sites	Yes	Yes	Yes	Yes	No	-	Yes	Yes
Impact 7: Changes to Prey Availability	Yes	Yes	Yes	Yes	No	Yes	-	Yes
Impact 8: Changes to Water Quality	Yes	Yes	Yes	Yes	No	Yes	Yes	-
Decommissioning								
It is anticipated that the decommissioning impacts will be similar or less than construction.								

Table 12-121: Interaction between impacts – phase and lifetime assessment

Receptor	Highest significance level				
	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 mitigation (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	**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 windfarms. It is therefore considered that over the project lifetime these impacts would not combine and represent an increase in the significance level.

	Highest significance level				
				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.	

	Highest 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	

12.11 Assessment Summary

810. The potential impacts on marine mammals during the construction, operation, maintenance and decommissioning phases of DEP and SEP and cumulative impacts are summarised in **Table 12-122**.

Table 12-122: Summary of potential impacts during construction, operation, maintenance and decommissioning of DEP or SEP, 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 UXO Clearance						
Permanent auditory injury (PTS)	Harbour porpoise and minke whale	High	Medium	Major adverse	MMMP for UXO Clearance	Minor adverse
	Bottlenose dolphin	High	Low	Moderate adverse		Minor adverse
	White-beaked dolphin	High	Negligible	Minor adverse		Minor adverse
	Grey and harbor seal	High	Low to Medium	Moderate to Major adverse		Minor adverse
Temporary auditory injury (TTS) / fleeing response	Harbour porpoise, bottlenose dolphin, white-beaked dolphin and harbour seal	Medium	Negligible	Minor adverse	MMMP for UXO Clearance	Minor adverse
	Minke whale	Medium	Low	Minor adverse		Minor adverse
	Grey seal	Medium	Negligible to Low	Minor adverse		Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 2: Behavioural Impacts from Underwater Noise Associated with UXO Clearance						
Disturbance	Harbour porpoise	Medium	Negligible to Low	Minor adverse	MMMP for UXO Clearance	Minor adverse
Impact 3: Auditory Injury from Underwater Noise Associated with Piling						
PTS from single strike of maximum hammer energy	Harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whale, grey seal and harbour seal	High	Negligible	Minor adverse	MMMP for piling	Minor adverse
PTS during piling from cumulative exposure	Harbour porpoise	High	Low to Medium	Moderate to Major adverse	MMMP for piling	Minor adverse
	Minke whale	High	Low	Moderate adverse		Minor adverse
	Bottlenose dolphin and white-beaked dolphin	High	Negligible	Minor adverse		Minor adverse
	Grey seal and harbour seal	High	Negligible to Low	Minor to Moderate adverse		Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
TTS from single strike of maximum hammer energy	Harbour porpoise, bottlenose dolphin, white-beaked dolphin, minke whales, grey and harbour seal	Medium	Negligible	Minor adverse	MMMP for piling	Minor adverse
TTS during piling from cumulative exposure	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse	MMMP for piling	Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 4: Behavioural Impacts from Underwater Noise Associated with Piling Activities						
ADD activation	Harbour porpoise, bottlenose dolphin white-beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse	Not applicable	Minor adverse
Disturbance	Harbour porpoise	Medium	Low to Negligible	Minor adverse	SNS SAC SIP	Minor adverse
Possible behavioural response	Harbour porpoise	Medium	Negligible	Minor adverse	SNS SAC SIP	Minor adverse
Impact 5: Impacts from Underwater Noise Associated with Other Construction Activities						
TTS / fleeing response from cumulative SEL during other construction activities	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse	No mitigation required	Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 6: Impacts from Underwater Noise and Disturbance Associated with Construction Vessels						
TTS / fleeing response from cumulative SEL for construction vessels	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse	No mitigation required	Minor adverse
Impact 7: Barrier Effects from Underwater Noise during Construction						
Barrier effects from underwater noise	Harbour porpoise	Medium	Low to Negligible	Minor adverse	No mitigation required. However, measures in SIP will reduce potential significant disturbance of harbor porpoise (and other marine mammals)	Minor adverse
	Bottlenose dolphin white-beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse		Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 8: Increased Risk of Collision with Vessels during Construction						
Increased collision risk	Harbour porpoise, bottlenose dolphin grey and harbour seal	Low	Low	Minor adverse	No further mitigation proposed other than good practice.	Negligible
	White-beaked dolphin and minke whale	Low	Negligible	Negligible		Negligible
Impact 9: Disturbance at Seal Haul-Out Sites						
Disturbance at seal haul-out sites	Grey and harbour seal	Low to medium	Negligible	Negligible to Minor adverse	No further mitigation required or proposed other than good practice.	Negligible to Minor adverse
Impact 10: Changes to Prey Availability						
	Harbour porpoise and minke whale	Low to medium	Negligible	Negligible to Minor adverse	No mitigation required for prey.	Negligible to Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Change in prey availability during piling	Bottlenose dolphin, white-beaked dolphin, grey and harbour seal	Low	Negligible	Negligible	However, measures in MMMP and SIP will also reduce potential impacts of underwater noise on prey.	Negligible
Impact 11: Changes to Water Quality						
Changes in water quality	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	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						
Underwater noise from operational turbines	Harbour porpoise, bottlenose dolphin white beaked dolphin, minke whale, grey and harbour seal	Low to Medium	Negligible	Negligible to Minor adverse	No mitigation required	Negligible to Minor adverse
Impact 2: Impacts from Underwater Noise Associated with Operational and Maintenance Activities						
Underwater noise from maintenance activities	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse	No mitigation required	Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 3: Impacts from Underwater Noise and Disturbance Associated with Operation and Maintenance Vessels						
Underwater noise from O&M vessels	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	Medium	Negligible	Minor adverse	No mitigation required	Minor adverse
Impact 4: Barrier Effects from Underwater Noise during Operation and Maintenance						
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						
Increased collision risk	Harbour porpoise, bottlenose dolphin grey and harbour seal	Low	Low	Minor adverse	No further mitigation proposed other than good practice.	Negligible
	White-beaked dolphin and minke whale	Low	Negligible	Negligible		Negligible

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 6: Disturbance at Seal Haul-Out Sites						
Disturbance at seal haul-out sites	Grey and harbour seal	Low to medium	Negligible	Negligible to Minor adverse	No further mitigation required or proposed other than good practice.	Negligible to Minor adverse
Impact 7: Changes to Prey Availability						
Change in prey availability during O&M	Harbour porpoise and minke whale	Low to medium	Negligible to Low	Negligible to Minor adverse	No mitigation required for prey.	Negligible to Minor adverse
	Bottlenose dolphin, white-beaked dolphin, grey and harbour seal	Low	Negligible to Low	Negligible to Minor adverse		Negligible to Minor adverse

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact
Impact 8: Changes to Water Quality						
Changes in water quality	Harbour porpoise, bottlenose dolphin, white beaked dolphin, minke whale, grey and harbour seal	Negligible	Negligible	Negligible	No further mitigation proposed other than embedded mitigation.	Negligible
Decommissioning						
Same or less than for construction						
Cumulative Impacts						
Overall cumulative impact of disturbance to marine mammals during construction of DEP and SEP	Harbour porpoise	Medium	Medium	Moderate adverse	Project specific SIP for the SNS SAC would manage and reduce potential for disturbance of harbor porpoise	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

12.12 References

Arso Civil, M., Quick, N.J., Cheney, B., Pirotta, E., Thompson, P.M. and Hammond, P.S. (2019). Changing distribution of the east coast of Scotland bottlenose dolphin population and the challenges of area-based management. Aquatic Conservation: Marine and Freshwater Ecosystems, 29, pp.178-196.

ASCOBANS (2015). Recommendations of ASCOBANS on the Requirements of Legislation to Address Monitoring and Mitigation of Small Cetacean Bycatch. October 2015.

Aynsley, C.L. (2017) Bottlenose dolphins (*Tursiops truncatus*) in north-east England: A preliminary investigation into a population beyond the southern extreme of its range. MSc Thesis, Newcastle University.

Beatrice Offshore Wind Farm Ltd (2018). Beatrice Offshore Wind Farm Piling Strategy Implementation Report. Available from: http://marine.gov.scot/sites/default/files/lf000005-rep-2397_bowlpilingstrategyimplementationreport_rev1_redacted.pdf

BEIS (2020). 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. September 2020. Department for Business, Energy and Industrial Strategy.

Blix, A.S. and Folkow, L.P. (1995). Daily energy expenditure in free living minke whales. Acta Physio. Scand., 153: 61-66.

Brandt, M. J., Diederichs, A. and Nehls, G. (2009). Investigations into the effects of pile driving at the offshore wind farm Horns Rev II and the FINO III research platform. Report to DONG Energy.

Brandt, M., Diederichs, A., Betke, K. and Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore windfarm in the Danish North Sea. Marine Ecology Progress Series, 421: 205-215.

Brandt, M.J., Dragon, C.A., Diederichs, A., Schubert, A., Kosarev, V., Nehls G., Wahl, V., Michalik A., Braasch, A., Hinz, C., Ketzer, C., Todeskino, D., Gauger, M., Laczny, M., Piper, W. (2016). Effects of offshore pile driving on harbour porpoise abundance in the German Bight. Assessment of Noise Effects. Prepared for Offshore Forum Windenergie. Husum.

Brandt, M.J., Dragon, C.A., Diederichs, A., Bellmann, M.A., Wahl, V., Piper, W., Nabe-Nielsen, J. and Nehls G. (2018). Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. Marine Ecology Progress Series, 596: 213-232.

Brasseur S., Carius F., Diederichs B., Galatius A., Jeß A., Körber P., Schop J., Siebert U., Teilmann J., Bie Thøstesen C. and Klöpper S. (2020). EG-Seals grey seal surveys in the Wadden Sea and Helgoland in 2019-2020. Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

British Standards Institution (BSI) (2015). Environmental Impact Assessment for offshore renewable energy project – guide. PD 6900:2015.

Cefas (Centre for the Environment and Fisheries and Aquaculture Science) (2012). Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects.

CIEEM (Chartered Institute of Ecology and Environmental Management) (2019). Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine. https://cieem.net/wp-content/uploads/2018/08/ECIA-Guidelines-2018-Terrestrial-Freshwater-Coastal-and-Marine-V1.1Update.pdf
CSIP (2015). UK Cetacean Strandings Investigation Programme Report. Annual Report for the period 1st January – 31st December 2015 (Contract number MB0111). http://ukstrandings.org/csip-reports/
Davis, G.E., Baumgartner, M.F., Corkeron. P.J., *et al*. (2020) Exploring movement patterns and changing distributions of baleen whales in the western North Atlantic using a decade of passive acoustic data. Glob Change Biol. 2020;00:1–29. https://doi.org/10.1111/gcb.15191
DECC (Department of Energy and Climate Change) (2011a). Overarching NPS for Energy (EN-1)
DECC (2011b). NPS for Renewable Energy Infrastructure (EN-3)
DECC (2011c). NPS for Electricity Networks Infrastructure (EN-5)
DECC (now Department for Business, Energy and Industrial Strategy (BEIS)) (2016), UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3)
Defra (Department for Environment, Food and Rural Affairs) (2003). UK small cetacean bycatch response strategy. Department for Environment, Food and Rural Affairs. March 2003.
Diederichs, A., Nehls, G., Dähne, M., Adler, S., Koschinski, S. and Verfuß, U. (2008). Methodologies for measuring and assessing potential changes in marine mammal behaviour, abundance or distribution arising from the construction, operation and decommissioning of offshore windfarms. Commissioned by COWRIE Ltd, 231.
DOWL (2016). Dudgeon Offshore Wind Farm - Piling Summary and Lessons Learned. August 2016.
EC (European Commission) (2008). 56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). OJEC L, 164, p.40.
Evans, P.G.H. and Bjørge, A. (2013). Impacts of climate change on marine mammals. Marine Climate Change Impacts Partnership (MCCIP) Annual Report Card 2011-2012 Scientific Review: 1-34.
Evans, P. G., Baines, M.E., and Anderwald. P. (2011). Risk Assessment of Potential Conflicts between Shipping and Cetaceans in the ASCOBANS Region. 18th ASCOBANS Advisory Committee Meeting AC18/Doc.6-04 (S) rev.1 UN Campus, Bonn, Germany, 4-6 May 2011 Dist. 2 May 2011.
Faulkner, R.C., Farcas, A. and Merchant, N.D. (2018). Guiding principles for assessing the impact of underwater noise. Journal of Applied Ecology 2018;1–6. DOI: 10.1111/1365-2664.13161: https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13161
Finneran, J.J., Carder, D.A., Schlundt, C.E. and Ridgway, S.H. (2005). Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. J Acoustic Soc Am 118:2696–705.
Friends of Horsey (2019). Seal Pup Count 2018-2019. Available from: http://friendsofhorseyseals.co.uk/wp-content/uploads/2019/01/Seal_Count_Report_2018-19.pdf

Galatius A., Brackmann J., Brasseur S., Diederichs B., Jeß A., Klöpper S., Körber P., Schop J., Siebert U., Teilmann J., Thøstesen B. and Schmidt B. (2020). Trilateral surveys of Harbour Seals in the Wadden Sea and Helgoland in 2020. Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

Gilles, A., Viquerat, S., Becker, E. A., Forney, K. A., Geelhoed, S. C. V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., van Beest, F. M., van Bemmelen, R.and Aarts, G. (2016). Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment. Ecosphere 7(6):e01367. 10.1002/ecs2.1367.

Goold, J.C. (1996). Acoustic assessment of populations of common dolphin (Delphinus delphis) in conjunction with seismic surveying. Journal of the Marine Biological Association of the United Kingdom. 76:811-820.

Graham, I.M., Merchant, N.D., Farcas, A., Barton, T.R., Cheney, B., Bono, S. and Thompson, P.M. (2019). Harbour porpoise responses to pile-driving diminish over time. R. Soc. Open sci. 6: 190335. http://dx.doi.org/10.1098/rsos.190335.

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Boerjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M., Scheidat, M. and Teilmann, J. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Wageningen Marine Research.

Harris, R.E., Miller, G. W. and Richardson, W. J. (2001). Seal responses to air gun sounds during summer seismic surveys in the Alaskan Beaufort Sea. Mar Mam Sci. 17:795-812.

Hastie, G., Merchant, N.D., Götz, T., Russell, D.J., Thompson, P. and Janik, V.M. (2019). Effects of impulsive noise on marine mammals: investigating range-dependent risk. Ecological Applications, p.e01906. Available from: https://research-repository.st-andrews.ac.uk/bitstream/handle/10023/17882/Hastie_2019_EA_Impulsivenoise_AAM.pdf?sequence=1&isAllowed=y

Heinänen, S. and Skov, H. (2015). The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area, JNCC Report No.544 JNCC, Peterborough.

HM Government (2011). Marine Policy Statement. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69322/pb3654-marine-policy-statement-110316.pdf.

HM Government (2014). The East Inshore and East Offshore Marine Plans.

IAMMWG (2013). Management Units for marine mammals in UK waters (June 2013).

IAMMWG (2015). Management Units for cetaceans in UK waters (January 2015). JNCC Report No. 547, JNCC Peterborough.

IJsseldijk, L.L., Brownlow, A., Davison, N.J., Deaville, R., Haelters, J., Keijl, G., Siebert, U. and ten Doeschate, M.T.I. (2018). Spatiotemporal trends in white-beaked dolphin strandings along the North Sea coast from 1991–2017. Lutra 61 (1): 153-163: https://www.uu.nl/sites/default/files/ijsseldijk_et_al._2018._spatiotemporal_analysis_of_white-beaked_dolphin_strandings._lutra_61_002.pdf

Jansen, J.K., Boveng, P.L., Dahle, S.P. and Bengston, J.L. (2010). Reaction of harbor seals to cruise ships.Journal of Wildlife Management,74,1186–1194. https://doi.org/10.1111/j.1937-2817.2010.tb01239.x

JNCC (2010a). JNCC guidelines for minimising the risk of injury to marine mammals from using explosives. August 2010.

JNCC (2010b). Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise. August 2010.
JNCC (2017). JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys. April 2017.
JNCC (2019). Article 17 Habitats Directive Report 2019: Species Conservation Status Assessments 2019. Available at: https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019-species/#regularly-occurring-species-vertebrate-species-mammals-marine
JNCC and Natural England (2013). Suggested Tiers for Cumulative Impact Assessment.
JNCC, Natural England and CCW (2010). Draft EPS Guidance - The protection of marine European Protected Species from injury and disturbance. Guidance for the marine area in England and Wales and the UK offshore marine area. Joint Nature Conservation Committee, Natural England and Countryside Council for Wales. October 2010.
JNCC, DAERA (Department of Agriculture, Environment and Rural Affairs) and Natural England (2020). Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (England, Wates and Northern Ireland). Dated June 2020.
Jones, D. and Marten, K. (2016). Dredging sound levels, numerical modelling and EIA. Maritime Solutions for a Changing World, p.21.
Jones, E.L., Hastie, G.D., Smout, S., Onoufriou, J., Merchant, N.D., Brookes, K.L. and Thompson, D. (2017). Seals and shipping: quantifying population risk and individual exposure to vessel noise. Journal of applied ecology, 54(6), pp.1930-1940.
Kastelein, R.A., Hardemann, J. and Boer, H. (1997). Food consumption and body weight of harbour porpoises (*Phocoena phocoena*). In The biology of the harbour porpoise Read, A.J., Wiepkema, P.R., Nachtigall, P.E (1997). Eds. Woerden, The Netherlands: De Spil Publishers. pp. 217–234.
Kastelein, R. A., Gransier, R., Hoek, L. and Olthuis, J. (2012). Temporary threshold shifts and recovery in a harbor porpoise (*Phocoena phocoena*) after octave-band noise at 4 kHz. J. Acoust. Soc. Am. 132, 3525–3537.
Kastelein, R. A., Gransier, R., Marijt, M. A. T. and Hoek, L. (2015). Hearing frequency thresholds of harbor porpoises (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds. J. Acoust. Soc. Am. 137, 556–564.
Kastelein, R. A., Helder-Hoek, L., Covi, J. and Gransier, R. (2016). Pile driving playback sounds and temporary threshold shift in harbor porpoises (*Phocoena phocoena*): Effect of exposure duration. J. Acoust. Soc. Am. 139, 2842–2851.
Kastelein, R.A., Van de Voorde, S. and Jennings, N. (2018). Swimming Speed of a Harbour Porpoise (*Phocoena phocoena*) During Playbacks of Offshore Pile Driving Sounds. Aquatic Mammals: 44(1):92-99.
Kershaw, J.L., Ramp, C.A., Sears, R., Plourde, S., Brosser, P., Miller, P.J.O. and Hall, A.J. (2020). Declining reproductive success in the Gulf of St. Lawrence's humpback whales (*Megaptera novaeangliae*) reflects ecosystem shifts on their feeding grounds. Global Change Biology (2020). DOI: 10.1111/gcb.15466
Ketten, D.R. (2004). Experimental measures of blast and acoustic trauma in marine mammals (ONR Final Report N000149711030).
Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta, M. (2001). Collisions between ships and whale'. Marine Mammal Science 17 (1) 30-75.

Learmonth, J.A., Macleod, C.D., Santos, M.B., Pierce, G.J., Crick, H.Q.P. and Robinson, R.A. (2006). Potential effects of climate change on marine mammals. Oceanography and Marine Biology: An Annual Review 44, 429-462.
Lindeboom, H.J., Kouwenhoven, H.J., Bergman, M.J.N., Bouma, S., Brasseur, S., Daan, Fijn, R.C., de Haan, D., Dirksen, S., van Hal, R, Hille Ris Lambers, R, ter Hofstede, Krijgsveld, R.K.L., Leopold, M. and Scheidat, M. (2011). Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environ. Res. Lett. 6 (3).
Lucke, K., Siebert, U., Lepper, P. A. and Blanchet, M. A. (2009). Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli, J. Acoust. Soc. Am., 125 (6), pp. 4060-4070.
Macdonald, M.A., Hildebrand, J.A. and Webb, S.C. (1995). Blue and fin whales observed on a seafloor array in the Northeast Pacific. J Acoust Soc Am. 98:712-721.
Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Mar Ecol Prog Ser, 309; 279-295.
Malme, C.I., Miles, P.R., Miller, G.W., Richardson, W.J., Roseneau, D.G., Thomson, D.H. and Greene, C.R. (1989). Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska. Final Report No. 6945 to the US Minerals Management Service, Anchorage, AK. BBN Systems and Technologies Corp. Available at: <http://www.mms.gov>.
MARINElife (2020). Marine mammal sightings from southern North Sea ferry routes: http://www.marine-life.org.uk/sightings
Marine Scotland (2012). MS Offshore Renewables Research: Work Package A3: Request for advice about the displacement of marine mammals around operational offshore windfarms. Available at: http://www.gov.scot/Resource/0040/00404921.pdf.
McConnell, B., Lonergan, M. and Dietz, R. (2012). Interactions between seals and offshore wind farms. The Crown Estate. ISBN: 978-1-906410-34-5.
McGarry, T., Boisseau, O., Stephenson, S. and Compton, R. (2017). Understanding the Effectiveness of Acoustic Deterrent Devices on Minke Whale (*Balaenoptera acutorostrata*), a low frequency cetacean. ORJIP Project 4, Phase 2. RPS Report EOR0692. Prepared on behalf of The Carbon Trust. November 2017.
McGarry, T., De Silva, R., Canning, S., Mendes, S., Prior, A., Stephenson, S. and Wilson, J. (2020). Evidence base for application of Acoustic Deterrent Devices (ADDs) as marine mammal mitigation (Version 2.0). JNCC Report No. 615, JNCC, Peterborough. ISSN 0963-8091.
Merchant, N.D. (2019). Underwater noise abatement: Economic factors and policy options. *Environmental Science and Policy*, *92* (November 2018), 116–123. https://doi.org/10.1016/j.envsci.2018.11.014.
Merchant, N.D. and Robinson, S.P. (2020). Abatement of underwater noise pollution from pile-driving and explosions in UK waters. Report of the UKAN workshop held on Tuesday 12 November 2019 at The Royal Society, London. 31pp. doi: https://dx.doi.org/10.6084/m9.figshare.11815449.
Nabe-Nielsen, J., van Beest, F.M., Grimm, V., Sibly, R.M., Teilmann, J. and Thompson, P.M. (2018). Predicting the impacts of anthropogenic disturbances on marine populations. Conserv Lett. 2018;e12563. https://doi.org/10.1111/conl.12563.

NIRAS Consulting Ltd and SMRU Consulting (2019). Reducing Underwater Noise, Report on Behalf of The Crown Estate. https://opendata-thecrownestate.opendata.arcgis.com/datasets/b07b8b046bb64d4b99c57ad993111c39

NMFS (National Marine Fisheries Service). (2018). 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

Otani, S., Naito, T., Kato, A. and Kawamura, A. (2000). Diving behaviour and swimming speed of a free-ranging harbour porpoise (*Phocoena phocoena*). Marine Mammal Science, Volume 16, Issue 4, pp 811-814, October 2000.

Orsted (2019). Hornsea Project Two Offshore Wind Farm UXO Clearance Close-out Report – Export Cable Route. Available from: https://marinelicensing.marinemanagement.org.uk/mmofox5/download/parcel/2bkm7phnlktpr8ha18tc5dfdrjfedrb8oaroh4578ivagf7vka4bo0dv0lq7edsb88oju9m1ijcqbkkqe8el0qumh2utmscd0d8r/5e850dadc0bb9e88c7ff539d311ef2d1/HOW02_OFF_EX+UXO+Clearance+Close+Out+Report_Export+Cable+%252804089732_A%2529.pdf

OSPAR (2009). Overview of the impacts of anthropogenic underwater sound in the marine environment. London: OSPAR Commission Biodiversity Series. Publication no. 441/2009. 133 pp.

Paterson, W., Russell, D. J. F, Wu, M., McConnell, B. J. and Thompson, D. (2015). Harbour seal haul-out monitoring, Sound of Islay. Scottish Natural Heritage Commissioned Report No. 894.

Paterson, W.D., Russell, D.J.F., Wu, Gi-Mick, McConnell, B.J., Currie, J., McCafferty, D. and Thompson, D. (2019). Post-disturbance haul-out behaviour of harbour seals. Aquatic Conservation: Marine and Freshwater Ecosystems. Doi: 10.1002/aqc.3092.

Paxton, C.G.M., Scott-Hayward, L., Mackenzie, M., Rexstad, E. and Thomas, L. (2016). Revised Phase III Data Analysis of Joint Cetacean Protocol Data Resources with Advisory Note, JNCC Report 517, ISSN 0963-8091: http://jncc.defra.gov.uk/page-7201.

Pirotta, E., Laesser, B. E., Hardaker, A., Riddoch, N., Marcoux, M., and Lusseau, D. (2013). Dredging displaces bottlenose dolphins from an urbanised foraging patch. Marine Pollution Bulletin, 74: 396–402.

Planning Inspectorate (2018). Advice Note Nine: Rochdale Envelope https://infrastructure.planninginspectorate.gov.uk/wp-content/uploads/2013/05/Advice-note-9.-Rochdale-envelope-web.pdf

Planning Inspectorate (2019a). Advice Note Seventeen: Cumulative effects assessment relevant to nationally significant infrastructure projects. Version 2 August 2019. https://infrastructure.planninginspectorate.gov.uk/wp-content/uploads/2015/12/Advice-note-17V4.pdf

Planning Inspectorate (2019b). Scoping Opinion: Proposed Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions. Case Reference: EN010109. November 2019.

Polacheck, T and Thorpe, L. (1990). The swimming direction of harbour porpoise in relation to a survey vessel. Report of the International Whaling Commission, 40: 463-470.

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., Halvorsen, M.B. and Løkkeborg, S., (2014). ASA

S3/SC1. 4 TR-2014 Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI-Accredited standards committee S3/SC1 and registered with ANSI. Springer.

Ransijn, J.M., Booth, C. and Smout, S.C. (2019). A calorific map of harbour porpoise prey in the North Sea. JNCC Report No. 633. JNCC, Peterborough, ISSN 0963 8091.

Richardson, J., Greene, C.R., Malme, C.I. and Thomson, D.H. (1995). Marine Mammals and Noise. San Diego California: Academic Press.

Robinson, S.P., Theobald, P.D., Hayman, G., Wang, L.S., Lepper, P.A., Humphrey, V. and Mumford, S. (2011). Measurement of underwater noise arising from marine aggregate dredging operations. Marine Aggregate Levy Sustainability Fund MEPF report 09/P108.

Robinson, S. P., Theobald, P.D. and Lepper, P. A., (2012). UW208. Underwater noise generated from marine piling. ECUA 2012 11th European Conference on Underwater Acoustics. Session UW: Underwater Acoustics.

Rogan, E., Breen, P., Mackey, M., Cañadas, A., Scheidat, M., Geelhoed, S. and Jessopp, M. (2018). Aerial surveys of cetaceans and seabirds in Irish waters: Occurrence, distribution and abundance in 2015-2017. Department of Communications, Climate Action & Environment and National Parks and Wildlife Service (NPWS), Department of Culture, Heritage and the Gaeltacht, Dublin, Ireland. 297pp.

Rose *et al*. (2019). Effects of noise-mitigated offshore pile driving on harbour porpoise abundance in the German Bight 2014-2016 (Gescha 2). Assessment of Noise Effects Final Report. Prepared for Arbeitsgemeinschaft OffshoreWind e.V.

Royal HaskoningDHV (2019). Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions - Scoping Report. October 2019. Document no.: PB8164-RHD-ZZ-XX-RP-Z-0003

Russell, D.J.F (2016a). Movements of grey seal that haul out on the UK coast of the southern North Sea. Report for the Department of Energy and Climate Change (OESEA-14-47).

Russell, D.J.F. (2016b). Activity Budgets: Analysis of seal behaviour at sea. Draft report for the Department of Energy and Climate Change (OESEA-15-66).

Russell, D.J.F. and McConnell, B.J. (2014). Seal at-sea distribution, movements and behavior. Report to DECC. URN: 14D/085. March 2014 (final revision).

Russell, D.J.F., Brasseur, S.M.J.M., Thompson, D., Hastie, G.D., Janik, V.M., Aarts, G., McClintock, B.T., Matthiopoulos, J., Moss, S.E.W. and McConnell, B. (2014). Marine mammals trace anthropogenic structures at se'. Current Biology Vol 24 No 14: R638–R639.

Russell, D.J.F, Jones, E.L. and Morris, C.D. (2017). Updated Seal Usage Maps: The Estimated at-sea Distribution of Grey and Harbour Seals. Scottish Marine and Freshwater Science Vol 8 No 25, 25pp. DOI: 10.7489/2027-1.

SCANS-II (2008). Small cetaceans in the European Atlantic and North Sea. Final Report submitted to the European Commission under project LIFE04NAT/GB/000245, SMRU, St Andrews.

Scheidat, M., Tougaard, J., Brasseur, S., Carstensen, J., van Polanen Petel, T., Teilmann, J., and Reijnders, P. (2011). Harbour porpoise (*Phocoena phocoena*) and wind farms: a case study in the Dutch North Sea. Environ. Res. Lett. 6 (April-June 2011) 025102.

Scira Offshore Energy (2010). Sheringham Shoal Offshore Windfarm Project Seabed Intervention UXO Clearance. Available from: https://www.marinedataexchange.co.uk/ItemDetails.aspx?id=11205
SCOS (2019). Scientific Advice on Matters Related to the Management of Seal Populations: 2019. Available at: http://www.smru.st-andrews.ac.uk/research-policy/scos/
Sea Watch Foundation (2020). Reports of cetacean sightings eastern England: http://www.seawatchfoundation.org.uk/recentsightings/
Sharples R.J., Matthiopoulos, J. and Hammond, P.S. (2008). Distribution and movements of harbour seals around the coast of Britain: Outer Hebrides, Shetland, Orkney, the Moray Firth, St Andrews Bay, The Wash and the Thames, Report to DTI July 2008.
Sigray, P., and Andersson, M. H. (2011). Particle motion measured at an operational wind turbine in relation to hearing sensitivity in fish. The Journal of the Acoustical Society of America 130, 200-207. https://doi.org/10.1121/1.3596464.
SMRU Ltd (Sea Mammal Research Unit Ltd) (2010). Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments. Final Report on behalf of The Crown Estate.
Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., and Tyack, P.L. (2007). Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, 33 (4), pp. 411-509.
Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P. and Tyack, P.L. (2019). Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects. Aquatic Mammals, 45(2), pp.125-232.
Sparling, C., Sams, C., Stephenson, S., Joy, R., Wood, J., Gordon, J., Thompson, D., Plunkett, R., Miller, B. and Götz, T. (2015). The use of Acoustic Deterrents for the mitigation of Evidence base for application of Acoustic Deterrent Devices (ADDs) as marine mammal mitigation injury to marine mammals during pile driving for offshore wind farm construction. ORJIP Project 4, Stage 1 of Phase 2. Final Report.
Statoil (2015). Dudgeon UXO Verification and Clearance Survey.
Strong, P. and Morris, S.R. (2010). Grey seal (*Halichoerus grypus*) disturbance, ecotourism and the Pembrokeshire Marine Code around Ramsey Island. J. Ecotourism 9(2): 117–132.
Teilmann, J., Carstensen, J., Dietz, R., Edrén, S. and Andersen, S. (2006). Final report on aerial monitoring of seals near Nysted Offshore Wind Farm Technical report to Energi E2 A/S. Ministry of the Environment Denmark.
Teilmann J, Larsen F and Desportes G (2007). Time allocation and diving behaviour of harbour porpoises (*Phocoena phocoena*) in Danish and adjacent waters. Journal of Cetacean Research and Management 9(3): 201-210.
Theobald, P.D., Robinson, S.P., Lepper, P.A., Hayman, G., Humphrey, V.F., Wang, L. and Mumford, S.E. (2011). The measurement of underwater noise radiated by dredging vessels during aggregate extraction operations. 4th International Conference and Exhibition on Underwater Acoustic Measurements: Technologies & Results.
Thompson, P.M., Hastie G. D., Nedwell, J., Barham, R., Brookes, K., Cordes, L., Bailey, H. and McLean, N. (2012). Framework for assessing the impacts of pile-driving noise

from offshore windfarm construction on the Moray Firth harbour seal population. Seal assessment Framework Technical Summary, 6th June 2012.
Thompson, P.M., Hastie, G.D., Nedwell, J., Barham, R., Brookes, K.L., Cordes, L.S., Bailey, H. and McLean, N. (2013). Framework for assessing impacts of pile-driving noise from offshore wind farm construction on a harbour seal population. Environmental Impact Assessment Review 43: 73–85.
Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006). Effects of offshore windfarm noise on marine mammals and fish, on behalf of COWRIE Ltd.
Todd, V.L.G., Todd, I.B., Gardiner, J.C., Morrin, E.C.N., MacPherson, N.A., DiMarzio, N.A. and Thomsen, F. (2014). A review of impacts of marine dredging activities on marine mammals. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu187.
Tougaard, J., Carstensen, J., Wisch, M.S., Teilmann, J., Bech, N., Skov, H. and Henriksen, O.D. (2005). Harbour porpoises on Horns reef—effects of the Horns Reef Wind farm. Annual Status Report 2004 to Elsam. NERI, Roskilde (Also available at: www.hornsrev.dk).
Tougaard, J., Henriksen, O.D. and Miller. L.A. (2009a). Underwater noise from three types of offshore wind turbines: estimation of impact zones for harbour porpoise and harbour seals. Journal of the Acoustic Society of America 125(6): 3766.
Tougaard, J., Carstensen, J. and Teilmann, J. (2009b). Pile driving zone of responsiveness extends beyond 20km for harbour porpoises (*Phocoena phocoena* (L.)) (L). J. Acoust. Soc. Am., 126, pp. 11-14.
Trigg, L.E., Chen, F., Shpiro, G/I., Ingram, S.N., Vincent, C., Thompson, D., Russell, D.J.F., Carter, M.I.D. and Embling, C.B. (2020). Predicting the exposure of diving grey seals to shipping noise. The Journal of the Acoustical Society of America 148, 1014 (2020); doi: 10.1121/10.0001727. https://asa.scitation.org/doi/pdf/10.1121/10.0001727
Verfuss, U.K., Sinclair, R.R. and Sparling, C.E. (2019). A review of noise abatement systems for offshore wind farm construction noise, and the potential for their application in Scottish waters. Scottish Natural Heritage Research Report No. 1070. Available from: https://www.nature.scot/sites/default/files/2019-07/Publication%202019%20-%20SNH%20Research%20Report%201070%20-%20A%20review%20of%20noise%20abatement%20systems%20for%20offshore%20wind%20farm%20construction%20noise%2C%20and%20the%20potential%20for%20their%20application%20in%20Scottish%20waters.pdf
von Benda-Beckmann, A.M., Aarts, G., Özkan Sertlek, H., Lucke, K., Verboom W.C., Kastelein, R.A., Ketten, D.R., van Bemmelen, R., Lam, F,A., Kirkwood, R.J. and Ainslie, M.A. (2015). Assessing the Impact of Underwater Clearance of Unexploded Ordnance on Harbour Porpoises (*Phocoena phocoena*) in the Southern North Sea. Aquatic Mammals 2015, 41(4), 503-523.
Waggitt, J.J., Evans, P.G., Andrade, J., Banks, A.N., Boisseau, O., Bolton, M., Bradbury, G., Brereton, T., Camphuysen, C.J., Durinck, J. and Felce, T. (2020). Distribution maps of cetacean and seabird populations in the North-East Atlantic. Journal of Applied Ecology, 57(2), pp.253-269.
Watson, A.P. and Gaskin, D.E. (1983). Observations on the ventilation cycle of the harbour porpoise (L.) in coastal waters of the Bay of Fundy. Canadian Journal of Zoology, Vol. 61, No. 1: pp. 126-132. https://doi.org/10.1139/z83-015.

Wilson, B. Batty, R. S., Daunt, F. and Carter, C. (2007). Collision risks between marine renewable energy devices and mammals, fish and diving birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland, PA37 1QA.
Wilson, S. (2014). The impact of human disturbance at seal haul-outs. A literature review for the Seal Conservation Society. Available at: http://www.pinnipeds.org/attachments/article/199/Disturbance%20for%20SCS%20-%20text.pdf.
WWT (2009). Distributions of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008. The Wildfowl and Wetlands Trust.