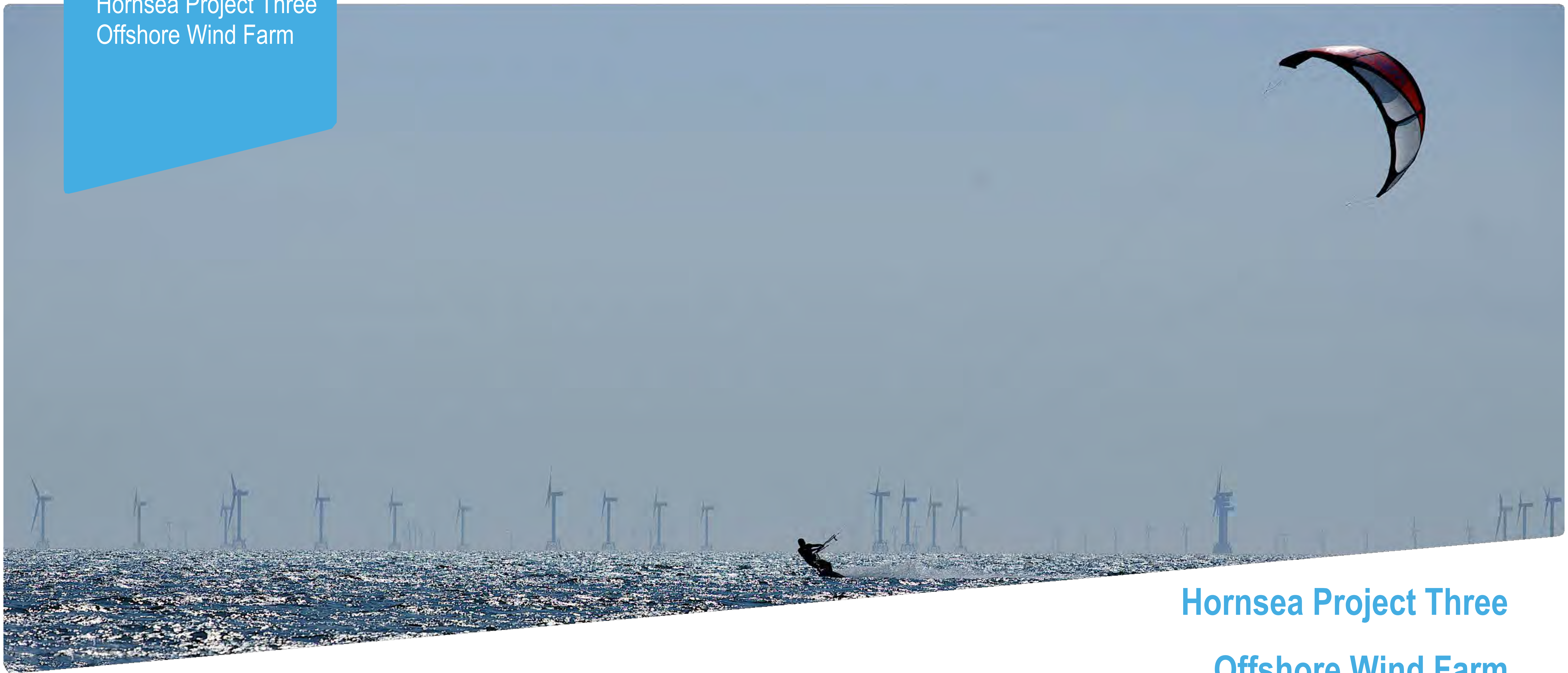
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Preliminary Environmental Information Report: Chapter 4 – Marine Mammals

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG
energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 2

Chapter 4 – Marine Mammals

Report Number: P6.2.4

Version: Final

Date: July 2017

This report is also downloadable from the Hornsea Project Three offshore wind farm website at: www.dongenergy.co.uk/hornseaproject3

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Liability

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Glossary

Term	Definition
Cetacean	The order Cetacea includes whales, dolphins and porpoises, collectively known as cetaceans.
k-selected	Species which possess relatively stable populations and tend to produce relatively low numbers of offspring. Offspring tend to be quite large in comparison with r-selected species. K-selected species are also characterised by long gestation periods, slow maturation, and long life spans. Examples of K – selected species include cetaceans and pinnipeds.
Odontocete	Odontocetes (toothed-whales) form a suborder of the order cetacea (cetaceans). This suborder is characterised by the presence of teeth, rather than the baleen of other whales and includes sperm whales, beaked whales and dolphins.
Pinniped	A fin-footed group of marine mammals which are semi-aquatic. Pinnipeds comprise of the following families: Odobenidae (walrus); Otariidae (eared seals, sea lions, and fur seals); and Phocidae (earless seals). Pinnipeds are more broadly known as "seals".
PAMGUARD	Software used with passive acoustic monitoring equipment (PAM) for acoustic detection, localisation and classification of marine mammals.
Permanent Threshold Shift (PTS)	Following a marine mammal's exposure to high noise levels, if a Threshold shift occurs and does not return to normal after several weeks then a Permanent Threshold Shift (PTS) has occurred. This results in a permanent auditory injury to the marine mammal.
r-selected	r-selected species are species whose populations are governed by their maximum reproductive capacity. r-selected species produce numerous offspring, have short gestation periods and mature quickly.
Small Cetacean Abundance in the North Sea and Adjacent Waters (SCANS)	Large scale surveys aimed at estimating the abundance of porpoises and other cetaceans in order to assess the impacts of by-catch. SCANS (1994), and SCANS II (2005) have been completed, SCANS III will be published later this year (2017). Outputs from SCANS III will be incorporated into the Environmental Statement.
Soft-start	The term 'soft-start' is applied to the gradual, or incremental, increase in hammer blow energy from the initiation of piling activity until required blow energy is reached for installation of each pile, usually over a period of 30 minutes (not less than 20 minutes). Maximum hammer blow energy may not be required to complete pile installation.
Temporary Threshold Shift (TTS)	A temporary change in the hearing threshold of marine mammals following noise exposure. Hearing loss in this case is not permanent.

Acronyms

Acronym	Description
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
CEA	Cumulative Effect Assessment
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CGNS	Celtic and Greater North Sea
CI	Confidence Interval
COWRIE	Collaborative Offshore Wind Research into the Environment
CPA	Coastal Protection Act
CTV	Crew Transfer Vessel
DCO	Development Consent Order
DECC	Department for Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DP	Dynamic Positioning
EEA	European Economic Area
EIA	Environmental Impact Assessment
EIONET	European Environment Information and Observation Network
EMF	Electromagnetic Field
ESAS	European Seabirds at Sea
EUNIS	European Site Nature Information System
FEPA	Food and Environment Protection Act
FoHS	Friends of Horsey Seals
GES	Good Environmental Status
GLNP	Greater Lincolnshire Nature Partnership
HF	High Frequency
HLV	Heavy Lift Vessel
HRA	Habitat Regulation Assessment
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
IAMMWG	Interagency Marine Mammal working group
IWC	International Whaling Committee
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
LF	Low Frequency
LNR	Local Nature Reserve
MCA	Maritime and Coastguard Agency
MCZ	Marine Conservation Zone
MF	Mid Frequency
MHWS	Mean High Water Springs
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MMOs	Marine Mammal Observers
MPCP	Marine Pollution Contingency Plan
MPS	Marine Protected Species
MSFD	Marine Strategy Framework Directive
MU	Management Unit
NOAA	National Oceanic and Atmospheric Administration
NM	Nautical Mile
NMSF	National Marine Fisheries Service
NNR	National Nature Reserve
NPS	National Policy Statement
NSIP	National Significant Infrastructure Projects
PAM	Passive Acoustic Monitoring
PDV	Phocine Distemper Virus
PEIR	Preliminary Environmental Impact Report

Acronym	Description
PEMMP	Project Environmental Management and Monitoring Plan
PINS	Planning Inspectorate
PTS	Permanent Threshold Shift
PW	Pinnipeds in Water
rMCZ	Recommended Marine Conservation Zone
RMS	Root Mean Squared
SAC	Special Area of Conservation
SCANS	Small Cetaceans in the European and Atlantic North Sea
SCI	Site of Conservation Importance
SCOS	Special Committee on Seals
SEA	Strategic Environmental Assessment
SEL	Sound Exposure Level
SMRU	Sea Mammal Research Unit
SNCBs	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPL	Sound Pressure Level
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
TTS	Temporary Threshold Shift
TWT	The Wildlife Trust
UXO	Unexploded Ordnance
VERs	Valued Ecological Receptors
WDC	Whale and Dolphin Conservation
WWT	Wildfowl and Wetlands Trust
ZoI	Zone of Impact

Units

Unit	Description
GW	Gigawatt (power)
kV	Kilovolt (electrical potential)
kW	Kilowatt (power)
kg	Kilogram
km	Kilometre
km^{-2}	Per kilometre squared (area)
km	Knot (speed of travel)
kV	Kilovolt (electrical potential)
l	Litre
m	Metre
mm	Millimetre
MW	Megawatt (power)
ms^{1}	Metres per second
m^2	Metres squared
m^3	Metres cubed
T	Tesla
V	Volt
µPa	Micropascal
µT	Microtesla
µV	Microvolt

4. Marine Mammals

4.1 Introduction

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

4.1.1.2 This chapter summarises information contained within the technical report, which is included at volume 5, annex 4.1: Marine Mammal Technical Report. The technical report provides a detailed characterisation of the marine mammal ecology of Hornsea Three and the wider southern North Sea, based on existing literature sources, field surveys across the former Hornsea Zone and Hornsea Three specific surveys, and includes information on marine mammal species of ecological importance and conservation value.

4.2 Purpose of this chapter

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

4.2.1.2 The PEIR will form the basis for Phase 2 Consultation which will commence on 27 July and conclude on 20 September 2017. At this point, comments received on the PEIR will be reviewed and incorporated (where appropriate) into the Environmental Statement, which will be submitted in support of the application for Development Consent scheduled for the second quarter of 2018.

4.2.1.3 In particular, this PEIR chapter:

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

4.3 Study area

4.3.1.1 For the purposes of the marine mammal characterisation, the study area (illustrated in Figure 4.1) was defined in two ways:

- Hornsea Three marine mammal study area – this study area encompasses the Hornsea Three array area and offshore cable corridor (including the temporary working areas). The area extends out to the former Hornsea Zone plus a 10 km buffer around its perimeter. Site-specific field surveys (boat-based and aerial) were collected over agreed survey extents within the Hornsea Three marine mammal study area and supplemented with data gathered through an extensive literature review (see section 4.6). This area provides a suitable baseline against which to assess potential impacts from Hornsea Three as it encompasses the majority of the zone of potential ecological impact (ZoI); and
- Regional marine mammal study area – this area is represented largely by SCANS (Small Cetacean Abundance in the North Sea) Block U as the central point of focus, and extends further east and south to ensure that all key areas within the southern North Sea are encompassed (Figure 4.1). The regional marine mammal study area provides a wider geographic context for comparison with Hornsea Three data in terms of the species present and their estimated densities and abundance. Sites designated for the conservation of marine mammal features within this region provide a useful context for understanding the relative importance of marine mammal species found within the southern North Sea, and consequently within the Hornsea Three marine mammal study area. It should be noted that the regional study area does not delineate populations of marine mammals, but does provide a sufficiently large area, within which ecological patterns of the key species can be understood. The most useful population-level information was referenced to the Management Units (MUs) for each of the key species, and the spatial extent and abundance of individuals within the MUs is detailed in section 4.7.1.

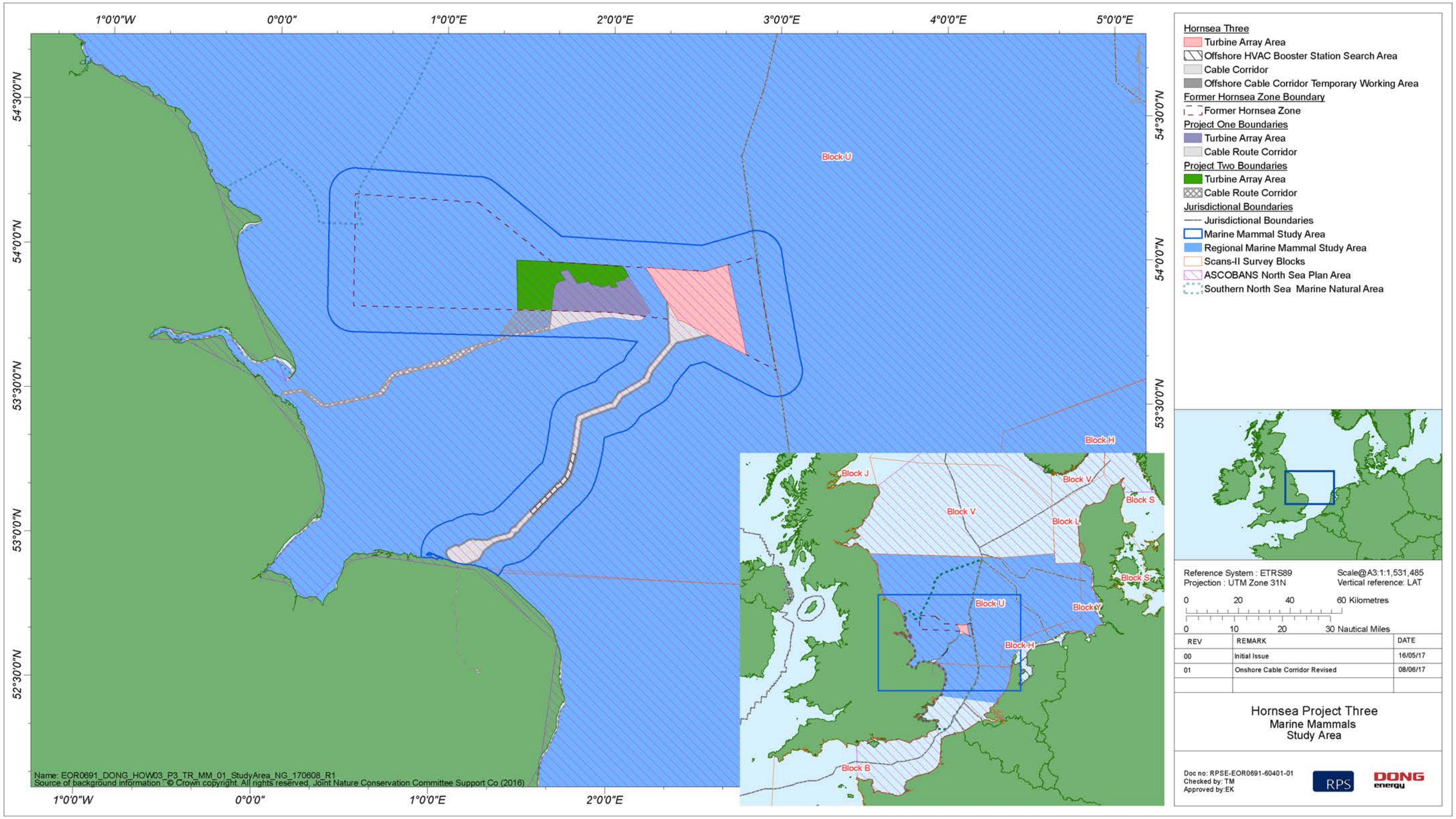

Figure 4.1: Location of the Hornsea Three marine mammal study area (within which is the Hornsea Three array area and offshore cable route corridor and the former Hornsea Zone) and location of the regional marine mammal study area.

4.4 Planning policy context

4.4.1.1 Planning policy on offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to marine mammals, is contained in the Overarching National Policy Statement (NPS) for Energy (EN-1; DECC, 2011a), the NPS for Renewable Energy Infrastructure (EN-3, DECC, 2011b) and the Marine Policy Statement (MPS). The MPS notes that marine planning authorities should be mindful of the high-level marine objectives set out by the UK in order to ensure due consideration of marine ecology and biodiversity interests. It also recognises the role of conservation of ecologically sensitive areas throughout the planning process and mitigation or compensatory actions where significant harm cannot be avoided (paragraph 2.6.1 of the MPS). The MPS also considers the effects of noise and vibration on wildlife and how these can be mitigated and minimised taking account of known sensitivities to particular frequencies of sound (paragraph 2.6.3 of the MPS).

4.4.1.2 NPS EN-3 (paragraphs 2.6.64 to 2.6.67 and 2.6.92 to 2.6.92) includes guidance on what matters are to be considered in the assessment. These are summarised in Table 4.1 below.

4.4.1.3 It is noted that NPS EN-3 also includes guidance relating to potential secondary or indirect impacts arising from changes to the physical environment which should also be considered.

4.4.1.4 The planning process for NSIPs is administered by PINS, with the decision on whether to grant a DCO taken by the Secretary of State. NPS EN-3 highlights a number of points relating to the determination of an application and in relation to mitigation (paragraphs 2.6.68 to 2.6.71 and 2.6.94 to 2.6.99); these are summarised in Table 4.2 below.

4.4.1.5 Guidance provided within the Marine Strategy Framework Directive (MSFD), adopted in July 2008 (Defra, 2014), has also been considered in the Hornsea Three assessment for marine mammals. The relevance of the MSFD to Hornsea Three is described in full in volume 1, chapter 2: Policy and Legislation.

4.4.1.6 The overarching goal of the MSFD is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, Annex I of the Directive identifies 11 high level qualitative descriptors for determining GES. Those descriptors relevant to the marine mammal assessment for Hornsea Three are listed in Table 4.3 including a brief description of how and where these have been addressed in the assessment.

Table 4.1: Summary of NPS EN-1 and NPS EN-3 provisions relevant to marine mammals for the Hornsea Three assessment.

Summary of NPS EN-3 provisions	How and where considered in the PEIR
Biodiversity	
Applicants should ensure that the Environmental Statement clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance, on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity (paragraph 5.3.3 of NPS EN-1).	Construction, operation and maintenance, and decommissioning phases of Hornsea Three have been assessed as part of the EIA on designated sites relevant to marine mammals (see section 4.11), and in the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017) for Natura 2000 sites.
Applicants should assess the effects on the offshore ecology and biodiversity for all stages of the lifespan of the proposed offshore wind farm (paragraph 2.6.64 of NPS EN-3).	The impact of construction, operation and maintenance, and decommissioning of Hornsea Three on marine mammals has been considered in section 4.11 below.
Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate (paragraph 2.6.65 of NPS EN-3).	Consultation with relevant statutory and non-statutory stakeholders has been carried out through the Marine Mammal Expert Working Group (EWG) (section 4.5.3) forum from the early stages of Hornsea Three.
Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore wind farms should be referred to where appropriate (paragraph 2.6.66 of NPS EN-3).	Relevant data collected as part of post-construction monitoring from other offshore wind farm developments has informed the assessment of Hornsea Three (Annex 4.1: Marine Mammal Technical Report).
Applicants should assess the potential for the scheme to have both positive and negative effects on marine ecology and biodiversity (paragraph 2.6.67 of NPS EN-3).	Both the positive and negative effects of Hornsea Three have been considered on marine mammals in section 4.11 below.
Marine mammals	
Where necessary the assessment of the effects on marine mammals should include details of: likely feeding areas; known birthing areas/haul out sites; nursery grounds; known migration or commuting routes; duration of potentially disturbing activity including cumulative/in-combination effects; baseline noise levels; predicted noise levels in relation to mortality, Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS); soft-start noise levels; and operational noise (NPS EN-3; paragraph 2.6.92).	All of the specified marine mammal ecology details are included in this chapter (section 4.7). The Hornsea Three assessment has considered the relevant marine mammal behaviour for key species present in the regional marine mammal study area. An assessment of construction and operational noise impacts and their likely effects upon marine mammal behaviour and ecology has been undertaken (section 4.11). This assessment also considers the cumulative impacts of Hornsea Three and other relevant plans or projects (section 4.1).
The Applicant should discuss any proposed piling activities with the relevant body. Where assessment shows that noise from offshore piling may reach noise levels likely to lead to an offence, the Applicant should look at possible alternatives or appropriate mitigation before applying for a European Protected Species (EPS) licence (NPS EN-3; paragraph 2.6.93).	The Hornsea Three assessment has considered the environmental impact of piling noise over a range of hammer energies and foundation types has been considered (section 4.8.1). Measures adopted as part of Hornsea Three are outlined in section 4.10.

Table 4.2: Summary of NPS EN-3 policy on decision making relevant to marine mammals for the Hornsea Three assessment.

Summary of policy on decision making (and mitigation)	How and where considered in the PEIR
Biodiversity	
The Secretary of State should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it (paragraph 2.6.68 of NPS EN-3).	The effects on marine mammals from the construction, operation and maintenance, and decommissioning have been described and considered within this assessment (see section 4.11).
The designation of an area as a Natura 2000 site does not necessarily restrict the construction or operation of offshore wind farms in or near that area (paragraph 2.6.69 of NPS EN-3).	Natura 2000 sites have been considered in the assessment (see section 4.11). Where there is potential for a likely significant effect on a marine mammal species identified as a reason for designation of the site, then this has been assessed within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).
Mitigation may be possible in the form of careful design of the development itself and the construction techniques employed (paragraph 2.6.70 of NPS EN-3).	Measures adopted as part of Hornsea Three have been taken into consideration in the assessment (see Table 4.19). A Marine Mammal Mitigation Protocol (MMMP), devised following consultation with the Statutory Nature Conservation Bodies (SNCBs) and approved by the Marine Management Organisation (MMO), will be implemented during construction.
Ecological monitoring is likely to be appropriate during the construction and operational phases to identify the actual impact so that, where appropriate, adverse effects can then be mitigated and to enable further useful information to be published relevant to future projects (paragraph 2.6.71 of NPS EN-3).	Monitoring will be carried out in order to test the predictions of the impact assessment, the detail of which will be established through consultation with the SNCBs and presented in a marine mammal monitoring plan. Monitoring will be implemented through the Construction Method Statement (CoCP), the Project Environmental Management and Monitoring Plan (PEMMP), which includes the Marine Mammal Mitigation Protocol (MMMP), the detail, timing and duration of which will be agreed through consultation.
Marine mammals	
The Secretary of State should be satisfied that the preferred methods of construction, in particular for foundations and the foundation type are designed to reasonably minimise significant disturbance effects. The Secretary of State may refuse the application if suitable noise mitigation measures cannot be imposed by requirements to any development consent (paragraph 2.6.94 of NPS EN-3).	Different foundation options and hammer energies have been considered for Hornsea Three. The maximum design scenario has been defined as those that represent the realistic maximum design scenario that have the potential to occur. These have been assessed and are presented in Table 4.14.
The conservation status of marine European Protected Species, and seals, are of relevance to the Secretary of State. The Secretary of State should take into account the views of the relevant statutory advisors (paragraph 2.6.95 of NPS EN-3).	The conservation status of species has been factored into the assessment of significance (Table 4.12).
Mitigation: monitoring of a mitigation area for marine mammals surrounding the piling works prior to commencement of, and during, piling activities. During construction, 24 hour working practices may be employed to reduce the total construction programme and the potential for impacts. Soft-start procedures during pile driving may be implemented to avoid significant adverse impacts (paragraphs 2.6.97 to 2.6.99 of NPS EN-3).	Measures adopted as part of Hornsea Three are set out in section 4.10 below. The measures include a soft-start and ramping up piling procedure to minimise impacts.

Table 4.3: Summary of the Marine Strategy Framework Directive's (MSFD) high level descriptors of Good Environmental Status (GES) relevant to marine mammals and consideration in the Hornsea Three assessment.

Summary of MSFD high level descriptors of GES relevant to marine mammals	How considered within this PEIR
Descriptor 1: Biological diversity: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	The effects on biological diversity has been described and considered within the assessment for Hornsea Three alone and in the cumulative effects assessment (CEA) (see sections 4.11 and 4.1, respectively).
Descriptor 2: Non-indigenous species: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.	The effects of non-indigenous species on marine mammal prey species within the Hornsea Three fish and shellfish ecology study area has been assessed in section 4.11.
Descriptor 4: Elements of marine food webs: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long term abundance of the species and the retention of their full reproductive capacity.	The effects on the abundance (and distribution) of marine mammal receptors within the Hornsea Three marine mammal study area and to the regional marine mammal study area have been described and considered within the assessment for Hornsea Three alone and in the CEA (see sections 4.11 and 4.1, respectively).
Descriptor 6: Sea floor integrity: Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	The effects of temporary and long term habitat loss and introduction of new habitat on marine mammal prey species within the Hornsea Three marine mammal study area have been described and considered within the assessment for Hornsea Three alone and the CEA (see sections 4.11 and 4.1, respectively).
Descriptor 8: Contaminants: Concentrations of contaminants are at levels not giving rise to pollution effects.	The effects of contaminants on marine mammal receptors and on prey species have been assessed in sections 4.11 and 4.1 below.
Descriptor 9:Contaminants in Seafood: Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.	The effects of contaminants on marine mammal prey species have been assessed in sections 4.11 and 4.1 below.
Descriptor 10: Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	A CoCP will be developed and implemented during the construction phase and an appropriate PEMMP will be produced and implemented during the operation and maintenance phase of Hornsea Three. These documents will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details (e.g. Environment Agency, Natural England and the Maritime and Coastguard Agency (MCA)). A Decommissioning Programme will be developed and implemented during the decommissioning phase (Table 4.19).
Descriptor 11: Energy including underwater noise: Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	The effects of underwater noise from piling of turbine, substation and platform foundations, from other construction activities (e.g. cable installation) and from vessel noise have been considered within the assessment for Hornsea Three alone (paragraph 4.11.1.118) and in the CEA (see paragraph 4.13.1.55).

4.5 Consultation

4.5.1.1 A summary of the key issues raised during consultation specific to marine mammals is outlined below, together with how these issues have been considered in the production of this PEIR. A summary of consultation specific to marine mammals undertaken for Hornsea Project One and Hornsea Project Two, which are applicable to Hornsea Three, are also set out below.

4.5.2 Hornsea Project One and Hornsea Project Two consultation

4.5.2.1 Hornsea Three has similarities, both in terms of the nature of the development and its location, to Hornsea Project One and Hornsea Project Two. The matters relevant to Hornsea Three, which were raised by consultees during the pre-application and examination phases of Hornsea Project One and Hornsea Project Two, on marine mammals, are set out in volume 4, annex 1.1: Hornsea Project One and Hornsea Project Two Consultation of Relevance to Hornsea Three.

4.5.3 Hornsea Three consultation and the Evidence Plan

4.5.3.1 Table 4.4 below summarises the issues raised relevant to marine mammals, which have been identified during consultation activities undertaken to date. Table 4.4 also indicates either how these issues have been addressed within this PEIR or how Hornsea Three has had regard to them.

4.5.4 Evidence Plan

4.5.4.1 Advice in relation to Hornsea Three specifically has been sought through consultation with the statutory consultees through the Evidence Plan process. The Evidence Plan process has been set out in the Draft Evidence Plan (DONG Energy, 2017b), the purpose of which is to agree the information Hornsea Three needs to supply as part of a DCO application for Hornsea Three. The Evidence Plan seeks to ensure compliance with the EIA and Habitat Regulations Assessment (HRA).

4.5.4.2 As part of the Evidence Plan process, a Marine Mammal EWG was established with representatives from the key regulatory bodies, SNCBs and non-statutory parties, including the MMO, Natural England and The Wildlife Trust (TWT). The Joint Nature Conservation Committee (JNCC) are not part of the Marine Mammal EWG as they have delegated responsibility to Natural England. Natural England will liaise with JNCC as part of the process. A number of meetings have been held in order to discuss and agree key elements of the marine mammal HRA and EIA. Meetings with key stakeholders commenced in March 2016 and have continued throughout 2016 and into 2017. Key issues arising from Hornsea Project One and Hornsea Project Two that were relevant to Hornsea Three, and in the Scoping Opinion for Hornsea Three were discussed during the EWG as outlined in Table 4.4 below (see column "*response to issue raised and/or where considered in this chapter*"). A meeting was also held with the Whale and Dolphin Trust in April 2017 to update them on Hornsea Three and discussions that were ongoing with the Marine Mammal EWG.

Table 4.4: Summary of key consultation issues raised during consultation activities undertaken for Hornsea Three relevant to marine mammals, including those subsequently discussed with the Marine Mammal EWG.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
December 2016	PINS (Scoping Opinion)	Adequacy of existing boat-based data from Hornsea Project One and Hornsea Project Two to inform the baseline for Hornsea Three. PINS recommended consultation with SNCBs to agree baseline.	Data to inform the Hornsea Three baseline was discussed and agreed as part of the Evidence Plan process with the Marine Mammal EWG. It was agreed that the existing boat-based survey data from the Hornsea Zone plus 10 km buffer would provide an appropriate characterisation of the baseline. It was also agreed that more recent data from aerial surveys of Hornsea Three array area plus 4 km buffer could provide additional detail with respect to harbour porpoise (Table 4.6). Additional contextual information was sought through third party sources, where available and appropriate to do so. This included publicly available information to define the referent populations (paragraph 4.7.1.2). Section 4.6 below provides an overview of the methodology to inform the baseline.
December 2016	PINS (Scoping Opinion)	Consideration of nationally and internationally designated sites and requirement to consult with relevant authorities to ensure correct sites are screened into assessment.	Sites screened into the assessment for Hornsea Three have been agreed with the Marine Mammal EWG (paragraph 4.6.2.1). The transboundary consultation is currently being undertaken.
December 2016	PINS (Scoping Opinion)	Scale over which cumulative impacts will vary for each species therefore it is recommended that this is discussed and agreed with the SNCBs.	The scale over which the CEA was conducted was discussed and agreed with the Marine Mammal EWG at a meeting on 28 March 2017. The scale was agreed to be the same area as the reference populations for each species (section 4.7.1).
December 2016	PINS/MMO (Scoping Opinion)	No specific modelling is proposed to assess vessel disturbance or decommissioning and the literature review proposed is considered to be acceptable.	A comprehensive literature review has been undertaken for the assessment of disturbance from vessels or decommissioning (section 4.11).
November 2016	MMO (Scoping Opinion)	Noise reduction technologies are available to mitigate against the noise impacts from pile driving and the Applicant is encouraged to consider using such measures during pile driving operations and to consult the JNCC (2010) guidance with regard to mitigation to prevent injury and mortality to marine mammals.	Hornsea Three continues to evaluate the potential for engineering solutions to reduce the noise at source, should this be required, and will consult with SNCBs post consent to discuss mitigation solutions once more detailed information is known.
November 2016	Natural England (Scoping Opinion)	Concern regarding the estimates of relative abundance for harbour porpoise from the aerial survey data.	The use of published data from telemetry studies to apply a correction factor to the relative abundance estimates, to approximate absolute abundance, was discussed with the Marine Mammal EWG at the meeting on 28 March 2017 and a suitable approach agreed (Table 4.6).
November 2016	Natural England (Scoping Opinion)	MMO should seek advice from Cefas on the noise modelling methodology.	The noise modelling methodology was submitted to Cefas for review on 31 March 2017. Hornsea Three has recently received comments back from Cefas. Hornsea Three are currently considering this advice, and updates will incorporate, where appropriate into the Environmental Statement..
November 2016	Natural England/RSPB (Scoping Opinion)	No surveys were undertaken of the Hornsea Three offshore cable route corridor but the assessment should take account of sensitive breeding and moulting periods for seals along the north Norfolk coast. There are important haul outs at Blakeney and Horsey and the population has been expanding in recent years at these locations.	Data has been gathered for seal colonies along this coastline as part of the desktop study, including the Friends of Horsea Seals, National Trust (Blakeney) and national datasets from the Sea Mammal Research Unit (SMRU) (section 4.6).
November 2016	Natural England (Scoping Opinion)	Natural England would welcome discussion concerning the use of offshore platforms to accommodate a marine mammal mitigation team.	A mitigation strategy will be discussed in detail with the Marine Mammal EWG. The details of this will need to be agreed once the project parameters have been further refined post consent.
November 2016	Natural England (Scoping Opinion)	The Applicant should use the densities from the Joint Cetacean Protocol (JCP) dataset once available.	The JCP data was not available for use in the baseline for this PEIR; however, it will be included in the Environmental Statement if it becomes available within the timescale.
November 2016	Natural England (Scoping Opinion)	Natural England welcomes the inclusion of Marine Conservation Zones (MCZs) in the baseline although noting that there are no marine mammal features of these sites.	MCZs were included as the habitat features within these sites may support marine mammal species (information on MCZs is presented in volume 5, annex 4.1: Marine Mammal Technical Report).
November 2016	Natural England (Scoping Opinion)	Natural England suggests that the new NOAA thresholds for permanent threshold shift (PTS) onset in marine mammals are also considered in future assessment. While the SNCBs have yet to fully assess how the new thresholds might be applied in UK, Natural England would expect the SNCBs to have formed a view by the time PEIR/Environmental Statement are released for consultation.	The approach to modelling of subsea noise was presented and discussed with the Marine Mammal EWG and the use of the NOAA thresholds for PTS (NMFS, 2016) was agreed as the most appropriate approach to take for the Hornsea Three assessment (section 4.11).

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
November 2016	Natural England (Scoping Opinion)	Subsea noise assessment should look at the cumulative impacts of other impulsive noise activities as well as piling operations at adjacent offshore wind farms including unexploded ordnance (UXO). We acknowledge that UXO will not be assessed within the EIA, however, some assumptions on size and number will need to be made for the EIA and HRA in terms of cumulative noise impacts.	It was agreed at the Marine Mammal EWG meeting on 28 March 2017 that whilst it would not be possible to quantify the effects of UXO detonations, there should be assumptions about the size and quantity of UXOs likely to be encountered and the possible effects on marine mammals (section 4.1). In addition it was agreed that a licence application should be made at the appropriate time (post-consent) if required.

4.6 Methodology to inform the baseline

4.6.1 Overview

4.6.1.1 The methodology to inform the baseline was discussed and agreed as part of the Evidence Plan process (see Table 4.4). The approach involved the use of existing site-specific, boat-based survey data gathered across the former Hornsea Zone plus 10 km buffer and re-analysed for the Hornsea Three array area, together with the use of additional site-specific aerial survey data from ongoing surveys across the Hornsea Three array area plus 4 km buffer. In addition, data were gathered through an extensive literature review of existing data sources. Further detail on the approach is provided below.

4.6.1.2 Further data from ongoing aerial surveys of Hornsea Three plus 4 km buffer and any publicly available information that becomes accessible in the required timescale (e.g. JCP data) will be used to inform the baseline for the Environmental Statement.

4.6.2 Desktop study

4.6.2.1 Information on marine mammals within the regional marine mammal study area was collected through a detailed desktop review of existing studies and datasets (see Table 4.5). A full review is provided in volume 5, annex 4.1: Marine Mammal Technical Report. In addition to SCANS I and II, SCANS III data that becomes available in 2017 will be incorporated into the Environmental Statement.

Table 4.5: Summary of existing data sources for marine mammals.

Title	Source	Year	Author
Atlas of cetacean distribution in north west European waters	JNCC	2003	Reid *et al.*
UK Cetacean Status Review	Sea Watch Foundation	2003	Evans *et al.*
Abundance of Harbour Porpoise and other Cetaceans in the North Sea and Adjacent Waters	SCANS I	2002	Hammond *et al.*
Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management	SCANS II	2006	Hammond
Cetacean and pinniped data for Norfolk and Lincolnshire coast	Wildfowl and Wetland Trust aerial surveys	2009	WWT Consulting Ltd
Seal data for Horsey	Friends of Horsey Seals (FoHS)	2017	Rothney E.
Seal data for Blakeney	National Trust	2017	N/A
Regional biodiversity records for marine mammals	Lincolnshire Environmental Records Centre	1997 to 2017	N/A
Regional biodiversity records for marine mammals	Norfolk Environmental Records Centre	1997 to 2017	N/A
Scientific Advice on Matters Related to the Management of Seal Populations	Special Committee on Seals (SCOS)	2011, 2012, 2013, 2014, 2015, 2016	SCOS
Telemetry data for grey and harbour seals tagged along the Norfolk and Lincolnshire coastlines	SMRU	1988 to 2015	Plunkett (2017) (appendix A of volume 5, annex 4.1: Marine Mammal Technical Report)
Updated Grey Seal Usage Maps in the North Sea	Department of Energy and Climate Change (DECC)	2016	Jones and Russell
Revised Phase III Data Analysis of Joint Cetacean Protocol Data Resources	JNCC	2016	Paxton *et al.*
Management Units for Cetaceans in UK Waters	JNCC	2015	Inter-Agency Marine Mammal Working Group (IAMMWG)
Management Units for Marine Mammals in UK Waters	JNCC	2013	IAMMWG
Monthly boat-based marine mammal sightings along ferry routes	Marine Life	2010 to 2016	Marine Life (2017)

4.6.3 Designated sites and legislation

4.6.3.1 All designated sites within the regional marine mammal study area that have marine mammals as qualifying interest features that could be affected by the construction, operation and maintenance, and decommissioning of Hornsea Three, were identified using the three step process described below:

- Step 1: All designated sites of international, national and local importance within the regional marine mammal study area were identified using a number of sources. These included:
  - JNCC's interactive map (http://jncc.defra.gov.uk/page-5201);
  - European Site Nature Information System (EUNIS) database for international designations (http://eunis.eea.europa.eu/);
  - Net Gain reports for recommended Marine Conservation Zones (rMCZs) (Net Gain, 2011);
  - Department for Environment, Food and Rural Affairs (Defra) MAGIC interactive map applications (http://magic.defra.gov.uk/); and
  - Defra Data and Evidence Coordination Programme for rMCZs (http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18983&FromSearch=Y&Publisher=1&SearchText=mb0129&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description).
- Step 2: Information was compiled on the relevant marine mammal features for each of these sites as follows:
  - Review of the conservation objectives for each site produced by JNCC and Natural England; and
  - Review of the conservation status of each species via the European Environment Information and Observation Network (EIONET) portal (http://bd.eionet.europa.eu/article17/speciessummary).
- Step 3: Using the above information and expert judgement, sites were included for further consideration if:
  - A designated site directly overlaps with Hornsea Three including the offshore cable route corridor;
  - Sites and features are located within the Potential Zone of Impact (ZoI) for impacts associated with Hornsea Three (e.g. subsea noise, vessel disturbance etc.);
  - Species of a designated site were recorded as present during the site-specific surveys and listed as a qualifying interest feature; and
  - Where national and locally designated sites (i.e., Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs) and Local Nature Reserves (LNRs) fall within the boundaries of an internationally designated site (e.g., SAC and Sites of Community Importance (SCI), only the international site was taken forward for assessment, as potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e., a separate assessment for the national site is not undertaken).

4.6.3.2 Designated sites within close proximity to Hornsea Three and therefore most likely to be potentially affected by activities associated with it, are described in the Species Accounts (section 4.7.2) and discussed in full in the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017). Figure 4.2 illustrates the location of relevant designated sites in relation to Hornsea Three. Protected sites for marine mammals are designated in the UK through the legislation described below.

European legislation

4.6.3.3 The Conservation of Species and Habitats Directive (Habitats Directive) provides for protection of animals and plants throughout EU member states through both the designation/classification of European Sites as well as the protection of European Protected Species.

4.6.3.4 The Habitats Directive was first transposed into UK law through the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended in 2007). In England and Wales the 1994 Regulations have been superseded by the Conservation of Habitats and Species Regulations 2010. These Regulations extend to 12 nautical miles (nm) offshore.

4.6.3.5 In the UK water beyond 12 nm, the Habitats Directive is transposed into law through the Offshore Marine Conservation (Natural Habitats &c.) Regulations 2007.

4.6.3.6 All of the above UK Regulations allow for the designation or classification of European Sites as specified under the Habitats Directive including SACs, Special Protection Areas (SPAs), and Ramsar sites.

National legislation

4.6.3.7 SSSIs are designated under the Wildlife and Countryside Act 1981.

4.6.3.8 Specific to seals, England and Wales also has the Conservation of Seals Act 1970, which protects seals in England and Wales (and adjacent territorial waters) by providing annual closed seasons for both grey and harbour seals. During the closed seasons, it is an offence to take or kill a seal except under licence.

4.6.3.9 MCZs/rMCZs have been included as part of the baseline where these have features that are considered to be important for marine mammals (e.g. habitats that support key prey species), however, as these sites are not intrinsically designated for marine mammal, no further consideration has been given to them in this PEIR chapter.

4.6.3.10 LNRs are designated by UK local authorities to protect species or habitats of local importance.

4.6.3.11 The Habitats Regulations 2010 (as amended in England and Wales) require that, a plan or project that is not directly connected with or necessary for the management of a Natura site, but which has a likely significant effect on the site, either individually or in combination with other plans or projects, will require an appropriate assessment of the impact of that plan or project on the interests of the Natura site. An assessment of the potential impacts of Hornsea Three on the qualifying interests of relevant SACs is presented in the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017)).

4.6.4 European Protected Species

4.6.4.1 Under both the Offshore Habitats Regulations 2007 (as amended) and the Habitats Regulations 2010 (as amended in England and Wales), all species of cetacean are considered to be European Protected Species (EPS) (as listed in Annex IV of the Habitats Directive).

4.6.4.2 Under the Offshore Habitats Regulations 2007 (as amended 2009, 2010, 2012) Regulation 39 and 40, it is an offence to:

- Deliberately capture, kill, injure any wild animal of a EPS;
- Deliberately disturb wild animals of any such species in such a way as to be likely to:
  - Impair their ability to survive, breed or to rear or nurture their young;
  - In the case of migratory species, to migrate; and
  - To affect significantly the local distribution or abundance of the species to which they belong.
- Deliberately damage or destroy a breeding site or resting place of such a species.

4.6.4.3 Offences under the Habitat Regulations 2010 (as amended 2011, 2012), Regulation 40 and 41 are as per Offshore Habitats Regulations 2007 (as amended).

4.6.4.4 The risk of an offence being committed against an EPS is dependent on a number of factors including the duration of noise associated with the activity; the presence or absence of EPS; the frequency and density of occurrence of EPSs; and the duration individuals stay within a given area. It is considered likely that increased activities associated with Hornsea Three, in particular increased anthropogenic noise, have the potential to cause injury or disturbance to cetacean species within the area. However, if risk of injury or disturbance of an EPS cannot be removed or reduced sufficiently through the use of alternative and/or mitigation measures, the activity may still be able to go ahead under licence.

4.6.4.5 Draft guidance published in March 2010 and entitled 'The Protection of Marine European Protected Species from Injury and Disturbance', was subsequently revised in June 2010 by the JNCC, Natural England and the Countryside Council for Wales (CCW) (JNCC *et al.,* 2010a). This guidance acts as a reference when considering whether an offence against an EPS has occurred in English or Welsh waters, or there is potential for one to occur as a result of an activity. It also considers the potential of certain activities that produce loud noises to result in an injury or disturbance offence in areas where an EPS could be present, unless appropriate mitigation measures are implemented.

4.6.5 Hornsea marine mammal surveys

4.6.5.1 In order to inform the EIA, marine mammal surveys were undertaken, as agreed with the Marine Mammal EWG (see section 4.5.3). A summary of the surveys undertaken to date is outlined in Table 4.6 below.

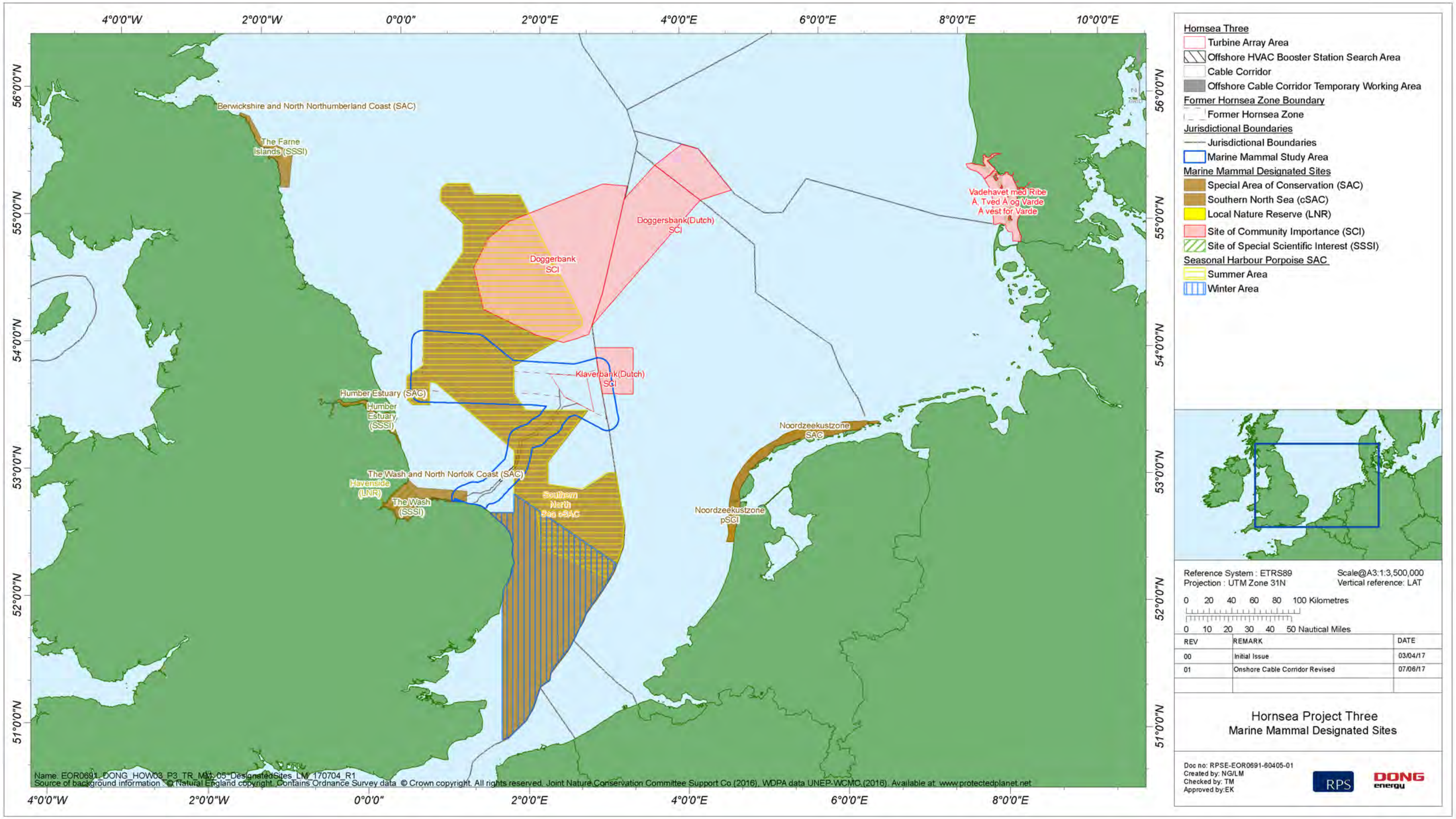

Figure 4.2: Designated sites relative to Hornsea Three.

Table 4.6: Summary of marine mammal survey data.

Title	Extent of survey	Overview of survey	Survey contractor	Year	Reference to further information
Hornsea Three aerial surveys	Hornsea Three array area plus 4 km buffer	Survey commissioned specifically for Hornsea Three. Monthly aerial surveys of marine mammals (and seabirds) along transects spaced approximately 2.5 km apart over the survey area (Figure 2.3 in annex 4.1: Marine Mammal Technical Report). Surveys commenced in April 2016 and will continue until September 2017. Six months of data were available to inform this PEIR. The full dataset will be available to inform the Environmental Statement. Aerial surveys were carried out using high resolution digital video cameras each month to record the abundance of each marine mammal species within the survey strip. The data were subsequently processed in the laboratory with identification carried out to species level where possible. Quality assurance was carried out on a 20% sample to validate the results. Data were analysed for harbour porpoise to produce surface-density estimates across the survey area. It was not possible to do the same for other species due to the low numbers recorded during the surveys. As no site-specific correction factor could be applied to the aerial data to estimate absolute abundance/density of harbour porpoise, it was agreed with the EWG that a published value from Teilmann *et al.* (2013) could be applied (see section 2.5.2 in Annex 4.1: Marine Mammal Technical Report)	HiDef	2016 to 2017	Volume 5, annex 4.1 Marine Mammal Technical Report
Hornsea boat based surveys	Former Hornsea Zone plus 10 km buffer	Survey commissioned for the former Hornsea Zone and re-analysed for the Hornsea Three array area. Monthly boat based visual and acoustic surveys across the survey area were undertaken over a 36 month period between March 2010 and February 2013. Transects were spaced 6 km apart across the former Hornsea Zone plus 10 km buffer with additional survey effort (2 km spaced transects) across the Hornsea Project One and Hornsea Project Two array areas plus 4 km buffers) (Figure 2.1 in annex 4.1: Marine Mammal Technical Report). Visual surveys were conducted following an adaptation of the European Seabirds at Sea (ESAS) methodology and using the Distance sampling technique. Surveys were conducted in sea state 3 or less and the resulting data were corrected for the effects of sea state on detection probability. Acoustic surveys were conducted at the same time from the survey vessel using a towed hydrophone system with a similar set up as employed during the SCANS surveys. Data were acquired using PAMGUARD which uses click detector software to identify the marine mammal species. The data were analysed to determine the abundance and density of marine mammal species across the survey area, using environmental data to model densities across areas not covered by the transects. Where possible the absolute (rather than relative) abundance of a marine mammal species was estimated.	EMU	2010 to 2013	Volume 5, annex 4.1: Marine Mammal Technical Report

4.7 Baseline environment

4.7.1 Marine mammal overview

4.7.1.1 From the data examined, including historic records of marine mammals in the southern North Sea, SCANS-II survey data, aerial surveys of the Hornsea Three array area plus 4 km buffer, and visual and acoustic surveys of the former Hornsea Zone plus 10 km buffer, the following five species of marine mammal have been identified as valued ecological receptors (VERs, see section 4.7.3) and are the focus of this PEIR:

- Harbour porpoise *Phocoena phocoena*;
- White-beaked dolphin *Lagenorhynchus albirostris*;
- Minke whale *Balaenoptera acutorostrata*;
- Harbour seal *Phoca vitulina*; and
- Grey seal *Halichoerus grypus*.

Management Units

4.7.1.2 The IAMMWG has recommended MUs for the most common species of marine mammals in the UK (IAMMWG, 2013), with a supplementary report provided in 2015 providing revised cetacean MUs (IAMMWG, 2015). MUs in UK waters extend to 12 nautical miles (NM) - the limit of territorial water. For each MU for each marine mammal, IAMMWG recommend reference populations (abundance and geographic area) against which to measure potential effects of development and these are presented in the individual species accounts (section 4.7.2).

4.7.2 Species accounts

Harbour porpoise

4.7.2.1 According to Reid *et al.*, (2003), harbour porpoise are widespread throughout the temperate waters of the North Atlantic and North Pacific and are the most abundant cetacean in UK waters. In UK water the whole of the coastline of the North Sea is considered an important area for this species. Harbour porpoise can live up to between 12 and 13 years, reach sexual maturity at between three and four years of age, with gestation occurring over a period of 10 to 11 years (Lockyer, 2003).

4.7.2.2 Visual and acoustic sightings data from surveys of the former Hornsea Zone plus 10 km show that harbour porpoise is widely distributed across the Hornsea Three marine mammal study area (Figure 4.3). Similarly, historical sightings data confirmed that harbour porpoise is commonly sighted along coastal waters, including within the Hornsea Three offshore cable corridor (Figures 4.4 and 4.5 in volume 5, annex 4.1: Marine Mammal Technical Report).

4.7.2.3 Harbour porpoise density and abundance data derived from boat-based visual and acoustic surveys of the former Hornsea Zone plus 10 km buffer and from aerial surveys of Hornsea Three array plus 4 km buffer are summarised in Table 4.7 below. Comparison of the densities using either the boat-based visual or boat-based acoustic shows that densities are similar in both survey extents, suggesting that the Hornsea Three array area plus 4 km buffer is not an area particular importance within the former Hornsea Zone plus 10 km buffer (Table 4.7). In addition the mean density estimate from the more recent aerial surveys is very similar to the boat-based visual density estimate (Table 4.7) (recognising the limitations of comparing these two datasets: see section 3.2.6 in volume 5, annex 4.1: Marine Mammal Technical Report). Similarly, comparison of the surface density estimates derived using the aerial data and boat-based visual data show that, spatially, the patterns of density are similar, with 'hot spots' occurring in the same area within Hornsea Three array area plus 4 km buffer (Figure 4.4).

Table 4.7: Summary of abundance and density estimates of harbour porpoise across the different survey areas and based on three datasets: boat-based visual, boat-based acoustic and aerial video.

Data source	Area (km^2)	Density	Abundance
Former Hornsea Zone plus 10 km buffer			
Visual boat-based	9,276	1.72	15,955
Acoustic boat-based	9,276	2.22	20,593
Hornsea Three plus 4 km buffer			
Visual boat-based	1,230	1.76	1,232
Acoustic boat-based	1,230	2.87	3,530
Aerial video	1,230	1.77	2,177

4.7.2.4 In comparison to the regional marine mammal study area these figures suggest that the Hornsea Three marine mammal study area is of relatively high importance for harbour porpoise since the densities are higher than the average density of 0.598 animals km^{-2} (CV = 0.28) recorded for SCANS block U in the south central North Sea (Hammond *et al.*, 2013). This conclusion is also supported by the modelled surface density maps for SCANS-II; (Hammond *et al.*, 2013), which show the highest densities in the whole of the North Sea are in the area that overlaps the former Hornsea Zone. In this relatively high density region, the densities are predicted to be greater than 1.2 animals km^{-2} (Hammond *et al.*, 2013).

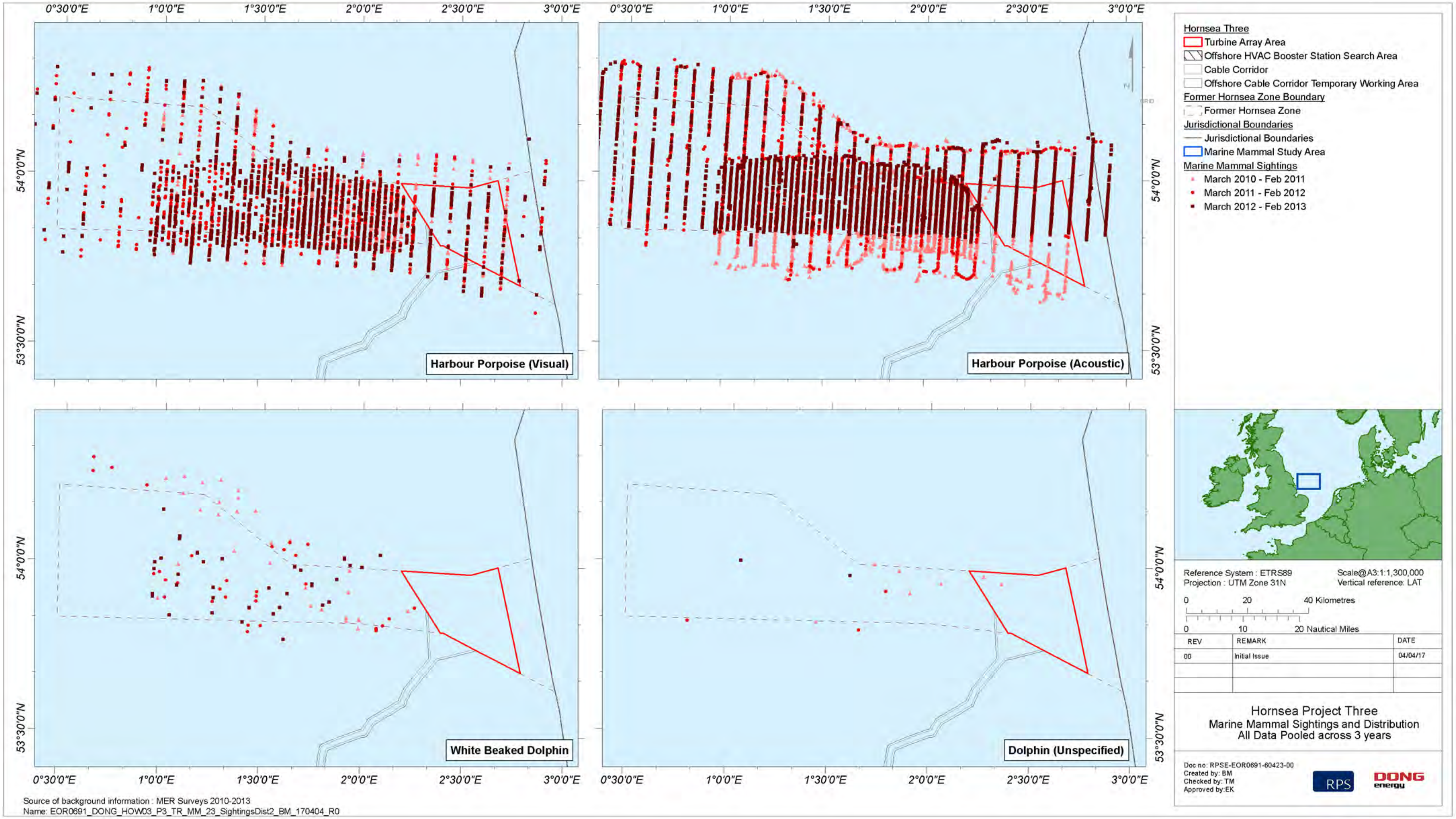

Figure 4.3: Marine mammal sighting and distribution. All data pooled across three years of boat-based surveys.

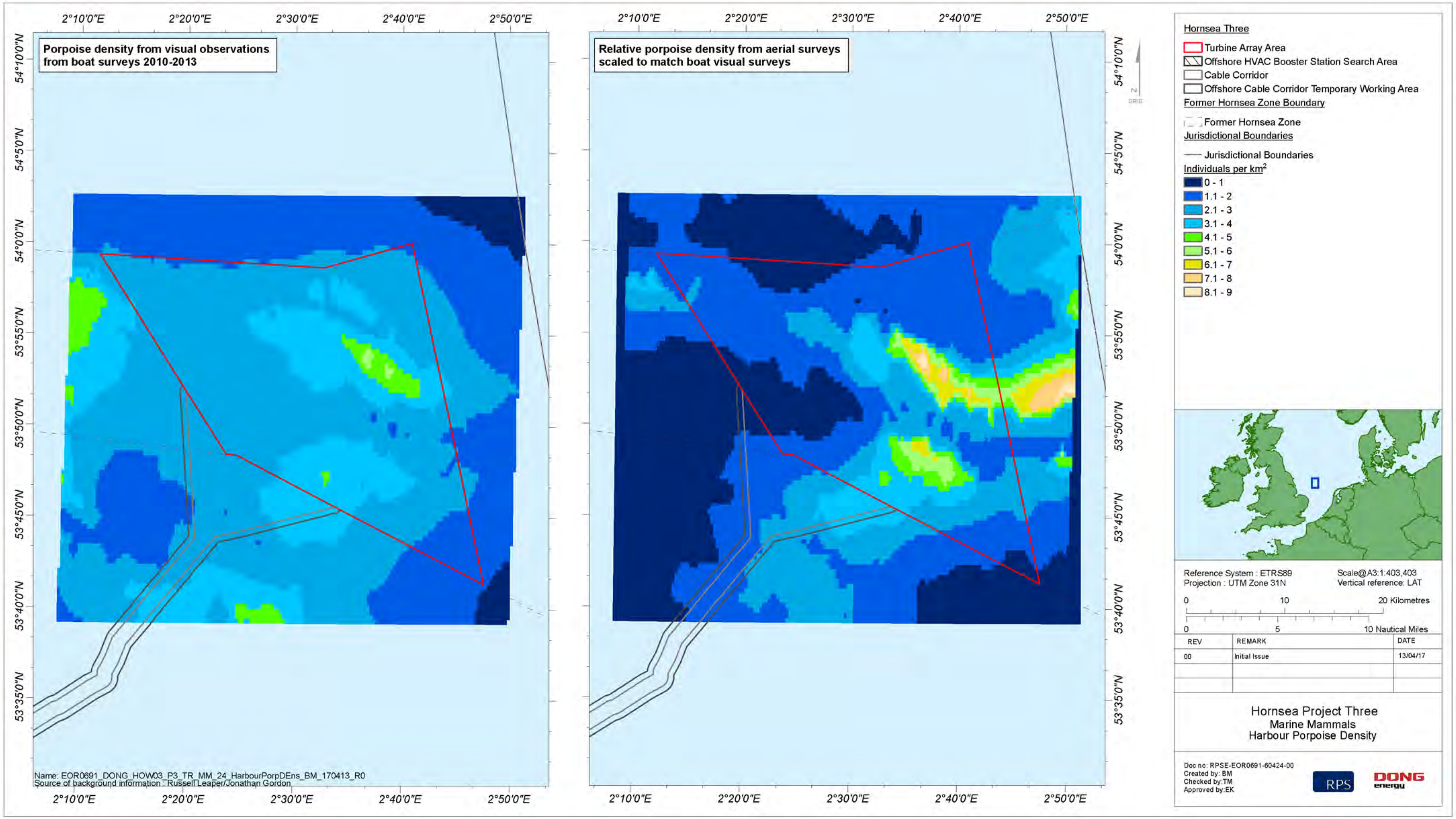

Figure 4.4: Surface density maps for harbour porpoise for Hornsea Three plus 4 km buffer with aerial data scaled to give the same mean density as the boat-based data for comparative purposes.

4.7.2.5 The IAMMWG has identified three MUs as appropriate for harbour porpoise: North Sea (NS), West Scotland (WS) and Celtic and Irish Seas (CIS). Hornsea Three array and offshore cable corridor falls within the North Sea MU which extends from the southeast coast up to the northern tip of Scotland and comprising the ICES areas IV, VIId and Division IIIa (Figure 4.5). The total harbour porpoise abundance for the North Sea MU was estimated as 227,298 animals (95% Confidence Interval 76,360 to 292,948) (IAMMWG, 2015). Where a quantitative assessment of impact is possible, the MU abundance estimate has been used as the reference population against which to assess impact.

4.7.2.6 Table 4.8 summarises the designated sites within the North Sea MU which have harbour porpoise listed as a qualifying interest feature (Figure 4.5). Designated sites for harbour porpoise within the North Sea MU have been considered to inform assessment of sensitivity of harbour porpoise as a feature of these sites as well as for the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017).

Table 4.8: Designated sites with harbour porpoise as a qualifying interest feature within the North Sea MU, and distances to the Hornsea Three array and offshore cable route.

Site Name	Distance from Hornsea Three array area (km)	Distance from Hornsea Three offshore cable route (km)
European sites		
Southern North Sea pSAC	1.6	0
Klaverbank pSCI	11	24
Noordzeekustzone II SCI[a]	138	155
Vadehavet med Ribe Å, Tved Å og Varde Å vest for Varde SAC	381	400

a Combined with Noordzeekustzone SAC for Draft Report to inform Appropriate Assessment (DONG Energy, 2017).

White-beaked dolphin

4.7.2.7 White-beaked dolphin is one of the most abundant *delphinid* species on the UK shelf water (Hammond *et al.*, 2002) and is distributed mainly through the sub-polar seas of the Northern Atlantic. Maximum recorded age for white-beaked dolphin is 37 years (Kinze, 2009) and adults become sexually mature at a length of approximately 2.6 m and at approximately 12 to 13 years of age (Reeves *et al.*, 1999b). Gestation period is approximately 11 to 12 months duration.

4.7.2.8 This species is common in waters cooler than 14°C and are absent in regions where the temperature exceeds 18°C (MacLeod *et al.*, 2008; Parsons *et al.,* 2012). Temperature is a critical factor in determining distribution (Canning *et al.,* 2008; MacLeod *et al.,* 2008) and during the warmer summer months it is likely that white-beaked dolphin in the North Sea are restricted to more northerly areas (Canning *et al*., 2008).

4.7.2.9 A total of 298 individuals were recorded in the former Hornsea Zone plus 10 km buffer during boat-based surveys, during all months except between July and October. The total abundance of the former Hornsea Zone plus 10 km buffer has been calculated as 148.6 animals (volume 5, annex 4.1: Marine Mammal Technical Report).

4.7.2.10 From boat-based surveys across the former Hornsea Zone plus 10 km buffer, mean relative density of white-beaked dolphin has been calculated as 0.016 animals km^{-2}. The densities were found to be highest to the northwest of the former Hornsea Zone plus 10 km buffer (0.12 animals km^{-2}) dropping to zero animals km^{-2} in the southeast of the former Hornsea Zone (see Figure 4.16 of volume 5, annex 4.1: Marine Mammal Technical Report). From SCANS II surveys, relative density was estimated as 0.003 animals km^{-2} (Hammond *et al.,* 2013).

4.7.2.11 Historic GLNP land-based sightings data confirm that white-beaked dolphin are present within the Greater Wash area as well as within proximity of the Hornsea Three offshore cable corridor (Figure 4.14 of volume 5, annex 4.1: Marine Mammal Technical Report).

4.7.2.12 Hornsea Three falls within the Celtic and Greater North Seas (CGNS) MU for white-beaked dolphin (Figure 4.6). The total abundance of white-beaked dolphin in the CGNS MU was estimated as 15,895 animals (IAMMWG, 2015) (95% Confidence Internal 9,107 to 27,743) (IAMMWG, 2015).

4.7.2.13 Where a quantitative assessment of impact is possible, the MU abundance estimate has been used as the reference population against which to assess impact.

4.7.2.14 There are no designated sites for white-beaked dolphin within the North Sea and therefore no connectivity to designated sites for this species.

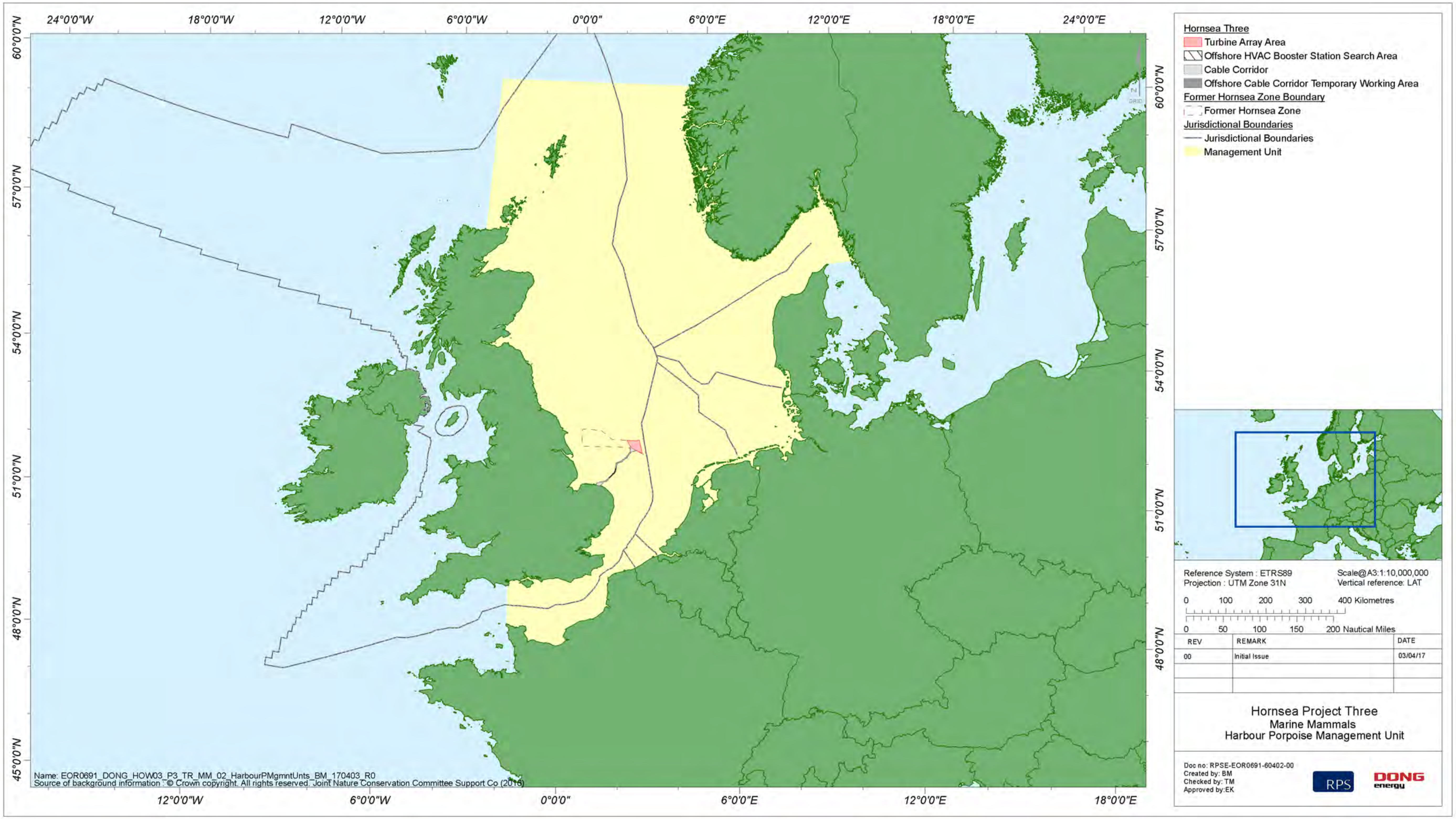

Figure 4.5: Harbour porpoise MU.

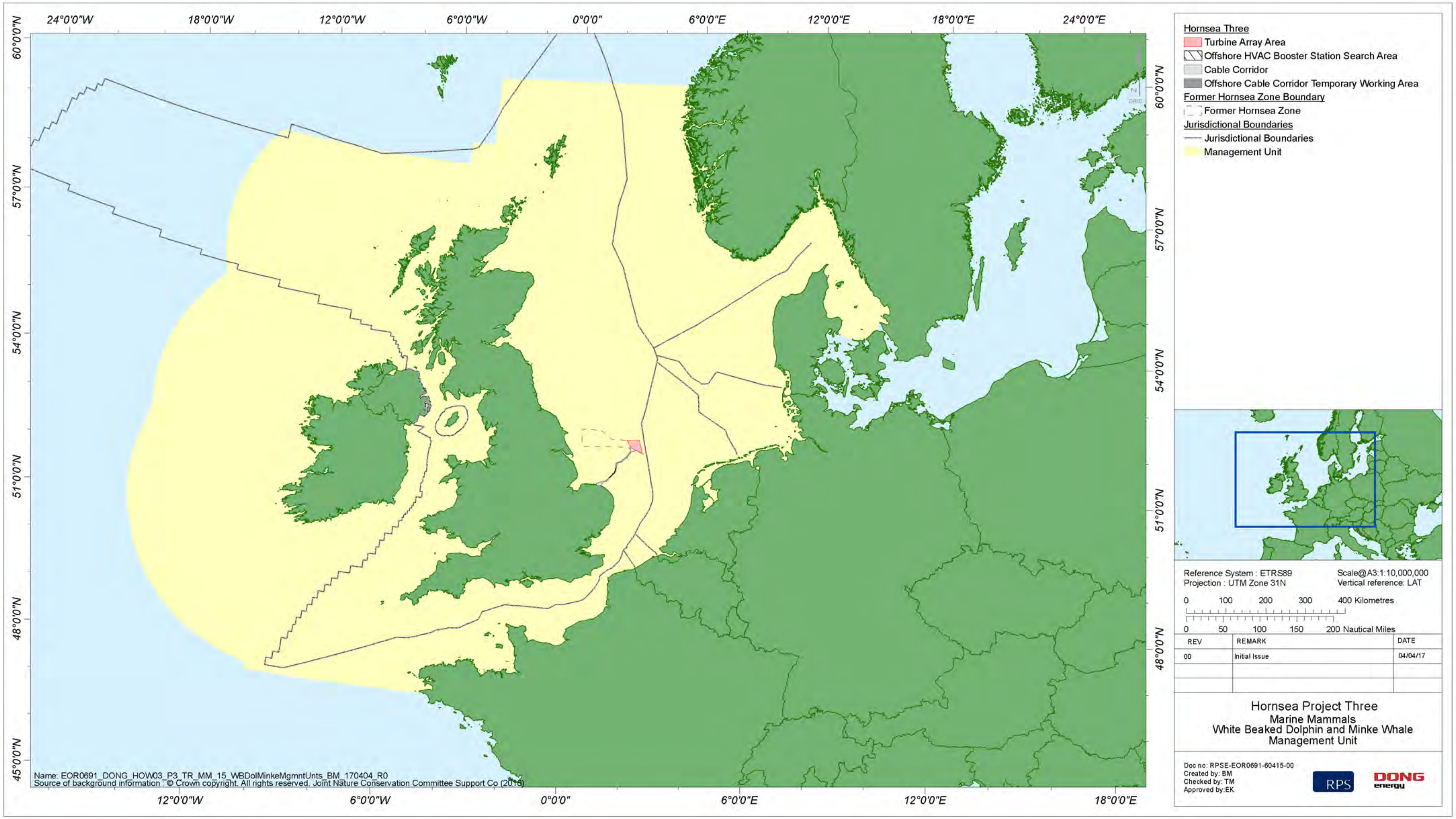

Figure 4.6: White beaked dolphin and minke whale MU.

Minke whale

4.7.2.15 Minke whale is widely distributed around the Atlantic seaboard of Britain and Ireland and occurs regularly in the northern and central North Sea (Evans *et al*., 2003; Reid *et al*., 2003). In total, 158 minke whale were recorded across the former Hornsea Zone plus 10 km buffer during boat-based surveys. No minke whale were recorded during boat-based surveys across the former Hornsea Zone plus 10 km buffer during the winter months (December to February). Minke whale typically live up to 60 years. Male minke whale reach sexual maturity at approximately 6.9 m in length (aged five to eight years) and females at about 7.3 m in length (aged six to eight years). Gestation occurs over a ten month period.

4.7.2.16 The total abundance of minke whale in the former Hornsea Zone plus 10 km buffer has been calculated as 56 individuals (calculated by multiplying the average density estimate for minke whale for the former Hornsea Zone plus 10 km buffer by the area). The averaged density across the Hornsea Three marine mammal study area was 0.012 animals km^{-2} which is double the estimate for the former Hornsea Zone plus 10 km buffer (0.006 animals km^{-2}).

4.7.2.17 Historic GLNP land-based sightings data confirm that minke whale are present within the Greater Wash area as well as within proximity to the Hornsea Three offshore cable corridor (Figure 4.14 of volume 5, annex 4.1: Marine Mammal Technical Report).

4.7.2.18 Hornsea Three falls within the Celtic and Greater North Seas (CGNS) MU for minke whale (Table 4.5). The total abundance of minke whale in the CGNS MU was estimated as 23,528 animals (IAMMWG, 2015) (95% Confidence Internal 13,989 to 39,572) (IAMMWG, 2015).

4.7.2.19 Where a quantitative assessment of impact is possible, the MU abundance estimate has been used as the reference population against which to assess impact.

4.7.2.20 There are no designated sites for minke whale within the North Sea and therefore no connectivity to designated sites for this species.

Grey seal

4.7.2.21 In the south central North Sea grey seal breed on the sandbanks at Donna Nook, Blakeney point and Scroby Sands, and also haul-out in the Wash between September and December. Grey seal can live for over 20 to 30 years, with females tending to live longer than males (SCOS, 2015). Sexual maturity is reached at approximately ten years in males, and five years in females (SCOS, 2015) and gestation occurs over 10 to 11 months.

4.7.2.22 During boat-based surveys across the former Hornsea zone plus 10 km buffer, a total of 247 grey seal were recorded. There was a notable decrease in recorded animals between September and December which coincides with the main haul-out period. Abundance of grey seal within the former Hornsea Zone plus 10 km buffer has been calculated as 371.5 individuals.

4.7.2.23 Grey seal at sea usage data provided by SMRU confirm that grey seal is present throughout the Hornsea Three array area and offshore cable corridor, with at-sea usage highest in the southwest near to the Donna Nook haul-out site and The Wash (Figure 4.7). The average density for the former Hornsea Zone plus 10 km buffer estimated from the SMRU at-sea data was 1.470 animals km^{-2} compared with 0.04 animals km^{-2} estimated using boat-based data from surveys across the former Hornsea Zone plus 10 km buffer.

4.7.2.24 Female grey seal store fat reserves prior to lactation (capital breeders), to allow reduced foraging during lactation. Grey seal are therefore be particularly vulnerable to disturbance when building up fat reserves and therefore tend to breed in remote locations. The colony at Donna Nook on the Lincolnshire coastline to the north of the Hornsea Three offshore cable corridor is an exception to this (SMRU, 2011).

4.7.2.25 Grey seal can travel up to 2,100 km on foraging trips, though most are within 145 km from haul out sites (SCOS, 2015). SMRU telemetry data show animals crossing the Hornsea Three marine mammal study area (SMRU, 2017) (Figure 4.26 of volume 5, annex 4.1: Marine Mammal Technical Report), and these are considered likely to be foraging animals.

4.7.2.26 Advice from UK SNCBs is that the Hornsea Three impact assessment for grey seal should be carried out against the South East England MU and the North East England MU combined (Figure 4.8), with combined associated abundance estimate. The abundance estimate for these combined MUs is 18,150 animals.

4.7.2.27 An estimate of the local (Greater Wash) breeding population has also been provided based on the grey seal pup counts within the Greater Wash area (SCOS, 2015) (see section 4.5.5 of volume 5, annex 4.1: Marine Mammal Technical Report for methodology). The Greater Wash population estimate has been estimated at 6,586 animals from a pup production estimate of 3,360 (SCOS, 2015). There has been a trend of increasing numbers of grey seal in the East of England of approximate 15% per year (since 2002) which reflects the general trend in the northeast Atlantic of increasing numbers of grey seal (at a rate of 6% per year).

4.7.2.28 Table 4.9 summarises the designated sites within normal foraging range of Hornsea Three which have grey seal listed as a qualifying interest feature (Figure 4.2). Sites designated for grey seal that lie within the normal foraging range of this species from Hornsea Three (SMRU, 2017) have been considered to inform assessment of sensitivity of grey seal as a feature of these sites as well as for the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017).

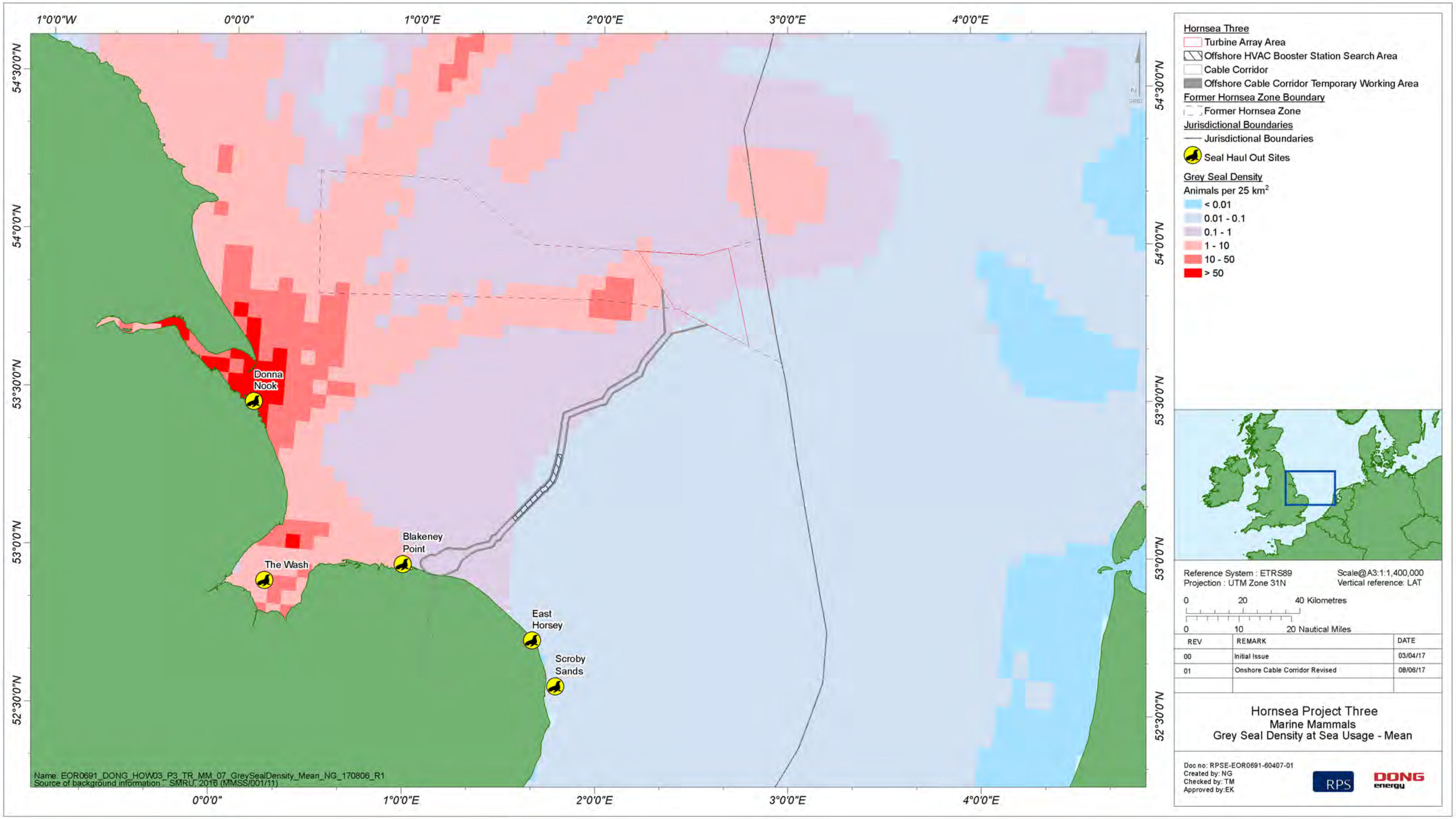

Figure 4.7: Grey seal density At-Sea usage - mean (per 25 km²) for the regional marine mammal study area based on data collected over a 15 year period up to 2015.

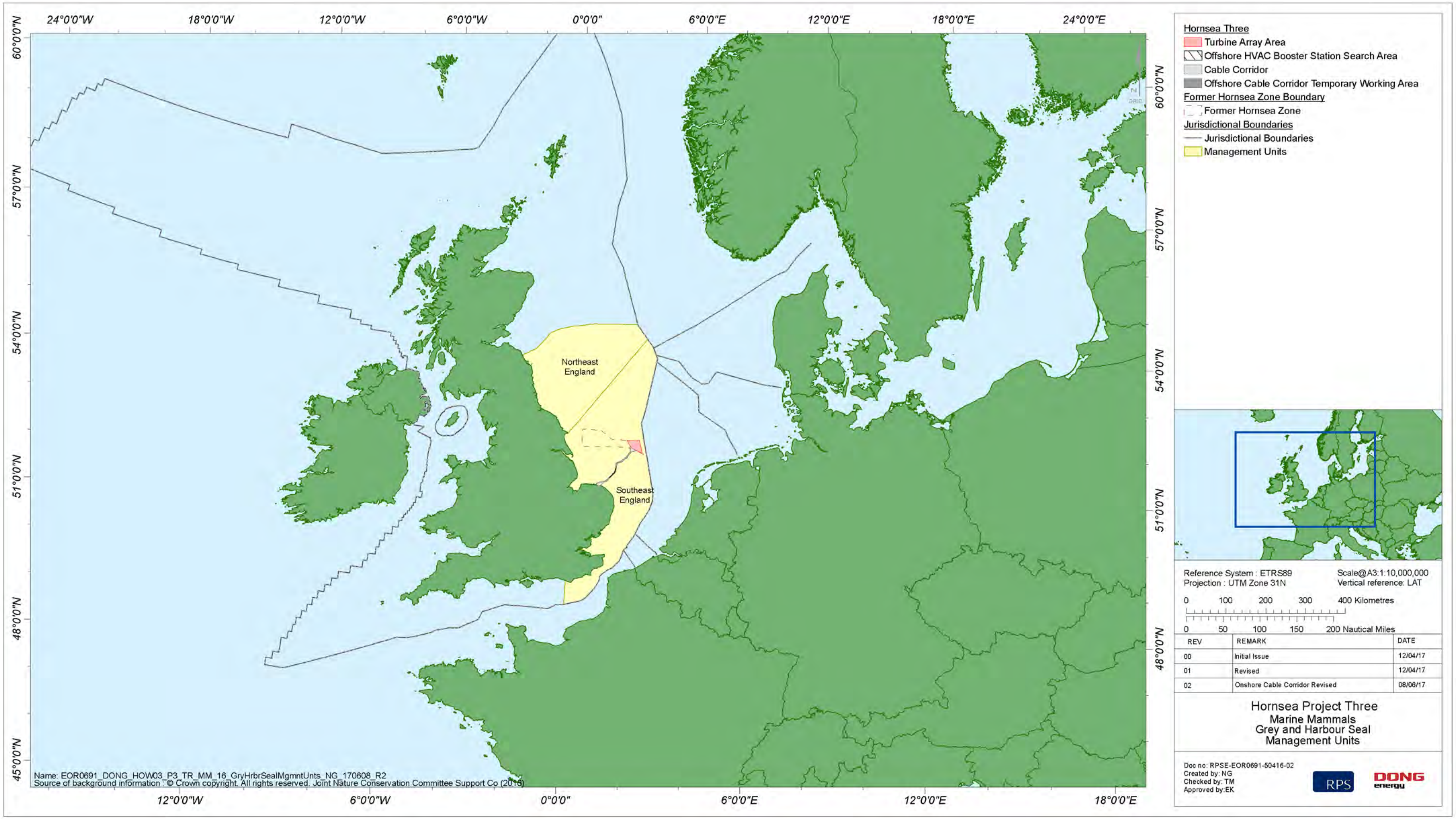

Figure 4.8: Seal MUs.

Table 4.9: Designated sites with grey seal as a notified interest feature within normal foraging range of the Hornsea Three array area and offshore cable corridor.

Site Name	Distance from Hornsea Three array area (km)	Distance from Hornsea Three offshore cable corridor (km)
European sites		
Klaverbank pSCI	11	24
Dogger Bank SCI (Dutch)	42	63
Humber Estuary SAC	145	74
Noordzeekustzone II SCI[a]	138	155
Nationally designated sites		
Humber Estuary	145	74

a Combined with Noordzeekustzone SAC for Draft Report to inform Appropriate Assessment (DONG Energy, 2017)

Harbour seal

4.7.2.29 The majority of the UK population of harbour seal is found in Scottish waters, although the densest concentration of harbour seal haul-out sites is found along the tidal sandbanks and mudflats of The Wash in East Anglia, Blakeney Point, Donna Nook, and Scroby Sands (SMRU, 2004) (Figure 4.31 of volume 5, annex 4.1: Marine Mammal Technical Report) where animals haul-out to breed and moult. The Wash and North Norfolk Coast support the largest colony of harbour seal in the UK (7% of the total UK population). Female harbour seal become sexually mature at three to five years of age and gestation lasts between 10.5 to 11 months (Thompson and Härkönen, 2008). Harbour seal are long-lived animals with individuals estimated to live to between 20 and 30 years (SCOS, 2015).

4.7.2.30 Boat based surveys of the former Hornsea Zone plus 10 km buffer recorded harbour seal throughout the survey area. In total, 147 harbour seal were recorded. This equated to an approximate absolute density within the former Hornsea Zone plus 10 km buffer of 0.039 animals km^{-2} and a relative abundance of 167.2 individuals.

4.7.2.31 Harbour seal at sea usage data provided by SMRU, confirm that harbour seal is present throughout the Hornsea Three array area and offshore cable corridor (Figure 4.9) with usage highest nearest to the main haul-out sites in The Wash. Telemetry data also showed that animals travel throughout the Hornsea Three marine mammal study area, particularly in proximity to the coast. Historical WWT aerial survey data (WWT, 2006) also recorded seal along the coastline to the north and south of The Wash and in the area coinciding with the Hornsea Three array area and the offshore cable corridor (Figure 4.5 of volume 5, annex 4.1: Marine Mammal Technical Report).

4.7.2.32 Using SMRU data, the average modelled surface densities across the former Hornsea zone plus 10 km buffer was calculated at 0.849 animal km^{-2} with a relative abundance of 315.5 animals. The surface density estimates show a clear density gradient across the former Hornsea Zone with the highest harbour seal densities in the southwest (0.28 animals km^{-2}) and the lowest densities in the north and east (0.0 animals km^{-2}) (Figure 4.9).

4.7.2.33 Harbour seal are likely to be most sensitive to disturbance during the breeding period when females are lactating (Lusseau *et al.*, 2012). Harbour seal tend to forage within 40 or 50 km of their haul-out sites however studies in the Greater Wash have found animals travel between 75 and 120 km when foraging (SMRU, 2011).

4.7.2.34 Advice from UK SNCBs is that the assessment of impacts of Hornsea Three on harbour seal should be carried out against the South East England MU (Figure 4.8). The abundance estimate for this MU is 3,567 animals.

4.7.2.35 Table 4.10 summarises the designated sites within normal foraging range of Hornsea Three which have harbour seal listed as a qualifying interest feature (Figure 4.2). Sites designated for harbour seal that lie within the normal foraging range of this species (SMRU, 2011) from Hornsea Three have been considered to inform assessment of sensitivity of harbour seal as a feature of these sites as well as for the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017).

Table 4.10: Designated sites with harbour seal as a notified interest feature within normal foraging range of the Hornsea Three array area and offshore cable corridor.

Site Name	Distance from Hornsea Three array area (km)	Distance from Hornsea Three offshore cable corridor (km)
European site		
The Wash and North Norfolk Coast SAC	9	0
Klaverbank pSCI	11	24
Dogger Bank SCI (Dutch)	42	63
Nationally designated sites		
The Wash SSSI	156	39

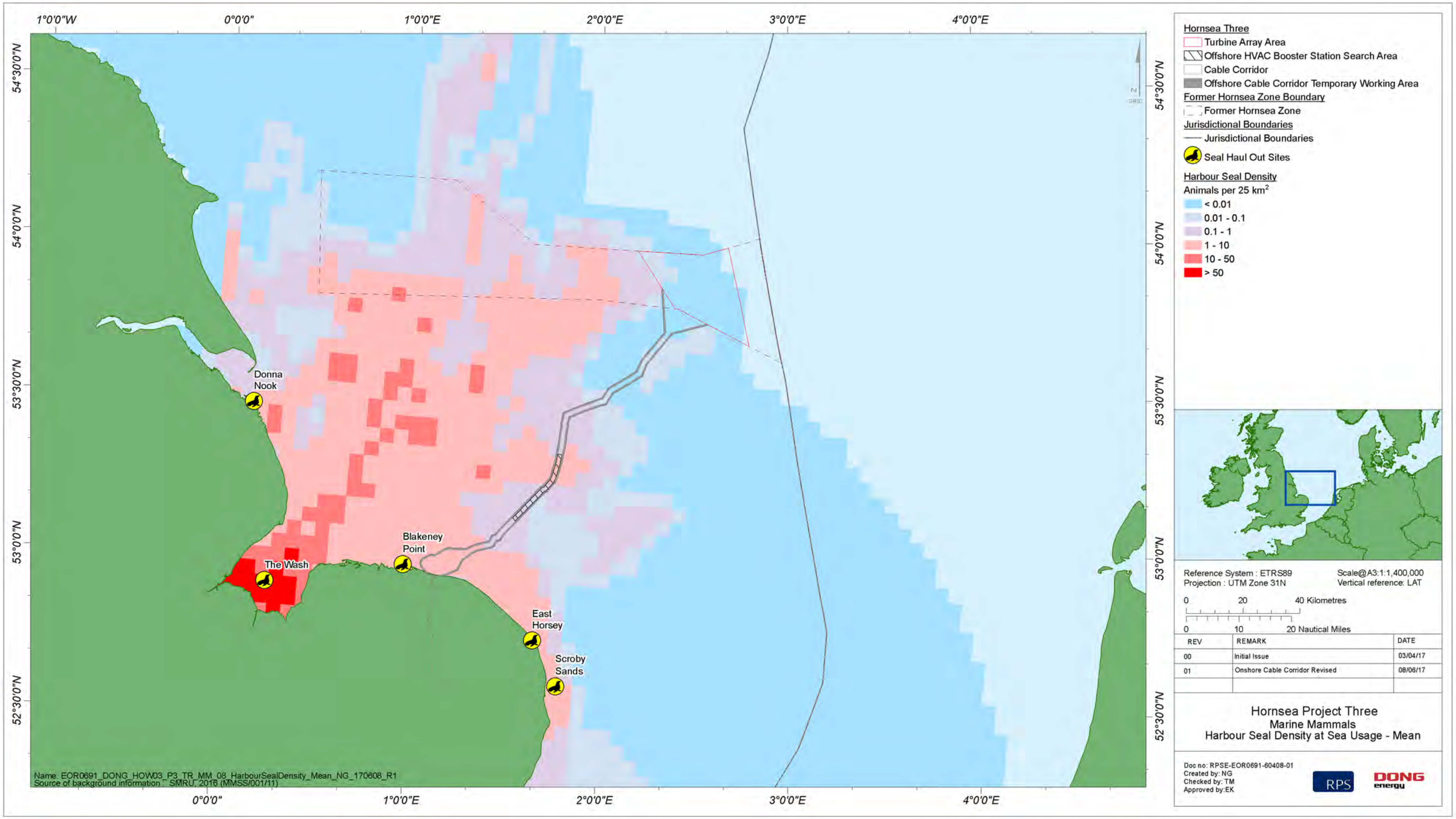

Figure 4.9: Harbour seal density At-Sea usage - mean (per 25 km²) for the regional marine mammal study area based on data collected over a 15 year period up to 2015.

Summary

4.7.2.36 For the purposes of quantifying potential impacts, the following table provides a summary of the mean densities used in the assessment (Table 4.11). The densities used were based on the best available data with consideration given to the most up to date information together with the necessary conservatism applied (i.e. for data collected over similar timeframes the higher value is used). For the subsea noise impact assessment, these densities were used to quantify shorter range effects whilst the modelled surface density estimates were used to quantify far-field effects as the latter captures spatial changes in density for each species and were therefore considered to represent a more accurate assessment of potential effects. Relevant MU reference populations have been agreed with the Marine Mammal EWG.

Table 4.11: Summary of mean density of each of the key species to be used in the impact assessment together with the reference population against which impacts have been assessed.

Species	Average density estimate to be used in impact assessment	Source of density estimate	Relevant MUs for reference population	Abundance of reference population
Harbour porpoise	2.87 individuals km^{-2}	Boat-based acoustic surveys of former Hornsea Zone plus 10 km buffer	North Sea (NS)	227,298
White-beaked dolphin	0.016 individuals km^{-2}	Boat-based visual survey of former Hornsea Zone plus 10 km buffer	Celtic and Greater North Seas (CGNS)	15,895
Minke whale	0.006 individuals km^{2}	Boat-based visual survey of former Hornsea Zone plus 10 km buffer	Celtic and Greater North Seas (CGNS)	23,528
Grey seal	1.47 individuals km^{2}	SMRU at-sea data	South-East England (SEE) and North East England (NEE) combined	18,150
Harbour seal	0.849 individuals km^{2}	SMRU at-sea data	South-East England (SEE)	3,567

4.7.3 Valued Ecological Receptors

4.7.3.1 The value of ecological features is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (IEEM, 2010). The most straightforward context for assessing ecological value is to identify those species and habitats that have a specific biodiversity importance recognised through international or national legislation or through local, regional or national conservation plans. The following table shows the criteria applied to determining the ecological value of valued ecological receptors (VERs) within the geographic frame of reference applicable to the regional marine mammal study area (Table 4.12).

Table 4.12: Criteria used to inform the valuation of ecological receptors in the Hornsea Three marine mammal study area.

Value	Justification
International	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 European designated site i.e. Natura 200 site).
National	Internationally protected species (including EPS) that are not qualifying features of a candidate or designated European Site but are regularly recorded within the regional marine mammal study area, but in relatively low densities and therefore the area is not considered to be important for the species in an international context. Internationally protected species that are not qualifying features of a European 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 regional marine mammal study area.
Regional	Internationally protected species that are not qualifying features of a European designated site and are infrequently recorded within the regional study area in very low numbers compared to other regions of the British Isles.
Local	There are no criteria given for local due to the high level of protection under international law for all marine mammal species which makes this category irrelevant.

4.7.3.2 Based on information provided in the baseline presented in volume 5, annex 4.1: Marine Mammal Technical Report, the five species presented in section 4.7.2 are considered to be VERs. The valuation is based on their protected status and their abundance and distribution within the Hornsea Three regional marine mammal study area, as well as their wider distribution and abundance within their natural range.

Table 4.13: Marine mammal VERs and their importance within the Hornsea Three marine mammal study area.

Receptor	Value	Justification
Harbour porpoise	International	High densities of harbour porpoise were recorded within the Hornsea Three marine mammal study area relative to the regional marine mammal study area and wider distribution and abundance in their natural range. There are links to European sites in the central and southern North Sea for which this species is a qualifying interest feature.
White-beaked dolphin	National	The Hornsea Three marine mammal study area is likely to be used by this species mainly during the winter months and it is likely that this area is at the southern limit of its distribution in the UK. Highest densities were in the northwest corner of the former Hornsea Zone.
Minke whale	International	The south central North Sea is important for minke whale and the densities in the Hornsea Three marine mammal study area are comparable with densities from the regional marine mammal study area. Minke whale were recorded throughout the Hornsea Three marine mammal study area between spring and autumn each year. Minke were absent from the area over the winter months, with highest densities in the northwest of the former Hornsea Zone.
Grey seal	International	Grey seal occurs throughout the Hornsea Three marine mammal study area and are present in high densities along the southern boundary and towards their haul-outs to the south and west. High densities occurred to the west of the former Hornsea Zone. There are links with SACs in the central and southern North Sea, with the largest haul-out along the Lincolnshire and Norfolk Coast at Donna Nook, within the Humber Estuary SAC.
Harbour seal	International	Harbour seal occurs throughout the Hornsea Three marine mammal study area and are present in high densities towards the south and west of the former Hornsea Zone. There are links with SACs in the central and southern North Sea, with the largest haul-out along the Lincolnshire and Norfolk Coast being The Wash located in The Wash and North Norfolk Coast SAC.

4.7.4 Future baseline scenario

4.7.4.1 Marine mammal populations naturally fluctuate over space and time and therefore changes are likely to occur over the 25 year lifetime of Hornsea Three. Their distribution is, to a large extent, mediated by the distribution and abundance of prey species. Many species range over large distances and, to a certain extent, can adapt to gradual changes in the environment, such as those that may occur as a result of climate change (Hoegh-Guldberg and Bruno, 2010). This is not the case for all species. Those that have more restricted habitat ranges are likely to be more vulnerable to changes in their environment. For the marine mammal VERs in the Hornsea Three regional marine mammal study area, species such as grey and harbour seal may be sensitive to long term changes, particularly harbour seal, whose natural foraging range is more restricted than that of grey seal.

4.7.4.2 The impact of anthropogenic-induced climate change has so far been recorded as decreased productivity of the oceans, altered food-web dynamics, reduced abundance of habitat-forming species, shifting species distributions and a greater incidence of disease (Hoegh-Guldberg and Bruno, 2010). The North Sea has seen one of the largest increases in sea surface temperature across the northeast Atlantic over the last 25 years, with a rate of increase of 0.6 and 0.8^{o}C per decade (Evans *et al.*, 2010). Species for which there is clear temperature partitioning, such as the white-beaked dolphin (Canning *et al.*, 2008), may be particularly vulnerable to such increases in temperature, and such increase could lead to a shift in their distribution.

4.7.4.3 Anthropogenic activities in the marine environment can influence the distribution and abundance of marine mammal populations. In the North Sea, potential impacts include: probable mortality due to bycatch from fisheries (particularly for harbour porpoise); direct or indirect effects of contamination (from pollution incidents, sewage discharge, or litter disposal at sea); injury or disturbance from introduced noise into the marine environment (e.g. from shipping, drilling, piling, seismic surveys, military activity, dredging and disposal, aggregate extraction, UXO detonations, and ADDs); death or injury due to collision with physical objects (vessels or renewable energy devices, particularly tidal devices); removal of prey species by overfishing.

4.7.4.4 SCANS abundance data for the North Sea suggests that the population of harbour porpoise is stable or increasing with the most recent 2016 estimate for SCANS-III given as 345,000 animals (CV=0.18) (Hammond *et al*., 2017). This is comparable to the 2005 estimate for SCANS-II of 355,000 (CV=0.22) (revised from Hammond *et al.,* 2013) and the 1993 estimate for SCANS of 289,000 (CV=0.14) (revised from Hammond *et al.* 2002). Similar results were seen for white-beaked dolphin across all surveyed areas (European Atlantic waters) with the SCANS-III, SCANS-II and SCANS estimates given as 36,300 (CV=0.29), 37,700 (CV=0.36) and 22,600 (CV=0.23) respectively (Hammond *et al.* 2017; revised from Hammond *et al.* 2013; revised from Hammond *et al*. 2002).

4.7.4.5 The results of the SCANS-II surveys suggested that for minke whale, the distribution in the North Sea had shifted to the south (Hammond *et al*., 2013). For SCANS-III a similar distribution was observed for minke whale in 2016. Not all data has been analysed for the European Atlantic survey area and therefore a direct comparison is not possible, however, the SCANS-III estimate for the North Sea of 8,900 (CV=0.24) was within the range of previous estimates for SCANS and SCANS-II and trend analysis provides little evidence for changes in numbers of minke whale since 1989 (Hammond *et al*., 2017).

4.7.4.6 Grey seal populations in the North Sea have increased annually up to the most recent survey in 2014. Between 2010 and 2014 there was a ~10% increase per annum due to the rapid expansion of newer colonies along the mainland coasts of Berwickshire, Lincolnshire, Norfolk and Suffock coastlines (SCOS, 2016). A general trend of increased pup production is also seen for the east coast colonies at the Farne Islands, Donna Nook, Blakeney and Horsey, albeit at a lower rate than the mainland coasts. The largest increase (55%) was for the number of pups born at Blakeney Point, and as a consequence this has overtaken the Farne Islands and Donna Nook as the biggest grey seal breeding colony in England (SCOS, 2016).

4.7.4.7 The most recent August haul-out counts of harbour seal in the period 2008-2015 shows a gradual increasing trend in numbers since the 1996-1997 counts for the southeast England colonies (SCOS, 2016). Aerial surveys carried out during the August moult along the Lincolnshire and Norfolk coastlines (between Donna Nook and Scroby Sands) by SMRU found that the numbers of harbour seal had increased in 2015 from the previous year. Overall, the population for southeast England has recovered to its pre-2002 phocine distemper virus (PDV) levels although the rate of recovery is slower than seen elsewhere (e.g. the Wadden Sea).

4.7.4.8 Against the backdrop of anthropogenic activities that may be associated with adverse effects on marine mammals, on the whole, the scientific evidence suggests that populations in the regional marine mammal study area appear to be stable or increasing for the marine mammal VERs. It is possible that there will be subtle shifts in distribution in relation to the ongoing effects of climate change, however, based on current population trends, these are likely to be difficult to detect across the regional marine mammal study area.

4.7.5 Data limitations

4.7.5.1 Marine mammals are mobile species and exhibit varying spatial and temporal patterns. All field surveys (Table 4.6) were undertaken on a monthly basis to capture some of the variation in marine mammals across the Hornsea Three marine mammal study area over time. It should be noted, however, that the data collected during these boat based and aerial surveys represent snapshots of the marine mammals at the time of sampling and that abundance and distribution of marine mammal species is likely to vary both seasonally and annually.

4.7.5.2 A detailed review of the assumptions and limitations of the boat based and aerial surveys is provided in volume 5, annex 4.1: Marine Mammal Technical Report, and include the following areas:

- Survey design;
- Survey restrictions;
- Species identification;
- Data measurement and recording; and
- Bias and uncertainty in g(0) estimation.

4.7.5.3 As discussed in section 4.5, the approach to data collection, including the use of field survey data from across the former Hornsea Zone (gathered for Hornsea Project One and Hornsea Project Two), and specific to Hornsea Three, was agreed during consultation with the regulators and the statutory and non-statutory advisors.

4.7.5.4 In order to control for data limitations, the field survey data have been discussed in the context of literature reviewed for the wider southern North Sea (the regional marine mammal study area), which provides a broader picture of marine mammals occurrence to ensure a robust characterisation for the purposes of the EIA.

4.8 Key parameters for assessment

4.8.1 Maximum design scenario

4.8.1.1 The maximum design scenarios identified in Table 4.14 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in the project description (volume 1, chapter 3: Project Description). Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the Design Envelope (e.g. different turbine layout), to that assessed here be taken forward in the final design scheme.

4.8.2 Impacts scoped out of the assessment

4.8.2.1 On the basis of the baseline environment and the project description outlined in volume 1, chapter 3: Project Description, the impact of entanglement from mooring lines has been scoped out of the assessment for marine mammals (Table 4.15).

Table 4.14: Maximum design scenario considered for the assessment of potential impacts on marine mammals.

<table>
<tr><th>Potential impact</th><th>Maximum design scenario</th><th>Justification</th></tr>
<tr><td colspan="3">Construction phase</td></tr>
<tr><td>Underwater noise from foundation piling and other construction activities (e.g. drilling of piles) within the Hornsea Three array area has the potential to cause injury or disturbance to marine mammals.</td><td><u>Maximum design spatial: monopile foundations with concurrent piling</u>
<u>Up to 361 monopiles (342 turbine foundations and 19 foundations for other infrastructure and platform foundations)</u>
• Piling of up to 342 monopile foundations of 7 m diameter;
• Piling of up to 19 monopile foundations, 15 m diameter, for substations and platforms including:
o Three offshore accommodation platforms;
o Twelve offshore HVAC collector substations; and
o Four offshore HVAC booster stations located within the Hornsea Three offshore cable route corridor (HVAC transmission option only).
• Absolute maximum hammer energy of up to 5,000 kJ, although typically the maximum hammer energy will be considerably less than this and the absolute maximum hammer energy (i.e. up to 5,000 kJ) would not be required at all locations;
• Maximum four hours piling duration per monopile (including 30 minute soft start) within a 24 hour period;
• Maximum total duration of actual piling is 1,444 hours (four x 361);
• Piling within Hornsea Three array area could occur as a single piling scenario or a two concurrent piling scenario (at opposite ends of the site) although the maximum design <u>spatial</u> scenario is for <u>concurrent piling.</u> Concurrent piling will occur only for infrastructure located within the Hornsea Three array area and not for infrastructure located within the offshore HVAC booster station search area in which only a single vessel scenario is possible;
• Assumed that one monopile could be installed in each 24 hours period for single piling or up to two monopiles installed for concurrent piling, plus a 20% contingency allowance.
• Therefore, <u>maximum design spatial scenario</u> (concurrent piling scenario for infrastructure located within the Hornsea Three array area and single piling scenario for infrastructure located within the offshore HVAC booster station search area) is 219 days which consists of:
o Hornsea Three array area: 214.2 days = (178.5 days piling for 342 turbines + three accommodation platforms + 12 offshore HVAC collector substations) * 20% contingency; and
o Hornsea Three offshore cable corridor: 4.8 days = (four days piling for four offshore HVAC booster stations) * 20% contingency.
• Foundation installation could occur over 2.5 years in up to two phases (i.e. of ~1.25 years each phase) with a gap of up to six years between phases. This includes foundation installation for the offshore HVAC booster substations within the Hornsea Three offshore cable corridor which is expected to occur within an eight month piling phase.</td><td>The maximum design spatial design scenario equates to the greatest <u>area</u> of effect from subsea noise at any one time during piling. The subsea noise Inspire 'lite' modelling showed that the greatest area of effect was for 5,000 kJ hammer and a 7 m diameter pile. The area of ensonification for a 15 m diameter pile was, in fact, smaller than for a 7 m diameter pile (due to the higher frequency components of the smaller pile leading to greater propagation; see section 5.1.1.2 in volume 4, annex 3.1: Subsea Noise Technical Report) and therefore the maximum design scenario presented here captures all pile diameters within the project description up to and including the largest 15 m diameter pile.
The HVAC transmission option results in the maximum design scenario spatially as the offshore HVAC booster stations are located in the offshore cable corridor and therefore, spatially, are closer to sensitive areas for SAC species (harbour porpoise, harbour seal and grey seal).
Two vessels piling concurrently at maximum spacing would result in the largest area of impact at any one time although there is only a single piling vessel scenario for installation of the HVAC booster station foundations.
Locations were selected for each species separately that would result in noise effects over the areas of highest density to ensure a precautionary approach was adopted.
Locations modelled for each species to reflect a maximum design scenario in terms of highest numbers potentially affected.</td></tr>
</table>

Potential impact	Maximum design scenario	Justification
	Maximum design temporal: jacket foundations with single piling Up to 2,016 pin piles (1,368 for turbine foundations and 648 for other infrastructure and platform foundations) • Piling of up to 342 jacket foundations (four piles per foundation, each pin pile 4 m diameter), with up to 1,368 piles (342 x 4) in total; • Piling of up to 19 jacket foundations, up to 4 m diameter, for substations and platforms including: o Three offshore accommodation platforms (six legs with four piles per leg), with up to 72 piles (three x 24) in total; o Twelve offshore HVAC collector substations (six legs with four piles per leg), with up to 288 piles (12 x 24) in total; and o Four offshore HVDC converter substations located in the Hornsea Three array area (72 piles per foundation) with up to 288 piles (four x 72) in total (HVDC transmission option only). • Maximum hammer energy of up to 2,500 kJ, although typically the maximum hammer energy will be considerably less than this, with only a proportion of the piles requiring the maximum hammer energy (i.e. up to 2,500 kJ); • Maximum four hours piling duration per pile (including 30 minute soft start); • Maximum total piling duration 8,064 hours of piling (four x 2,016); • Piling could occur as single vessel scenario or two concurrent vessels (at opposite ends of the site) although maximum design temporal scenario is for single piling; • Assumed that four pin piles could be installed in each 24 hour period for single piling, or up to eight pin piles installed for concurrent piling, plus a 20% contingency; • Therefore maximum design temporal scenario (single piling scenario for infrastructure located within the Hornsea Three array area only) is 604.8 days comprising: o 342 days piling for turbines (1,368 pin piles) o 18 days piling for accommodation platforms (72 pin piles) o 72 days for offshore HVAC collector substations (288 pin piles) o 72 days for + for offshore HVDC converter substations (288 pin piles) o Total = 504 days x 20% contingency. • Foundation installation could occur over 2.5 years in up to two phases (i.e. of ~1.25 years each phase) with a gap of up to six years between phases.	The maximum design **temporal** scenario represents the longest duration of effects from subsea noise. This scenario assumes piled foundations again but this time for jackets as this could result in a longer duration of piling per foundation compared with monopiles. The HVDC transmission option results in the maximum design scenario temporally as the offshore HVDC converter substations (HVDC transmission option) requires a greater number of pin piles compared to the offshore HVAC booster stations (HVAC transmission option) and therefore would lead to a longer duration of piling. Scenario assumes longest duration of piling per pile (4 hours) and number of days piling is estimated assuming four pile jacket foundation installed per day, although realistically there is potential to install up to eight piles in one day. Single vessel piling is assumed as this would prolong the total number of days on which piling could occur within the 2.5 year piling phase (although noting that the piling phase itself has not actually increased under this scenario). Locations were selected for each species separately that would result in noise effects over the areas of highest density to ensure a precautionary approach was adopted. Locations modelled for each species to reflect a maximum design scenario in terms of highest numbers potentially affected.
Increased vessel traffic during construction may result in an increase in disturbance to or collision risk with marine mammals.	Total of 11,776 vessel movements throughout the Hornsea Three array area and offshore cable corridor during a two phase construction scenario over a total offshore construction period of 11 years, with a gap of up to six years between the same activity in each construction phase), comprising: • Up to 4,446 vessel movements over construction period based on gravity base foundations (self-installing concept); • Up to 3,420 vessel movements over construction period for turbine installation; • Up to 304 vessel movements over construction period for substations; • Up to 2,856 vessel movements over construction period for array cables; and • Up to 750 vessel movements over construction period for the export cable. A range of vessels (engine sizes and speeds) will be used during the construction phase, specified within the project description (volume 1, chapter 3) include: self-propelled jack up vessels, jack up barges pulled by tugs, sheerleg barges, heavy lift vessels (HLV), dredging vessels, drilling vessels, crew transfer vessels, guard boats and cable installation vessels.	Maximum design scenario considers a wide range of vessel types likely to result in different noise signatures within the marine environment which may affect each identified marine mammal receptor differently (depending on their hearing sensitivity). The number of vessel movements was summed for each potential foundation type and gravity bases was found to have the greatest number of return vessel trips over the construction phase, although noting that the range of vessels required will be different for each foundation type. The maximum design scenario assumes that, for each of the different construction events listed, a summed total of the highest number of vessel movements is achieved. The summed total of the highest number of vessel movement during each construction event is considered to be the maximum design scenario for collision risk, although noting that some vessels, such as fast moving vessels, may pose a greater risk to marine mammals in terms of collision.

Potential impact	Maximum design scenario	Justification
Increased suspended sediments arising from construction activities, such as cable and foundation installation, may reduce water clarity and impair the foraging ability of marine mammals.	**<u>Drilling operations for foundation installation: greatest sediment disturbance from a single foundation location</u>** Total sediment volume of 581,611 m³ (113,104 + 253,338 + 193,962 + 21,207), comprising: • 113,097 m³ (160 x 10% x 7,069 m³) of spoil as a result of the largest turbine monopile foundations (up to 160 monopiles with an associated diameter of up to 15 m drilled to a penetration depth of up to 40 m) and up to 10% of foundations drilled, with a spoil volume of up to 7,069 m³ per foundation (160 x 10% x 7,069 m³ = 113,104 m³; • 253,338 m³ (12 x 21,112 m³) of spoil as a result of up to 12 offshore HVAC collector substations with piled jacket foundations (up to 24 piles per foundation (six legs, four piles per leg), up to 4 m diameter per pile, drilled to a penetration depth of up to 70 m and a spoil volume of up to 21,112 m³ per foundation) and up to 100% of foundations may be drilled (12 x 21,112 m³ = 253,338 m³); • 193,962 m³ (four x 48,490 m³) of spoil as a result of up to four offshore HVDC converter substations with piled jacket foundations (up to 72 piles per foundation (18 legs, four piles per leg), up to 3.5 m diameter per pile, drilled to a penetration depth of up to 70 m and a spoil volume of up to 48,490 m³ per foundation) and up to 100% of foundations may be drilled (four x 48,490 m³ = 193,962 m³); • Up to 21,207 m³ (three x 7,069 m³) of spoil as a result of up to three offshore accommodation platforms with monopile foundations (up to three monopiles with an associated diameter of up to 15 m, drilled to a penetration depth of up to 40 m and a spoil volume of up to 7,069 m³ per foundation) and up to 100% of foundations may be drilled (three x 7,069 m³ = 21,207 m³); • Up to two foundations may be simultaneously drilled with a minimum spacing of 1,000 m; • Disposal of drill arisings at water surface; and • Construction phase lasting up to 11 years over two phases, with a gap of up to six years between the same activity between phases	Drilling of individual turbine monopile foundations results in the release of relatively larger volumes of relatively fine sediment, at relatively lower rates (e.g. potentially leading to suspended sediment concentrations (SSC) effects over a wider area or longer duration), than similar potential impacts for bed preparation via dredging for individual gravity base foundations (which are separately assessed). The greatest volume of sediment disturbance by drilling, for both individual foundations and for the array as a whole, is associated with the largest diameter monopile and piled jacket foundations for substations in the array area. The volume of sediment released through drilling of other turbine and offshore accommodation platform foundation types (e.g. piled jackets) is smaller than for monopiles. The HVDC transmission system option (up to12 offshore HVAC collector substations and up to four offshore HVDC converter substations) results in the largest number of offshore substation foundations and the largest total volume of associated sediment disturbance in the array area compared to the HVAC transmission system option.
	<u>Dredging for seabed preparation for foundation installation: greatest sediment disturbance from a single foundation location</u> Total sediment volume of 1,827,287 m³ (935,200 + 735,000 + 139,552 + 17,535), comprising • 935,000 m³ total spoil volume per foundation based on the largest turbine gravity base foundation (up to 160 gravity base foundations), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m, spoil volume per foundation 5,845 m³ (160 x 5,845 = 935,000 m³); • 735,000 m³ total spoil volume per foundation for the largest offshore HVAC collector substation gravity base foundation (up to 12 gravity base foundations), associated base dimensions 75 m, associated bed preparation area dimensions 175 m, average depth 2 m, spoil volume per foundation 61,250 m³ (12 x 61,250 m³ = 735,000 m³); • 139,552 m³ total spoil volume per foundation for the largest offshore HVDC converter substation gravity base foundation (up to four gravity base foundations), associated base dimensions 90 x 170 m, associated bed preparation area dimensions 98 x 178 m, average depth 2 m, spoil volume per foundation 34,888 m³ (four x 34,888 m³ = 139,552 m³); • 17,535 m³ total spoil volume per foundation for the largest offshore accommodation platform gravity base foundation (up to three gravity base foundations), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m, spoil volume per foundation 5,845 m³ (three x 5,845 m³ = 17,535 m³); • Disposal of material on the seabed within Hornsea Three; • Dredging carried out using a representative trailer suction hopper dredger (11,000 m³ hopper capacity with split bottom for spoil disposal). Up to two dredgers to be working simultaneously and a minimum spacing of 1,000 m.; and Construction phase lasting up to 11 years over two phases, with a gap of up to six years between the same activity between phases.	Dredging as part of seabed preparation for individual gravity base foundation foundations results in the release of relatively smaller overall volumes of relatively coarser sediment, at relatively higher rates (e.g. leading to higher concentrations over a more restricted area), than similar potential impacts for drilling of individual monopile or piled jacket foundations (which are separately assessed above). The greatest sediment disturbance from a single gravity base foundation location is associated with the largest diameter or dimension gravity base foundation, which results in the greatest volume of spoil from a single foundation. Due to differences in both scale and number, gravity base foundations for turbines, electrical substations and offshore accommodation platforms are separately considered. The HVDC transmission system option (up to12 offshore HVAC collector substations and up to four offshore HVDC converter substations) results in the largest number of offshore substation foundations and the largest total volume of associated sediment disturbance in the array area compared to the HVAC transmission system option. Note: this assessment considers effects on benthic ecology from a passive plume (i.e. sediments transported via tidal currents) during dredging and disposal operations for foundation installation. Placements of coarse dredged materials during dredge disposal are considered in temporary habitat loss

Potential impact	Maximum design scenario	Justification
	Cable installation Total sediment volume of 13,026,381 m^3 (5,100,000 + 168,325 + 1,350,000 + 6,226,000 + 182,056), comprising: Array cables • Installation method: mass flow excavator; • Total length 850 km; • 5,100,000 m^3 total spoil volume from installation of up to 850 km cables in a V-shape trench of width = 6 m and depth =2 m (850 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 5,100,000 m^3); and • 168,325 m^3 total spoil volume from sand wave clearance by dredging or mass flow excavation within the Hornsea Three array area (based on the Hornsea Three array area geophysical survey data combined with cable installation design specifications). Substation interconnector cables • Installation method: mass flow excavator; • 15 in-project cables, total length 225 km; and • 1,350,000 m^3 total spoil volume from installation of up to 225 km cables in a V-shape trench of width = 6 m and depth =2 m (225 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 1,350,000 m^3). Export cables • Up to six cable trenches; each 173 km in length (1,038 km in total); • Installation method: mass flow excavator; • 6,226,000 m^3 total spoil volume from installation of up to 225 km cables in a V-shape trench of width = 6 m and depth =2 m (six x 173 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 6,226,000 m^3); and • 182,056 m^3 total spoil volume from sandwave clearance via either a dredger or mass flow excavator within the Hornsea Three offshore cable corridor (based on the Hornsea Three offshore cable corridor geophysical survey data combined with cable installation design specifications). • Offshore construction phase lasting up to 11 years over two phases with a gap of up to six years between the same activity between phases..	Cable installation may involve ploughing, trenching, jetting, rock-cutting, surface laying with post lay burial, and/or surface laying installation techniques. Of these, mass flow excavation will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to be the maximum design scenario for sediment dispersion. The volume of material to be cleared from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data, the bedforms requiring clearance are likely to be in the range 1 to 2 height in the array or 1 to 6 m in height in the offshore cable corridor. Sandwave clearance may involve dredging or mass flow excavation tools. Of these, mass flow excavation will most energetically disturb sediment in the clearance profile and as such is considered to be the maximum design scenario for sediment dispersion causing elevated SSC over more than a very short period of time. Dredging will result in a potentially greater instantaneous local effect in terms of SSC and potentially a greater local thickness of sediment deposition, but likely of a shorter duration and smaller extent, respectively. Note: this assessment considers effects on benthic ecology from a passive plume (i.e. sediments transported via tidal currents) during dredging and disposal operations. Placements of coarse dredged materials during dredge disposal are considered in temporary habitat loss.
Accidental pollution released during construction (including construction activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals.	Accidental pollution from synthetic compound, heavy metal and hydrocarbon contamination resulting from offshore infrastructure installation particularly associated with construction vessels (maximum of 11,566 round trips to ports over the construction period): • 4,446 vessel movements over the construction period based on gravity base foundations (self-installing concept); • Up to 3,420 vessel movements over construction period for WTG installation; • Up to 304 vessel movements over construction period for substations; • Up to 2,856 vessel movements over construction period for array cables; and • Up to 540 vessel movements over construction period for the export cable. Water-based drilling muds associated with drilling to install foundations, should this be required. A typical accommodation platform is likely to contain up to 10,000 l of coolant, up to 10,000 l of hydraulic oil and up to 3,500 kg of lubricates. Offshore fuel storage tanks: • One tank on each of the up to three accommodation platforms for helicopter fuel and with a total capacity of up to 255,000 l across all accommodation platforms; and • One on each of the up to three offshore accommodation platforms for crew transfer vessel fuel and each with a capacity of 210,000.	These parameters are considered to represent the likely maximum design scenario with regards to vessel movements during construction and the offshore storage of fuel.

Potential impact	Maximum design scenario	Justification
Changes in the fish and shellfish community resulting from impacts during construction may lead to loss of prey resources for marine mammals.	Changes in the fish and shellfish community based on maximum design scenarios presented in chapter 3: Fish and Shellfish, for the following impacts: • Subsea noise from piling over a 2.5 year piling phase; • Total subtidal temporary habitat loss of 23,888,423 m^2 due to seabed preparation for gravity base foundations, sandwave clearance, and trenching for cable installation in up to three phases over an offshore construction window of up to 11 years; • Increased sediment deposition arising from installation of foundations for 342 turbines, dredging for seabed preparation and cable installation over a 11 year construction window; and • Potential for contamination arising from installation works and construction vessels could over a two phase construction scenario, with a gap of up to six years between activities.	This represents the maximum design scenarios for fish and shellfish receptors as described in chapter 3: Fish and Shellfish Ecology, and therefore the maximum design scenario for effects on marine mammal prey species.
Operation phase		
Noise and vibration arising from operational turbines may cause disturbance to marine mammals.	Subsea noise and vibration arising from the operation of up to 342 turbines over a project lifetime of 25 years.	The maximum design scenario is based on the maximum number of turbines over the maximum lifetime of the project rather than size of turbine since the potential effects are expected to be localised regardless of the power output (Madsen *et al*., 2006, Nedwell *et al*., 2007).
Increased vessel traffic during operation and maintenance may result in an increase in disturbance to marine mammals.	Total return vessel movements per year during operation = 2,832. Vessel activity throughout the Hornsea Three array area and offshore cable corridor comprising: • Jack up wind turbine visits: up to 82 visits per year over project lifetime; • Jack up platform visits: up to five visits per year over project lifetime; • Crew vessel visits: up to 2,433 per year over project lifetime; and • Supply vessel accommodation platform visits: up to 312 per year over project lifetime.	The maximum design scenario represents the maximum number of vessels and range of vessels likely to lead to disturbance.
Electromagnetic Fields (EMF) emitted by -array and export cables may affect marine mammal behaviour.	EMF resulting from a total of 2,113 km of cables: • Up to 850 km of array cable (maximum 170 kV); • Up to 225 km of interconnector cables (maximum 600 kV if HVDC or 400 kV if HVAC transmission); and • Up to 1,038 km (six x 173 km) of export cable (maximum 400 kV if HVAC transmission option and 600 kV if HVDC transmission option). The maximum design scenario is that array cables, export cables and interconnector cables will either be buried to a target minimum burial depth of 1 m or by cable protection subject to a cable burial risk assessment.	HVDC transmission represents the maximum design scenario for magnetic field strengths, though for induced electrical fields it is unclear whether HVAC or HVDC transmission represents the maximum design scenario. Both HVDC and HVAC transmission have therefore been assessed.

Potential impact	Maximum design scenario	Justification
Accidental pollution released during operation and maintenance (including maintenance activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals.	Synthetic compounds (e.g. from antifouling biocides), heavy metal and hydrocarbon contamination resulting from up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations (or up to four offshore HVAC booster substations on the Hornsea Three offshore cable corridor) and up to three accommodation platforms. Accidental pollution may also result from offshore refuelling for crew vessels and helicopters (i.e. up to 2,832 round trips to port by operational and maintenance vessels (including supply/crew vessels and jack-up vessels) and up to 25,234 round trips by helicopter per year over the 25 year design life). A typical turbine is likely to contain approximately 1,300 l of grease, 20,000 l of hydraulic oil and 2,000 l of gear oil, 80,000 l of liquid nitrogen and 7,000 kg of transformer silicon/ester oil, 2,000 l of diesel and 13,000 l of coolant. A typical offshore accommodation platform is likely to contain up to 10,000 l of coolant, up to 10,000 l of hydraulic oil and up to 3,500 kg of lubricates. Offshore fuel storage tanks: • One tank on each of the up to three accommodation platforms for helicopter fuel and with a total capacity of up to 255,000 l across the Hornsea Three array area; and • One on each of the up to three accommodation platforms for crew transfer vessel fuel and each with a capacity of 210,000 l. Potential leachate from zinc or aluminium anodes used to provide cathodic protection to the turbines. Potential contamination in the intertidal resulting from machinery use and vehicle movement.	These parameters are considered to represent the maximum design scenario with regards to maximum number of turbines, vessel movements, and machinery required, and therefore the maximum volumes of potential contaminants carried during operation and maintenance activities
Changes in the fish and shellfish community resulting from impacts during operation and maintenance may lead to loss of prey resources for marine mammals.	Changes in fish and shellfish community over the lifetime (25 years) of the project due to: • Long term loss of 6,392,484 m^2 of benthic habitat (from 342 turbines, anchors, mooring lines, drag anchor scour protection); • Underwater noise from operation of up to 342 turbines and maintenance vessel traffic; • Introduction of 5,046,797 m^2 hard substrates from foundations, scour protection and cable protection; • Maximum EMF as described above; • Reduced fishing pressure within the Hornsea Three array area; and • Accidental release of pollutants from WTGs, substations, accommodation platforms and vessel movements as described above.	This represents the maximum design scenarios for fish and shellfish receptors as described in chapter 3: Fish and Shellfish Ecology, and therefore the maximum design scenario for effects on marine mammal prey species.
Decommissioning phase		
Underwater noise arising from turbine and cable removal within the Hornsea Three array area and the Hornsea Three offshore cable corridor and associated vessels may cause disturbance to marine mammals.	Underwater noise associated with decommissioning: • Removal of 361 foundations: 342 turbines, three offshore accommodation platforms, 12 offshore HVAC collector substations and four offshore HVDC substations /offshore HVAC booster stations; • Removal of 2,113 km of cables (1,038 km of subtidal export cable (i.e. 6 x 173 km cables), 850 km of array cable, and 225 km interconnector cable); and • Up to 11,566 vessel round trips during the decommissioning phase.	Maximum design scenario assumes largest number of foundations, maximum cable length and greatest number of return trips to port during the decommissioning phase. Total number of vessel movements is assumed to be the same as during the construction phase.
Increased vessel traffic during decommissioning activities may result in an increased collision risk to marine mammals.	Increased vessel movements during decommissioning of up to 361 foundations (i.e. up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations and up to three accommodation platforms) and up to 2,113 km of array cables (including substation interconnector cables) and export cables. Estimated to be up to 11,566 vessel round trips during the decommissioning phase.	Maximum vessel traffic movements will be associated with greatest turbine numbers (and associated infrastructure). Total number of vessel movements is assumed to be the same as during the construction phase.
Increased suspended sediments arising from decommissioning activities such as cable and foundation removal may impair the foraging ability of marine mammals.	Increases of SSC associated with the removal of up to 361 foundations (i.e. up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations/offshore HVAC booster stations and up to three accommodation platforms) and up to 2,113 km of cables (1,038 km of subtidal export cable (i.e. six x 173 km cables), 850 km of array cable, and 225 km interconnector cable).	Maximum design scenario as per the construction phase and assumes removal of all foundations and all subtidal and intertidal cables.

Potential impact	Maximum design scenario	Justification
Accidental pollution released during decommissioning (including decommissioning activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals.	Synthetic compound, heavy metal and hydrocarbon contamination resulting from up to 361 foundations (i.e. up to 342 WTGs, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations and up to three accommodation platforms) and up to 2,113 km of cables (1,038 km of subtidal export cable (i.e. six x 173 km cables), 850 km of array cable, and 225 km interconnector cable). Accidental pollution may arise from vessel activity from up to 11,566 round trips to port by vessels over the decommissioning period.	These parameters are considered to represent the likely maximum design scenario with regards to vessel movements during decommissioning and the offshore storage of fuel. Contamination of intertidal habitats could lead to pollution effects within the marine food chain, therefore affecting higher trophic level predators, such as marine mammals.
Changes in the fish and shellfish community resulting from impacts during decommissioning may lead to loss of prey resources for marine mammals.	Changes in the fish and shellfish community associated with all decommissioning activities including: • Temporary habitat loss/disturbance totalling 23,433,040 m²; • Temporary increases in SSC from removal of up to 361 foundations and 2,113 km of cables (1,038 km of subtidal export cable (i.e. six x 173 km cables), 850 km of array cable, and 225 km interconnector cable); • Sediment deposition (as above for suspended sediment); • Subsea noise from decommissioning of up to 361 foundations and 2,113 km of cables; • Loss of hard substrates and structural complexity (1,595,791 m² based on 361 gravity base foundations); • Habitat alteration (due to presence of scour and cable protection left *in situ*) totalling 3,047,670 m²; and • Accidental release of pollutants from decommissioning of up to 361 foundations and from vessels used during the decommissioning phase (up 11,566 round trips).	Maximum design scenario as per decommissioning phase in chapter 3: Fish and Shellfish Ecology.

Table 4.15: Impacts scoped out of the assessment for marine mammals.

Potential impact	Justification
Operation phase	
Entanglement with anchored mooring lines	Entanglement can be defined as the inadvertent capture or restraint of marine animals by strong, flexible materials of anthropogenic origin. Most scientific studies have focussed on entanglement as bycatch; however, in recent work by Benjamins *et al.* (2014) and Harnois *et al.* (2015), the entanglement risk to marine megafauna from offshore renewable developments has been explored. Based on an extensive literature review, it was concluded in Benjamins *et al.* (2014) that moorings such as those proposed for marine renewable energy devices will likely pose a relatively modest risk in terms of entanglement for most marine megafauna, particularly when compared to the risk posed by fisheries. The paper by Harnois *et al.* (2015) presents a semi-quantitative methodology for assessing risk. The key parameters used in the risk assessment were tension characteristics, mooring line swept volume ratio and mooring line curvature with relative risk ranked from 1 (low) to 3 (high). The assessment concluded that moorings with taut configurations are likely to have the lowest relative risk, whilst catenary moorings with chains and ropes or with accessory buoys are likely to present the highest relative risk. Benjamins *et al.* (2014) also concluded that taut systems represented the lowest relative risk. Due to the paucity of data on entanglement risk from moorings it is difficult to provide a quantitative impact assessment, however, the moorings described for Hornsea Three in volume 1, chapter 3: Project Description are catenary moorings that can be either taut or slack (with a 2 m movement range). According to the risk assessment described by Harnois *et al.* (2015) moorings that are taut will present a low risk of entanglement to all marine mammals. The risk increases as the line becomes slacker and therefore the risk may increase to medium for larger marine mammal species.

4.9 Impact assessment criteria

4.9.1.1 The criteria for determining the significance of effects is a two-stage process involving consideration of the magnitude of the impact on a receptor and cross reference with defined sensitivity of that receptor. The outcome of the assessment is to determine the significance of these effects against predetermined criteria. Significance is assessed by correlating the magnitude of the impact and the sensitivity of the receptor. The terms used to define sensitivity and magnitude are based on those used in the Design Manual for Roads and Bridges (DMRB) methodology, which is described in further detail in volume 1, chapter 5: Environmental Impact Assessment Methodology. Specific to the marine mammal EIA the following guidance documents have also been considered:

- Guidelines for Ecological Impact Assessment in Britain and Ireland: Marine and Coastal (IEEM, 2010);
- Offshore Wind Farms. Guidance note for EIA in respect of Food and Environment Protection Act (FEPA) and Coastal Protection Act (CPA) requirements (Cefas *et al*., 2004);
- Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Judd, 2012);
- Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008);
- 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 (JNCC *et al*., 2010a); and
- Statutory Nature Conservation Protocol for Minimising the Risk of Injury to Marine Mammals from Piling Noise (JNCC *et al*., 2010b).

4.9.1.2 In addition, the marine mammal EIA has been informed by the legislative framework as defined by the Offshore Marine Conservation (Natural Habitats, and c.) Regulations 2007 (Offshore Habitats Regulations) (as amended), the Conservation of Habitats and Species Regulations 2010 (Habitats Regulations) (as amended in England and Wales), the Wildlife and Countryside Act 1981 (as amended) and the Marine and Coastal Access Act (MCAA) 2009 (as amended) (UK Government, 2009).

4.9.1.3 The magnitude of the impact on an identified VER was predicted by characterising the impact and the effect on the relevant marine mammal receptors. This was done by defining: a) the spatial extent of impact in relation to the natural range of the species; b) duration of the impact in relation to the lifecycle of the species; c) frequency/timing of the impact in relation to seasonal variation, if known, and critical life stages and d) reversibility of the impact (i.e. whether the impact would lead to a reversible or irreversible change to the baseline conditions).

4.9.1.4 The magnitude was then assigned one of five levels based on the factors set out above. The criteria for defining magnitude in this chapter are outlined in Table 4.16 below.

Table 4.16: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition used in this chapter
Major	Major shift away from baseline (spatial and temporal); potential for impact at the population level in the long term, with potential loss of ecological functionality which would be irreversible.
Moderate	Moderate shift away from baseline (spatial and/or temporal); potential for impact at the population level that would be reversible in the medium to long-term; there may be a medium to long-term effect on ecological processes.
Minor	Minor shift away from baseline (spatial and/or temporal); there may be a short-term effect at the population level or to ecological processes that would be reversible in the short to medium term.
Negligible	Very slight change from baseline conditions (spatial and/or temporal) which will not affect population level or ecological processes in the short term.
No change	No change from baseline conditions (spatial and/or temporal).

4.9.1.5 The sensitivity of marine mammal VERs is defined according to a five point scale which is based on an assessment of the combined vulnerability of the receptor to a given impact and the likely rate of recoverability to pre-impact conditions (CIEEM, 2016). Vulnerability is defined as the susceptibility of a species to disturbance, damage or death, from a specific external factor. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. It is dependent on its ability to recover or reproduce depending on the extent of disturbance/damage incurred.

4.9.1.6 Information on these aspects of sensitivity of the marine mammal VERs to given impacts has been informed by the best available evidence from published studies and evidence from analogous activities such as those associated with other offshore wind farms and oil and gas industries.

4.9.1.7 The criteria for defining sensitivity in this chapter are outlined in Table 4.17 below. Refinements to these criteria (magnitude and/or sensitivity) may be implemented for the Environmental Statement following discussion and agreement with the Marine Mammal EWG.

Table 4.17: Definition of terms relating to the sensitivity of the receptor.

Sensitivity	Definition used in this chapter
Very High	Receptor that has a high vulnerability and a limited capacity to avoid or habituate to an anticipated effect with little or no potential for recovery following cessation of the effect.
High	Receptor that has a high to medium vulnerability and low capacity to avoid or habituate to an anticipated effect, with slow to moderate recovery (>5 years) following cessation of the effect.
Medium	Receptor that has a medium vulnerability and a medium capacity to avoid or habituate to an anticipated effect, with medium recovery (one to five years) following cessation of the effect.
Low (or lower)	Receptor that has a low vulnerability and a high capacity to avoid or habituate to an anticipated effect, with high recovery (<1 years) following cessation of the effect. <1% of the population could be affected.
Negligible	Receptor is generally tolerant of predicted impact and can recover rapidly from the anticipated effect.

4.9.1.8 The significance of the effect upon marine mammal VERs is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The particular method employed for this assessment is presented in Table 4.18. Where a range of significance of effect is presented in Table 4.18, the final assessment for each effect is based upon expert judgement. For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations.

Table 4.18: Matrix used for the assessment of the significance of the effect.

		Magnitude of impact				
Sensitivity of receptor		*No change*	*Negligible*	*Minor*	*Moderate*	*Major*
	Negligible	Negligible	Negligible	Negligible or minor	Negligible or minor	Minor
	Low	Negligible	Negligible or minor	Negligible or minor	Minor	Minor or moderate
	Medium	Negligible	Negligible or minor	Minor	Moderate	Moderate or major
	High	Negligible	Minor	Minor or moderate	Moderate or major	Major or substantial
	Very high	Negligible	Minor	Moderate or major	Major or substantial	Substantial

4.9.1.9 Where Natura 2000 sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the interest features of internationally designated sites as described within paragraph 4.6.2.1 of this chapter (with the assessment on the site itself deferred to the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

4.9.1.10 With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site (e.g. SSSIs which have not been assessed within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017)), only the international site has been taken forward for assessment. This is because potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken). There are no nationally designated sites that do not fall within an internationally designated site within proximity to Hornsea Three.

4.9.1.11 The Draft Report to Inform Appropriate Assessment (DONG Energy, 2017) has been prepared in accordance with Advice Note Ten: Habitats Regulations Assessment Relevant to NSIPs (PINS, 2016) and has been submitted as part of the Application for Development Consent. An assessment of potential impact on MCZs and rMCZs has been undertaken and is presented in volume 5, annex 2.3: Marine Conservation Zone Assessment.

4.10 Measures adopted as part of Hornsea Three

4.10.1.1 As part of the project design process, a number of designed-in measures have been proposed to reduce the potential for impacts on marine mammals (see Table 4.19). This approach has been employed in order to demonstrate commitment to measures by including them in the design of Hornsea Three and have therefore been considered in the assessment presented in section 4.11 below. These measures are considered standard industry practice for this type of development. Assessment of sensitivity, magnitude and therefore significance includes implementation of these measures.

Table 4.19: Designed-in measures adopted as part of Hornsea Three.

Measures adopted as part of Hornsea Three	Justification
A CoCP (construction phase), PEMMP (operation phase) and Decommissioning Plan (decommissioning phase) will be produced and followed (Table 4.2). The CoCP, PEMMP and Decommissioning Plan will cover the construction, operation and maintenance, and decommissioning phases of Hornsea Three respectively and will include a Marine Pollution Contingency Plan (MCMP). This MCMP will outline procedures to protect personnel working and to safeguard the marine environment in the event of an accidental pollution event arising from offshore operations relating to Hornsea Three. The MPCP will also outline mitigation measures should an accidental spill occur, address all potential contaminant releases and include key emergency contact details (e.g. Environment Agency, Natural England and MCA).	Measures will be adopted to ensure that the potential for release of pollutants from construction, operation and maintenance, and decommissioning plant is minimised. In this manner, accidental release of potential contaminants from rigs and supply/service vessels will be strictly controlled, thus providing protection for marine life across all phases of the wind farm development.
Array, export and interconnector cables will typically be buried to a target burial depth of 1 to 2 m, subject to a cable burial risk assessment. Where it is not possible to ensure that cables will remain buried, cable protection will be installed.	While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the effect on those receptors.
During piling operations, soft starts will be used, with lower hammer energies (i.e. approximately 15% of the maximum hammer energy; see Table 4.14) used at the beginning of the piling sequence before increasing energies to the higher levels.	The soft-start will provide an audible cue to allow marine mammals to flee the area before piling at full hammer energy commences. The soft/slow-start will help to mitigate any potential auditory injury.
A MMMP, approved by the MMO in consultation with Natural England will be implemented during construction. The MMMP will use acoustic deterrent devices (ADDs) as the primary mitigation measure prior to soft start to ensure marine mammals are deterred. The details of the MMMP will be agreed with Natural England.	The use of an approved MMMP will mitigate for the risk of physical or permanent auditory injury to marine mammals within a 'mitigation zone'. The mitigation zone was determined based on the potential for instantaneous auditory injury based on the initial hammer strike at 750 kJ (soft-start hammer energy).
Codes of conduct for vessel operators including advice to operators to not deliberately approach marine mammals and to avoid abrupt changes in course or speed should marine mammals approach the vessel to bow-ride, will be issued to all Hornsea Three vessel operators and adhered to at all times.	To minimise the potential for collision risk or potential injury to, marine mammals.

4.11 Assessment of significance

4.11.1 Construction phase

4.11.1.1 The impacts of the offshore construction of Hornsea Three have been assessed on marine mammals. The environmental impacts arising from the construction of Hornsea Three are listed in Table 4.14 above along with the maximum design scenario against which each construction phase impact has been assessed.

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

Underwater noise from foundation piling within the Hornsea Three array area has the potential to cause injury or disturbance to marine mammals

4.11.1.3 Marine mammals use sound for foraging, orientation, communication, navigation, echolocation of prey and predator avoidance, and are therefore potentially susceptible to elevated levels of anthropogenic sound that may impair auditory cues or disrupt normal behaviour (Richardson *et al*., 1995). Various construction activities at Hornsea Three could lead to elevations in subsea noise, however, the focus in this assessment is on the impact of subsea noise arising from piling due to other sources of noise having a low likelihood of detection by marine mammals during piling activity (see volume 4, annex 3.1: Subsea Noise Technical Report). Vessel noise is considered separately in the assessment for the impact of increased vessel traffic during construction (paragraph 4.11.1.118 *et seq.*).

4.11.1.4 This section of the PEIR provides information to inform the assessment of the magnitude and sensitivity of marine mammals to subsea noise arising from piling. However, at this stage of the project, no magnitude or sensitivity evaluation has been given, and therefore no conclusion on the significance of the effect has been made. The reason for this are as follows:

- Hornsea Three are currently undertaking a review of the maximum design scenario for piling, as well as defining a more typical design scenario, by reviewing construction experience at other offshore wind farms. Pending the completion of this review, the Hornsea Three marine mammal noise related assessments will be revisited, including where applicable the subsea noise modelling, and this will enable a more fully developed and accurate impact assessment to be completed.
- There is uncertainty in the application of new noise impact assessment criteria (NMF, 2016) as agreed by the Marine Mammal EWG. Further discussion with the Marine Mammal EWG will therefore be sought prior to finalising application of these criteria for PTS and TTS;
- Refinements to the magnitude and/or sensitivity criteria are currently being considered and may be implemented for the Environmental Statement;
- Refinements to the noise modelling, to include but not limited to consideration of noise propagation at the 2 m depth contour;
- Review of the differences in densities between the various datasets referred to in the PEIR (e.g. SCANS I, II and III, and former Hornsea Zone/Hornsea Three specific datasets); and
- Application of dose response to the noise contours and subsequent recalculations of potential animals that may occur within these.

4.11.1.5 Whilst it is acknowledged that certain elements of the project and assessment methodology will be further refined prior to submission of the Environmental Statement, information to inform the final assessment presented here is considered appropriate to inform ongoing consultation on marine mammals. Hornsea Three will however consult with the Marine Mammal EWG on any changes to the marine mammal noise assessment, as well as incorporate comments received on the PEIR prior to the submission of the Environmental Statement in Quarter 2 of 2018.

4.11.1.6 It should be noted that the noise assessment is based on levels of conservatism adopted throughout, which leads to a very precautionary approach to assessment. In summary, the information presented at PEIR makes the following conservative assumptions:

- For the maximum design spatial scenario, the largest hammer energy is achieved at all locations and for the full duration of piling (other than soft start);
- For the maximum design temporal scenario, piling is assumed to occur for the longest duration for each pile installed, and that a minimum number of piles would be installed per day therefore increasing the number of days on which piling could occur;
- The precautionary thresholds for PTS and TTS from the new NOAA guidelines have been used (NMFS, 2016);
- The precautionary behavioural threshold for harbour porpoise from Lucke *et al.* (2009) have been used;
- The subsea noise modelling itself is based on a suite of precautionary assumptions, as described in paragraph 4.11.1.37;
- The maximum range of effect (as well as the mean ranges) and the mitigation is based on the maximum potential extent;
- The density estimates used to calculate the number of animals affected for PTS and TTS are based on the maximum available values from the range presented in the marine mammal baseline;
- The locations modelled were sited according to the areas where greatest sensitivity could occur (e.g. closest to designated sites for marine mammals or areas of highest density);
- To estimate the number of animals affected using the behavioural noise contours overlaid on the surface density maps, the extrapolation of numbers where there were 'missing' density estimates was undertaken using the 75% upper quartile from the available site-specific densities, rather than the mean;
- The animals are assumed to be displaced over the entire 24 hour period within which piling occurs, with recovery to baseline levels only commencing after this period; and
- The behavioural effects on pinnipeds includes an assumption that effects could occur beyond the range at which TTS/fleeing occurs, although noting that there are no noise criteria currently available to quantify this.

Marine mammals and noise

4.11.1.7 Marine mammals have a highly developed auditory sense and both cetaceans and pinnipeds vocalise underwater to communicate. Odontocete cetaceans (including dolphin species and harbour porpoise) echolocate; producing click trains (rapid series of clicks or buzzing noises) that these species use to locate prey, navigate, and which also may have a communicative role. Passive listening is likely to be important in detecting the presence of predators and other threats. Some species are highly vocal: pelagic dolphin species for example, appear to use whistles as contact calls to coordinate school structure and behaviour. Harbour porpoise appear to click almost continuously in coastal habitats. Underwater vocal activity in other species, including pinnipeds and baleen whales, may predominantly occur at certain times of the year associated with breeding or migration.

4.11.1.8 The range of sounds produced varies between species groups, as does the hearing thresholds of these species. Hearing sensitivity is based on both the frequency range of marine mammals (range over which they hear) and their threshold of hearing (i.e. the level of sound at which these animals perceive noise; see volume 4, annex 3.1: Subsea Noise Technical Report). For example, harbour porpoise is of high sensitivity as these animals hear over a large bandwidth of frequencies and their range of perception starts at a much lower sound pressure level than other species. In order to factor in the sensitivity of species based on their frequency range, different species can be classified into hearing groups (see Table 3.1 in volume 4, annex 3.1: Subsea Noise Technical Report). Of the species encountered in the Hornsea Three marine mammal study area, minke whale is placed in the low frequency (LF) cetaceans group, white-beaked dolphin in the mid-frequency (MF) group, harbour porpoise in the high-frequency (HF) group and harbour and grey seals in the pinnipeds in water group (PW).

4.11.1.9 High levels of underwater sound can potentially have a negative impact on marine mammals ranging from changes in their acoustic communication, displacing them from an area, and in more severe cases causing physical injury or mortality (Richardson *et al*., 1995). The following paragraphs describe the range of effects that could arise from the impact of subsea noise during piling, on marine mammals.

<u>Injury</u>

4.11.1.10 In general, biological damage as a result of sound is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor over a set period. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration, such as an explosion. However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. For example, a continuous source operating at a given sound pressure level has a higher total energy and is therefore more damaging than an intermittent source reaching the same sound pressure level (Southall *et al*., 2007).

4.11.1.11 High levels of noise exposure can cause an instantaneous auditory injury resulting in a Permanent Threshold Shift (PTS) that persists once sound exposure has ceased. In addition, PTS may also result from prolonged exposure at lower levels sufficient to cause a Temporary Threshold Shift (TTS). Although animals are able to recover fully from TTS, particularly as they move away from the sound source, hearing loss may become permanent if hearing does not return to normal after several weeks. Therefore, the distinction between TTS and PTS depends on whether there is complete recovery of the individual's hearing.

4.11.1.12 The relationship between these two thresholds is complex since PTS can either be induced by a single high level noise exposure, or by chronic (longer term) noise exposure at lower levels (Southall *et al*., 2007). The threshold for auditory injury is therefore taken as the levels at which PTS starts to occur, based on the overall noise dose received over time, and is termed the PTS-onset criteria. Given that PTS cannot be ethically or legally induced in animals to determine the threshold, Southall *et al*. (2007) proposed that noise exposure criteria for PTS-onset should be extrapolated from the onset of TTS based on the assumed relationships between the relative levels of noise likely to cause TTS and PTS.

4.11.1.13 As marine mammals rely heavily on their underwater auditory sense, it may be assumed that PTS will affect an individual's long-term fitness and survival. Therefore, following the precautionary approach described above for Southall *et al*. (2007), JNCC (2010) recommend the use of PTS-onset to define permanent auditory injury from underwater noise.

Fleeing response (TTS onset)

4.11.1.14 The onset of TTS is taken as the level at which exposed animals could experience temporary auditory injury. This is precautionary as it assumes that the hearing of all individuals will be affected in the same way. This is unlikely to be the case, as demonstrated by Finneran *et al.* (2005), in a study which looked at the proportion of individual harbour porpoise exposed to different SELs that experienced TTS as a result of the sound exposure. This study revealed that to induce TTS in just 50% of animals, it would be necessary to extrapolate well beyond the range of measured SEL levels and 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. Though this study focused on SEL, the same is likely to hold true for the SPLpeak TTS criteria. The ecological effect of TTS depends not only on the magnitude of the TTS, its duration (depending on the exposure duration), and the recovery time after the exposure ceases, but also on the frequency at which hearing is affected and whether this frequency is important, for example, for echolocation (Kastelein *et al.*, 2013). The most likely response of marine mammals to noise levels that could induce TTS is to flee from the ensonified area (Southall *et al.,* 2007). Subsequently, the onset of TTS is often referred to as the 'fleeing response' threshold and as an animal flees an area its exposure to the noise level decreases and therefore the likelihood of TTS is reduced (paragraph 4.11.1.11).

Behavioural effects

4.11.1.15 Studies of the behavioural responses of marine species to sound, describe a variety of different behavioural reactions. At lower levels, anthropogenic noise may temporarily impair hearing, cause stress or disturbance to behaviour by disrupting communication, echolocation or threat detection. Based on this, JNCC (2010) define disturbance in terms of animals incurring a sustained or chronic disruption of behaviour, or undergoing a significant change from their expected distribution.

4.11.1.16 Whilst it is widely acknowledged that hearing sensitivity of the animal is a key factor (Finneran and Schlundt, 2011; Terhune, 2013 and Nedwell *et al*., 2007b), the context of the exposure is also likely to have an influence on behaviour, in addition to the level of the underlying ambient noise (i.e., the perceived signal-to-noise ratio). Clearly, the frequency characteristics of the source need to be taken into account, as does the type of sound exposure (Southall *et al.,* 2007).

4.11.1.17 For behavioural disturbance of cetaceans to multiple pulse noise (such as piling noise) Southall *et al.* (2007) developed a severity scaling which accounts for the duration of the sound producing activity. Severity scales of 4 to 6 are considered to have potential to affect foraging, reproduction, or survival. Specifically, a severity score of 5 indicates a change in swimming behaviour and modification of vocalisations but not avoidance, and 6 indicates startle responses, aggressive reactions to noise and minor to moderate avoidance.

Marine mammal noise criteria

4.11.1.18 The criteria used to determine potential impact ranges were based on recent guidance from the National Oceanographic Atmospheric Administration (NOAA) (National Marine Service (NMFS), 2016) for auditory injury, and on Southall *et al.,* (2007) and Lucke *et al.* (2009) for behavioural disturbance, and have been discussed and agreed with the Marine Mammal EWG (see Table 4.22).

4.11.1.19 The impact criteria previously used to determine the onset of PTS and fleeing (TTS onset) for offshore wind farm assessments were typically those recommended by Southall *et al.,* (2007). These have subsequently been revised by NOAA to reflect the current state of scientific knowledge regarding the characteristics of sound that have the potential to impact marine mammal hearing sensitivity (NMFS, 2016).

4.11.1.20 The new NOAA guidance proposes new refinements to the frequency weightings of the marine mammal hearing groups in addition to revising the thresholds for the onset of PTS and TTS using the dual metrics of Sound Pressure Level (SPL) and Sound Exposure Level (SEL). The criteria for SEL are estimated from studies of exposure of animals to a single pulse, however, these are also applied to cumulative SEL and therefore may be precautionary in this respect. The criteria applied in the Subsea Noise Technical Report (volume 4, annex 3.1) are summarised in Table 4.20.

Table 4.20: Assessment criteria and thresholds used in marine mammal noise assessment.

Criteria	Species				Source
	Harbour Porpoise	White-beaked dolphin	Minke whale	Pinnipeds	
Auditory Injury (PTS)	Unweighted SPLpeak – 202 dB re. 1μPa.	Unweighted SPL peak – 230 dB re. 1μPa.	Unweighted SPL peak – 219 dB re. 1μPa.	Unweighted SPL peak – 218 dB re. 1μPa.	NMFS
Onset of TTS/fleeing response	Unweighted SPL peak - 196 dB re. 1μPa.	Unweighted SPL peak – 224 dB re. 1μPa.	Unweighted SPL peak – 213 dB re. 1μPa.	Unweighted SPL peak - 212 dB re. 1μPa.	NMFS
Behavioural Effects: likely avoidance	Not available	SEL single pulse – 170 dB re.1μPa²s	SEL single pulse – 152. dB re.1μPa²s	Not available	Southall *et al.*
Behavioural Effects: possible avoidance	Unweighted SEL single pulse – 145 dB re.1μPa²s	Unweighted SEL single pulse – 160 dB re.1μPa²s	Unweighted SEL single pulse – 142. dB re.1μPa²s	Not available	Harbour Porpoise - Lucke *et al*; White-beaked dolphin and Minke whale – Southall *et al.*

4.11.1.21 Behavioural disturbance criteria were based on the received noise levels given in Southall *et al*. (2007) for a minimum severity scaling response score of 5 to 6. Measurements of noise levels that could elicit behavioural responses are presented in Southall *et al.* (2007) as Root Mean Square (RMS) over pulse duration. These were converted to unweighted pulse SELs for the purposes of modelling (see volume 4, annex 3.1: Subsea Noise Technical Report). For LF and MF cetaceans the Southall *et al.* (2007) severity scaling is broken into upper and lower limits which are referred to generically as 'likely avoidance' (severity score 6) and 'possible avoidance' (severity score 5) (Table 4.20).

4.11.1.22 The criteria adopted for harbour porpoise (HF cetacean) was modified slightly to adopt a more precautionary approach. Based on studies of seismic airgun pulses, and supported by field observations of harbour porpoise during the construction of Horns Rev offshore wind farm in Denmark, Lucke *et al*. (2009) suggested that the generic HF cetacean group criteria are not suitable for use with harbour porpoise since disturbance may occur at greater distances from the sound source than for other HF cetaceans. This is further acknowledged by Southall *et al.* (2007). The harbour porpoise disturbance threshold for 'possible avoidance', is therefore based on the more precautionary criteria derived by Lucke *et al.* (2009) (Table 4.20).

4.11.1.23 There are no equivalent criteria for behavioural effects for pinnipeds in Southall *et al*. (2007) and therefore the criterion most commonly used for behavioural disturbance is the same as for onset of TTS/fleeing (Table 4.20). This would be considered to be at the upper end of the behavioural scale as it is assumed that animals subjected to noise levels that elicit TTS/fleeing would be displaced from the affected area. It has therefore not been possible to present results for lower level behavioural effects, such as likely or possible avoidance, for pinnipeds.

Magnitude of impact

4.11.1.24 The primary source of subsea noise during construction is from pile-driving activities for the installation of the foundations within the Hornsea Three array area and offshore HVAC booster station search area along the Hornsea Three offshore cable corridor. For the maximum design scenario it is assumed that pile-driving would be carried out using maximum blow energies of up to 5,000 kJ for monopiles and up to 2,500 kJ for pin-piles (see Table 4.28). However, typically the maximum hammer energy will be considerably less than this for a large proportion of the piling duration and the absolute maximum hammer energy (i.e. up to 5,000 kJ for monopiles and 2,500 kJ for pin-piles) would not be required at all locations. Modelling of these energy levels is therefore considered to be highly precautionary. A soft-start procedure has been included as one of the designed-in measures adopted for Hornsea Three (Table 4.19). This assumes that piling will be initiated at 15% of the maximum hammer energy for a period of 7.5 minutes (1 strike per six seconds), ramping up over a period of 30 minutes until the maximum energy is achieved (see Table 5.2 in volume 4, annex 3.1: Subsea Noise Technical Report).

4.11.1.25 The installation programme depends on the foundation and size of turbine selected and may either be carried out by a single vessel throughout the piling sequence, or by two vessels which in the latter case would result in periods of concurrent piling. For piling of the offshore HVAC booster stations, within the Hornsea Three offshore cable corridor, the installation of either monopile or jacket foundations will be via a single vessel and therefore a concurrent vessel scenario has not been assessed. The project design specifies a piling period of 2.5 years for all scenarios, divided into two phases, with potential for a gap of up to six years between phases. It is assumed that a worst case would be where there is a gap in piling (as opposed to piling occurring in one continuous period of 2.5 years) as this could potentially affect a larger number of breeding cycles over the lifetime of marine mammals. The maximum design scenarios for the spatial and temporal scenarios are summarised in Table 4.28 and described below.

4.11.1.26 Spatially, the maximum design scenario for the Hornsea Three array area is likely to arise for the installation of monopiles, where the maximum energy is specified as 5,000 kJ, and where two vessels pile concurrently within the Hornsea Three array area. For this scenario a total of 214.2 days of piling could occur and could be spread over a two and a half year period, divided into two phases (i.e. ~1.25 years per phase) and a gap of up to six years between the phases. Similarly, the maximum design scenario for the offshore HVAC booster search area is for installation of monopile foundations using the 5,000 kJ hammer energy. Piling would occur over a maximum of 4.8 days and would be phased over eight months within the two and a half year piling period. For comparison purposes, the assessment also considers piling with a single vessel using the 5,000 kJ hammer energy, with a total duration of piling of 433.2 days within the Hornsea Three array area plus offshore HVAC booster station search area.

4.11.1.27 Temporally, the maximum design scenario is represented by a single vessel installing pin piles (using a maximum 2,500 kJ energy) for jacket foundations, as the duration of piling would be longer compared to monopile foundations. For this scenario a total of 604.8 days piling could occur over a two and a half year piling period, again, split into two phases with a gap of up to six years between phases. For the temporal maximum design scenario there is no piling within the offshore HVAC booster station search area as the scenario with the largest number of piles comprised HVDC converter stations, which are located within the Hornsea Three array area. For comparison purposes, the assessment has also considered the potential for concurrent piling to occur for installation of jacket foundations, and in this case the spatial extent would be increased but the duration of impact is decreased to an estimated 302.4 days of piling (phasing as described previously). Similarly, the assessment includes a scenario for piling with a single vessel within the offshore HVAC booster station search area using the 2,500 kJ hammer energy (offshore HVAC booster station with 96 piles instead of the HVAC converter substation), for which the duration is calculated as 28.8 days over eight months.

4.11.1.28 Subsea noise modelling was carried out at three locations within the Hornsea Three array area (south, northwest and northeast) and two locations within the offshore HVAC booster station search area which is located along the Hornsea Three offshore cable corridor (south and north). These locations were selected to represent the geographical extents of Hornsea Three and to provide a precautionary assessment in terms of proximity to sensitive areas for marine fauna (e.g. areas of highest density or closest to nature conservation designations). A detailed description of the modelling approach is presented in volume 4, annex 3.1: Subsea Noise Technical Report.

Auditory injury

4.11.1.29 High levels of noise exposure can cause an instantaneous auditory injury resulting in a Permanent Threshold Shift (PTS) that persists once sound exposure has ceased. An estimate of the range out to which PTS could occur for each marine mammal hearing group was modelled using the SPL_{peak} thresholds given in NMFS (2016) (see Table 4.21).

Table 4.21: Ranges and areas over which auditory injury (PTS) could occur in marine mammals as a result of single and concurrent piling at Hornsea Three array area for pin piles (2,500 kJ) and monopiles (5,000 kJ).

Marine mammal hearing group	Threshold SPL_{peak} (dB re. 1μPa) [a]	Range (m): maximum (mean) [b]	Area (km²) single piling: maximum (mean)	Area (km²) concurrent piling: maximum (mean) [c]
375 kJ (15% soft start for 2,500 kJ maximum energy)				
High Frequency Cetaceans	202	280 (149)	0.25 (0.07)	0.5 (0.14)
Mid Frequency Cetaceans	230	1 (1)	<0.0001	<0.0002
Low Frequency Cetaceans	219	9 (7)	0.0003 (0.0002)	0.0006 (0.0004)
Pinnipeds	218	11 (9)	0.0004 (0.0003)	0.0008 (0.0006)
750 kJ (15% soft start for 5,000 kJ maximum energy)				
High Frequency Cetaceans	202	1,500 (660)	7.07 (1.37)	14.14 (2.74)
Mid Frequency Cetaceans	230	2 (2)	<0.0001	<0.0001
Low Frequency Cetaceans	219	34 (23)	0.004 (0.002)	0.008 (0.004)
Pinnipeds	218	42 (28)	0.006 (0.002)	0.012 (0.004)

a Unweighted SPL peak criteria from NMFS (2016).
b Ranges presented are based on the maximum and mean (in parenthesis) propagation at 15% soft start energy for the location (south, northwest, or northeast) that resulted in the largest ranges.
c To estimate the area of effect for concurrent piling (for the 5,000 kJ hammer only) the areas for single piling were doubled.

4.11.1.30 Since a soft-start would be initiated at 15% of the maximum hammer energy, the range out to which auditory injury could occur from the initial strike of the hammer (375 kJ soft start for 2,500 kJ hammer and 750 kJ soft start for 5,000 kJ hammer) dictated the extent over which mitigation should be applied (if required), as agreed with the Marine Mammal EWG (see Table 4.22).

Table 4.22: Ranges and areas over which auditory injury (PTS) could occur in marine mammals as a result of piling at a single location within the offshore HVAC booster station search area for pin piles (2,500 kJ) and monopiles (5,000 kJ).

Marine mammal hearing group	Threshold SPL$_{peak}$ (dB re. 1µPa) [a]	Range (m): maximum (mean) [b]	Area (km^2): maximum (mean)
375 kJ (15% soft start for 2,500 kJ maximum energy)			
High Frequency Cetacean	202	200 (120)	0.13 (0.05)
Mid Frequency Cetacean	230	<1 (<1)	<0.0001
Low Frequency Cetacean	219	7 (5)	0.0002 (0.00008)
Pinnipeds	218	8 (7)	0.0002 (0.0002)
750 kJ (15% soft start for 5,000 kJ maximum energy)			
High Frequency Cetacean	202	1100 (520)	3.80 (0.85)
Mid Frequency Cetacean	230	2 (1)	<0.0001
Low Frequency Cetacean	219	24 (17)	0.002 (0.0009)
Pinnipeds	218	31 (21)	0.003 (0.002)

a Unweighted SPL peak criteria from NMFS (2016).

b Ranges presented are based on the maximum and mean (in parenthesis) propagation at 15% soft start energy for the location (north or south) that resulted in the largest ranges.

4.11.1.31 In order to adopt a precautionary approach, the assessment considered the greatest range over which auditory injury (PTS) could occur across all locations modelled either within the Hornsea Three array area or within the offshore HVAC booster station search area. Within the Hornsea Three array area, the greatest range out to which auditory injury (PTS) could occur was for HF cetaceans (i.e. harbour porpoise) and was estimated at 280 m for a soft start energy of 375 kJ hammer and 1,500 m for a soft start energy of 750 kJ (Table 4.21). Similarly, within the offshore HVAC booster station search area, auditory injury (PTS) was estimated out to a maximum range of 200 m and 1,100 m for HF cetaceans initiating with a soft start of 375 kJ and 750 kJ respectively (Table 4.22). For other marine mammal hearing groups, and in both the Hornsea Three array area and offshore HVAC booster station search area, the ranges were much smaller and within a few tens of metres maximum (Table 4.21 and Table 4.22).

4.11.1.32 Areas of impact have also been presented in Table 4.21 and Table 4.22 for piling using a single vessel with either the 2,500 kJ (for pin piles) or 5,000 kJ (for monopiles) hammer energy using πr^2, where radius 'r' = range. The area of impact has been estimated for concurrent piling (which assumes that vessels are piling at opposite ends of the Hornsea Three array area) by simply doubling the area estimated for the single piling scenario.

4.11.1.33 Based on the results in Table 4.21 and Table 4.22, the maximum extent over which mitigation would need to be applied to avoid injury to any species of marine mammal is 1,500 m (Table 4.33). This has been agreed with the Marine Mammal EWG and details of mitigation measures to be adopted will be included in the MMMP (Marine Mammal Management Plan).

4.11.1.34 Another way to investigate the potential for auditory injury (PTS) to occur is to consider the injury ranges as the hammer energy ramps up over the soft start procedure. As agreed with the Marine Mammal EWG, modelling was undertaken to predict the auditory injury (PTS) ranges for the different marine mammal hearing groups during this ramp up. Results are presented in Tables 5.4, Table 5.5, Table 5.6 and Table 5.7 in volume 4, annex 3.1: Subsea Noise Technical Report. For LF cetaceans, MF cetaceans and pinnipeds in water, the auditory injury (PTS) ranges do not exceed 140 m at either of the maximum energies (2,500 kJ or 5,000 kJ) or at any location modelled (i.e. within the Hornsea Three array area or offshore HVAC booster station search area). Therefore, a mitigation zone of 1,500 m will be sufficient to ensure injury does not occur in minke whale, white-beaked dolphin, harbour seal or grey seal.

4.11.1.35 In contrast, the ranges at which auditory injury (PTS) could occur in HF cetaceans increase from 1,500 m at a 750 kJ soft start up to a range of 4.9 km at the 5,000 kJ hammer energy for the modelled 'south' location within the Hornsea Three array area (Table 4.23). In order to estimate whether there is potential for harbour porpoise to be exposed to noise levels that cause auditory injury (PTS) as hammer energy ramps up, it was assumed that animals flee the area at a speed of 1.5 m^{-1}, based on the cruising speed of harbour porpoise (Otani *et al*., 2000), from a starting point of 1.5 km as the proposed distance over which mitigation should be implemented. It can be seen that, based on this precautionary swim speed, there is potential for animals to experience auditory injury (PTS) over the ramp up procedure for the 5,000 kJ hammer as the distance that they clear during fleeing is less than the maximum ranges over which auditory injury (PTS) is predicted to occur at 40%, 60% and 80% up to the maximum (Table 4.23). It should be noted that there needs to be a careful balance between ensuring auditory injury (PTS) does not occur and increasing the duration of pile-driving (by increasing the duration of soft start) particularly as the fleeing distances are likely to be underestimated using the precautionary swim speed of 1.5 m^{-1}. For example, if we base the fleeing speed on the maximum cruising speed recorded by Otani *et al.* (2000 and 2001) of 4.2 m^{-1} this would suggest that harbour porpoise could potentially increase their distance by 1,890 m for each 7.5 minute step in piling. Thus, when 100% hammer energy is finally reached, an animal could potentially be up to 9 km from the piling and at each step will be beyond the range of potential injury (Table 4.23).

Table 4.23: Ranges out to which auditory injury (PTS) predicted for high frequency cetaceans as hammer energy ramps up from soft start (15% blow energy) to maximum hammer energy (100% blow energy).

		15% blow energy	40% blow energy	60% blow energy	80% blow energy	100% blow energy
Auditory injury (PTS) range(m) for 2,500 kJ	Hornsea Three array area [a]	230 (150)	790 (470)	1,100 (690)	1,500 (860)	1,700 (1,000)
	Offshore HVAC booster station search area	200 (120)	710 (380)	1,000 (560)	1,400 (700)	1,700 (870)
Auditory injury (PTS) range(m) 5,000 kJ	Hornsea Three array area	1,500 (660)	2,900 (1,800)	3,800 (2,800)	4,300 (3,500)	4,900 (3,800)
	Offshore HVAC booster station search area	1,100 (520)	2,300 (1,400)	2,900 (1,800)	3,600 (2,300)	3,900 (2,800)
Duration of piling		7.5 minutes	7.5 minutes	7.5 minutes	7.5 minutes	3 hours 30 minutes
Fleeing distance (m) [b]		1,500	2,175 (3,390)	2,850 (5,280)	3,525 (7,170)	4,200 (9,060)

a Ranges presented are for the maximum and mean (in parenthesis) propagation based on pile-driving at location 'south' in the Hornsea Three array area and location 'south' in the offshore HVAC booster station search area , as the locations that resulted in the largest ranges.

b Fleeing distance has been estimated for harbour porpoise based on how far an animal can swim over each 7.5 minute step in piling using conservative estimates of 1.5 ms^{-1} for mean cruising speed and 4.2 ms^{-1} for maximum cruising speed (in parenthesis).

4.11.1.36 Auditory injury (PTS) may also result from prolonged exposure at lower levels sufficient to cause a Temporary Threshold Shift (TTS). Although animals are able to recover fully from TTS, particularly as they move away from the source, hearing loss may become permanent if hearing does not return to normal after several weeks. Therefore, the distinction between TTS and auditory injury (PTS) depends on whether there is complete recovery of the individual's hearing. The criteria used to look at prolonged exposure leading to auditory injury (PTS) is cumulative sound exposure levels (SEL_{cum}) and these are weighted according to the hearing range of each of the marine mammal groups (i.e. HF, MF, LF and PW; paragraph 4.11.1.8). Due to the potential for overestimating the effect ranges using marine mammal weighted SEL_{cum}, these criteria have not been applied to this marine mammal impact assessment (as agreed with the Marine Mammal EWG).

4.11.1.37 The modelled ranges of effect can, however, be viewed in the Subsea Noise Technical Report (volume 4, annex 3.1: Subsea Noise Technical Report), however these ranges should be treated with caution as it is likely that they are unrealistic due to the precautionary assumptions applied in the model, including:

- The maximum noise level vertically in the water column was used in the SEL_{cum} model which assumes that an animal is at the loudest position at all times therefore the model overestimates the noise exposure an animal receives since it does not account for any time that marine mammals spend at the surface, the reduced sound levels near the surface, nor the temporal hearing recovery between piling sequences;
- A precautionary swim speed of 1.5 ms^{-1} was adopted for all marine mammals, except for low frequency cetaceans where a swim speed of 3.25 ms^{-1} was adopted following Blix and Folkow (1995) therefore the model would overestimate the received noise levels for animals that swim faster than these speeds;
- The modelling did not take into account the reduction in 'sharpness' of the noise as noise spreads over distance which would lead to lower peak levels than predicted by the model, and therefore a reduced likelihood of experiencing auditory injury (PTS) at greater ranges;
- The noise model applied precautionary values for parameters (e.g. water temperature) that would lead to the greatest ranges;
- The noise model assumed that SEL_{cum} starts at the source location, whereas if mitigation were applied to deter animals out to a range of 1,500 m the noise levels experienced by fleeing animals would be much lower and lead to a reduced likelihood of auditory injury (PTS);
- The soft-start procedure simulated did not allow for short pauses in piling (e.g. for realignment), and therefore the modelled cumulative SEL is likely to be an overestimate since, in reality, these pauses will reduce the noise exposure that animals experience whilst fleeing; and
- The model assumed that the maximum hammer energy would be achieved at the end of the soft start and continues throughout the remainder of the piling sequence, whereas in reality it is more likely that the maximum energy would only be required for a very short duration at the end of the piling sequence, if at all.

TTS/Fleeing response (TTS onset)

4.11.1.38 Since TTS-onset levels lead to a fleeing response, this threshold can also be viewed as the range out to which animals may be displaced from the area of potential impact.

4.11.1.39 A simple approach to investigating the potential for fleeing (TTS onset), as recommended by Southall *et al*., (2007), is to look at the range of effect assuming a single pulse type source as it has previously been associated with fleeing response in belugas. For reasons described above (paragraph 4.11.1.29) the threshold applied here was for unweighted SPL_{peak} as set out in NMFS (2016).

4.11.1.40 The range out to which a fleeing (TTS onset) response is predicted is greatest for HF cetaceans and for the largest hammer energy. Distances over which displacement of harbour porpoise could occur were predicted to be 4 km for the 2,500 kJ hammer and 12.8 km for the 5,000 kJ for pile-driving within the Hornsea Three array area (Table 4.24). The calculated areas of effect (πr^2) for single piling were 50.27 km² and 514.79 km² for the 2,500 kJ and 5,000 kJ hammer energies respectively (Table 4.24). For concurrent piling within the Hornsea Three array area, the areas of effect for harbour porpoise were calculated as 100.55 km² and 1,028 km² for the 2,500 kJ and 5,000 kJ hammer energies respectively, assuming maximum spacing between piling operations. Similarly, for piling at the offshore HVAC booster station search area, displacement of harbour porpoise was predicted to occur out to ranges of 3.4 km and 9.0 km for the 2,500 kJ and 5,000 kJ hammer energy respectively (Table 4.25), although the duration of effect would be limited as there are only four monopile or jacket foundations to be installed within this area.

Table 4.24: Ranges and areas over which fleeing (TTS onset) and therefore displacement could occur in marine mammals, as a result of single and concurrent piling at Hornsea Three array area for pin piles (2,500 kJ) and monopiles (5,000 kJ).

Marine mammal hearing group	Threshold SPL_{peak} (dB re. 1µPa) [a]	Range (m): maximum (mean) [b]	Area (km²) single piling: maximum (mean) [c]	Area (km²) concurrent piling: maximum (mean) [d]
2,500 kJ				
High Frequency Cetacean	196	4,000 (3200)	50.27 (32.17)	100.54 (64.34)
Mid Frequency Cetacean	224	22 (19)	0.002 (0.001)	0.004 (0.002)
Low Frequency Cetacean	213	170 (130)	0.09 (0.05)	0.18 (0.1)
Pinnipeds	212	260 (170)	0.21 (0.09)	0.42 (0.18)
5,000 kJ				
High Frequency Cetacean	196	12,800 (9,600)	514.79 (289.57)	1,028.00 (579.14)
Mid Frequency Cetacean	224	71 (42)	0.02 (0.006)	0.04 (0.012)
Low Frequency Cetacean	213	810 (360)	2.06 (0.41)	4.12 (0.82)
Pinnipeds	212	1,000 (480)	3.14 (0.72)	6.28 (1.44)

a Unweighted SPL peak criteria from NMFS (2016).
b Ranges presented are based on the maximum and mean (in parenthesis) propagation from the selected location for each species.
c Single piling locations are: south for harbour porpoise and pinnipeds and northwest for white-beaked dolphin and minke whale.
d To estimate the area of effect for concurrent piling (for the 5,000 kJ hammer only) the areas for single piling were doubled.

Table 4.25: Ranges over which fleeing (TTS onset) and therefore (displacement) could occur in marine mammals, as a result of piling at a single location within the offshore HVAC booster station search area for pin piles (2,500 kJ) and monopiles (5,000 kJ).

Marine mammal hearing group	Threshold SPL_{peak} (dB re. 1µPa)[a]	Range (m): maximum (mean)	Area (km²): maximum (mean)
2,500 kJ			
High Frequency Cetacean	196	3,400 (2,300)	36.32 (16.62)
Mid Frequency Cetacean	224	23 (16)	0.002 (0.0008)
Low Frequency Cetacean	213	200 (120)	0.13 (0.05)
Pinnipeds	212	250 (140)	0.20 (0.06)
5,000 kJ			
High Frequency Cetacean	196	9,000 (7200)	254.50 (162.88)
Mid Frequency Cetacean	224	67 (39)	0.01 (0.005)
Low Frequency Cetacean	213	840 (360)	2.22 (0.41)
Pinnipeds	212	1,000 (440)	3.14 (0.06)

a unweighted SPL peak criteria from NMFS (2016).
b Ranges presented are based on the maximum and mean (in parenthesis) propagation for the location (south or north) that resulted in the largest ranges.

Behavioural effects

4.11.1.41 Beyond the ranges at which injury and displacement are predicted, a range of other behavioural effects can arise in response to lower received levels of noise (paragraph 4.11.1.15 *et seq.*).

4.11.1.42 The ranges and areas of effect out to which behavioural effects could occur are presented for all marine mammal hearing groups (other than pinnipeds for which there is no criteria for behavioural effects) in the following tables for the Hornsea Three array area (Table 4.26) and offshore HVAC booster station search area (Table 4.27). Figure 4.10 to Figure 4.16 illustrates the extent of behavioural contours for harbour porpoise, white-beaked dolphin and minke whale, and each scenario modelled. The greatest spatial effects were predicted for pile-driving within the Hornsea Three array area.

4.11.1.43 For piling of both monopile and jacket foundations within the Hornsea Three array area, range and therefore area of effect is greatest where there is concurrent piling, with vessels spaced at opposite ends of the Hornsea Three array area.

4.11.1.44 As discussed previously, there are no criteria for behavioural effects available for pinnipeds and therefore the assessment has focussed on the fleeing response (TTS onset) as the area over which likely displacement could occur. As can be seen in Table 4.24 and Table 4.25 the ranges over which the onset of TTS/fleeing for pinnipeds are out to 1 km from the source. Recent work by Hastie *et al*. (2015), however, demonstrated that the closest approach of tagged harbour seal to pile-driving at the Lincs offshore wind farm was recorded as 4.7 to 9.8 km. This suggests that the ranges predicted for TTS-onset do not capture the full extent of behavioural effects leading to avoidance of the affected area by seals during pile-driving.

Table 4.26: Ranges and areas over which behavioural effects could occur in cetacean species a result of single or concurrent piling at Hornsea Three array area for pin piles (2,500 kJ) and monopiles (5,000 kJ).

Marine mammal hearing group	Behavioural effects		Areas of effect (km²)	
	Threshold (dB re.1µPa².s)	Range (km): maximum (mean) [d]	Single piling [e]	Concurrent piling [f]
2,500 kJ				
High Frequency Cetacean	145[c]	61 (50)	7,948	13,796
Mid Frequency Cetacean	170[b]	8.1 (7.7)	188	339
	160[c]	29 (23)	1,713	2,888
Low Frequency Cetacean	152[b]	57 (40)	5,078	8,882
	142[c]	95 (62)	12,460	16,834
5,000 kJ				
High Frequency Cetacean	145 [c]	66 (55)	9,706	16,106
Mid Frequency Cetacean	170[b]	11 (10)	346	497
	160[c]	36 (28)	2,461	4,124
Low Frequency Cetacean	152[b]	66 (45)	6,470	14,659
	142[c]	105 (67)	9,550	19,427

a Weighted SEL cumulative criteria from NMFS (2016) for TTS/fleeing.
b Unweighted SEL single pulse criteria from Southall *et al.* (2007) for likely avoidance.
c Unweighted SEL single pulse criteria from Lucke *et al.* (2009) for possible avoidance.
d Ranges presented are based on the maximum and mean (in parenthesis) propagation from the selected location for each species.
e Single piling locations were: south for harbour porpoise and pinnipeds and northwest for white-beaked dolphin and minke whale.
f Concurrent piling locations were south and northwest for all species.

Table 4.27: Ranges over which behavioural effects could occur in cetacean species as a result of piling at a single location within the offshore HVAC booster station search area for pin piles (2,500 kJ) and monopiles (5,000 kJ).

Marine mammal hearing group	Behavioural effects		Area (km²): Likely avoidance – possible disturbance
	Threshold (dB re.1µPa².s)	Range (km): maximum (mean)	
2,500 kJ			
High Frequency Cetacean	145[c]	49 (35)	3,922
Mid Frequency Cetacean	170[b]	5.8 (5.6)	97
	160[c]	17 (16)	777
Low Frequency Cetacean	152[b]	32 (26)	2,140
	142[c]	57 (39)	4,895
5,000 kJ			
High Frequency Cetacean	145[c]	56 (39)	4,754
Mid Frequency Cetacean	170[b]	8 (7.6)	182
	160[c]	22 (19)	1,113
Low Frequency Cetacean	152[b]	38 (29)	2,755
	142[c]	63 (42)	5,805

a Weighted SEL cumulative criteria from NMFS (2016) for TTS/fleeing.
b Unweighted SEL single pulse criteria from Southall *et al.* (2007) for likely avoidance.
c Unweighted SEL single pulse criteria from Lucke *et al.* (2009) for possible avoidance.
d Ranges presented are based on the maximum and mean (in parenthesis) propagation for the location (north or south of the offshore HVAC booster station search area) that resulted in the largest ranges.

4.11.1.45 Temporally, piling could occur up to 604.8 days over a 2.5 year, two phase piling period, with a gap of up to six years between phases within the Hornsea Three array area, therefore, within the context of the life history of each species, piling could potentially lead to reproductive failure over up to a maximum of four breeding cycles[1].

4.11.1.46 The duration of piling within the offshore HVAC booster station search area will be much shorter than for piling within the Hornsea Three array area, with a maximum duration of 4.8 days for monopiles and 28.8 days for jacket foundations (both phased over eight months). Therefore, although the spatial extent of effects could extend beyond the boundaries of the marine mammal study area for all species except white-beaked dolphin, within the context of the life history of the species, only one breeding cycle may be affected and therefore the duration of effects is short term.

[1] Up to two breeding cycles could be affected within each 1.25 year piling phase.

Magnitude summary by species

Harbour porpoise

4.11.1.47 TTS/fleeing arising from piling within the Hornsea Three array area or offshore HVAC booster station search area could lead to potential displacement of harbour porpoise over part of their range within the southern North Sea (a pSAC for harbour porpoise which is located in close proximity to the southern boundary of the Hornsea Three array area and which intersects the Hornsea Three offshore cable corridor). Behavioural effects (possible avoidance) could occur over a much larger area with approximately 16,106 km^2 affected for the spatial worst case of concurrent piling with the 5,000 kJ hammer energy (Figure 4.10 and Figure 4.11). Although the extent of the impact from subsea noise is similar for piling within the offshore HVAC booster search area compared to within the Hornsea Three array, the magnitude would be much smaller for the former due to the short temporal nature of the impact (Figure 4.12).

4.11.1.48 The extent of the impact was predicted on the basis of concurrent piling occurring at opposite ends of the Hornsea Three array area, and on the highly precautionary assumption that the maximum hammer energy would be required at all locations. However, for two vessels located in closer proximity the area of impact would be considerably reduced and it is also unlikely that the maximum of 5,000 kJ would be required at all locations across the Hornsea Three array area.

4.11.1.49 The piling duration is estimated as 604.8 days (temporal worst case) phased over 2.5 years, equivalent of up to ~21% of the species lifespan; piling would however occur intermittently over this period (i.e. four to eight hours per 24 hour period) but has the potential to overlap with key life stages, including up to four breeding cycles. As for the spatial scenario, this is considered to be very precautionary as it assumes the longest duration of piling would occur at each location and that the minimum number of piles would be installed in any one 24 hour period. In practice, both the duration of piling and the number of days on which piling occurs would be considerably less than currently described for the maximum design scenario.

4.11.1.50 No magnitude evaluation has been undertaken for harbour porpoise, for the following reasons:

- Hornsea Three are currently undertaking a review of the maximum design scenario for piling, as well as defining a more typical design scenario, by reviewing construction experience at other offshore wind farms. Pending the completion of this review, the Hornsea Three marine mammal noise related assessments will be revisited, including where applicable the subsea noise modelling, and this will enable a more fully developed and accurate impact assessment to be completed.
- There is uncertainty in the application of new noise impact assessment criteria (NMF, 2016) as agreed by the Marine Mammal EWG. Further discussion with the Marine Mammal EWG will therefore be sought prior to finalising application of these criteria for PTS and TTS;
- Refinements to the magnitude and/or sensitivity criteria are currently being considered and may be implemented for the Environmental Statement;
- Refinements to the noise modelling, to include but not limited to consideration of noise propagation at the 2 m depth contour;
- Review of the differences in densities between the various datasets referred to in the PEIR (e.g. SCANS I, II and III, and former Hornsea Zone/Hornsea Three specific datasets); and
- Application of dose response to the noise contours and subsequent recalculations of potential animals that may occur within these.

4.11.1.51 Hornsea Three will consult with the Marine Mammal EWG on the magnitude evaluation for harbour porpoise prior to the submission of the Environmental Statement in Quarter 2 of 2018.

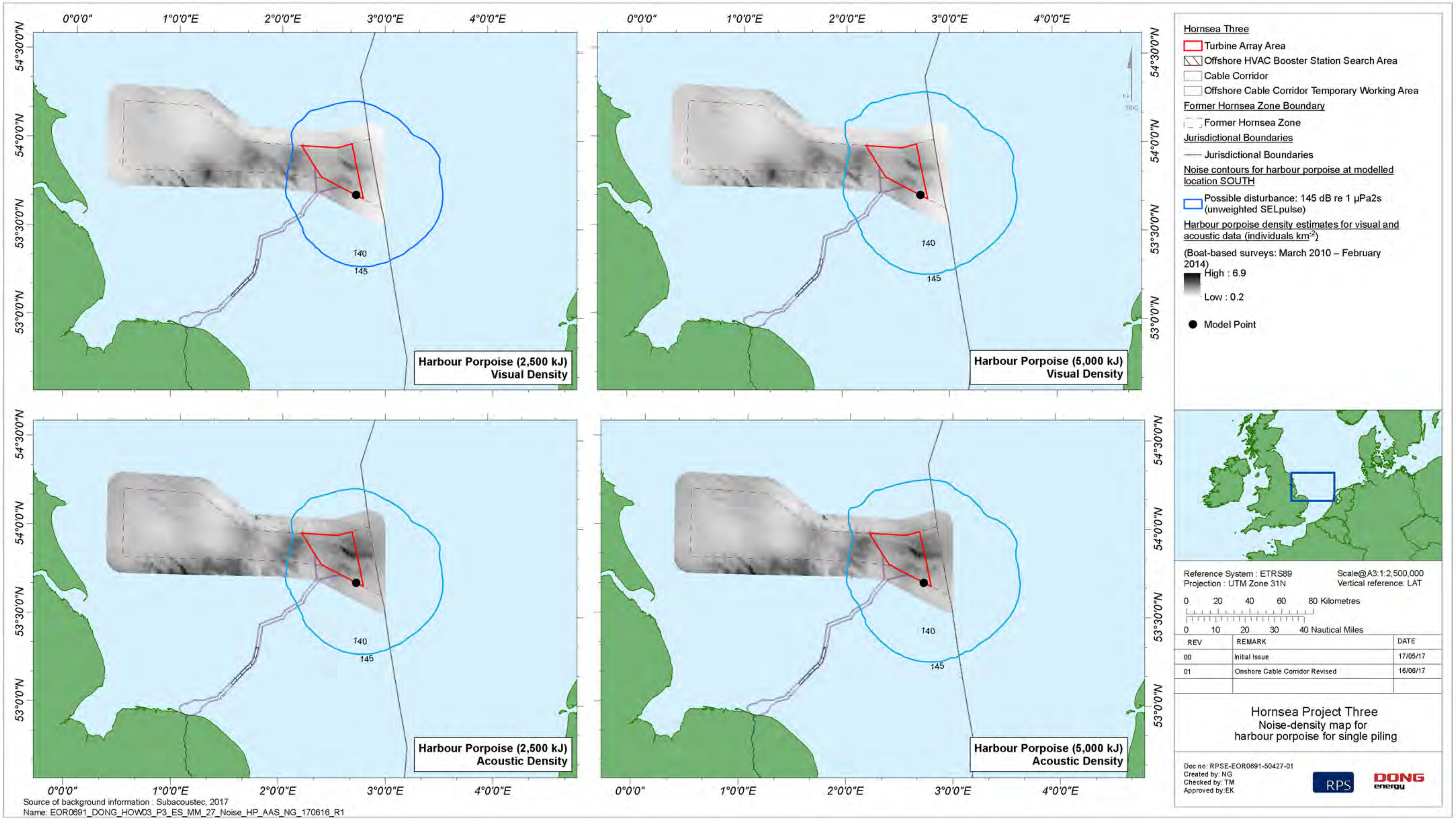

Figure 4.10: Noise density map for harbour porpoise for single piling in the Hornsea Three array area.

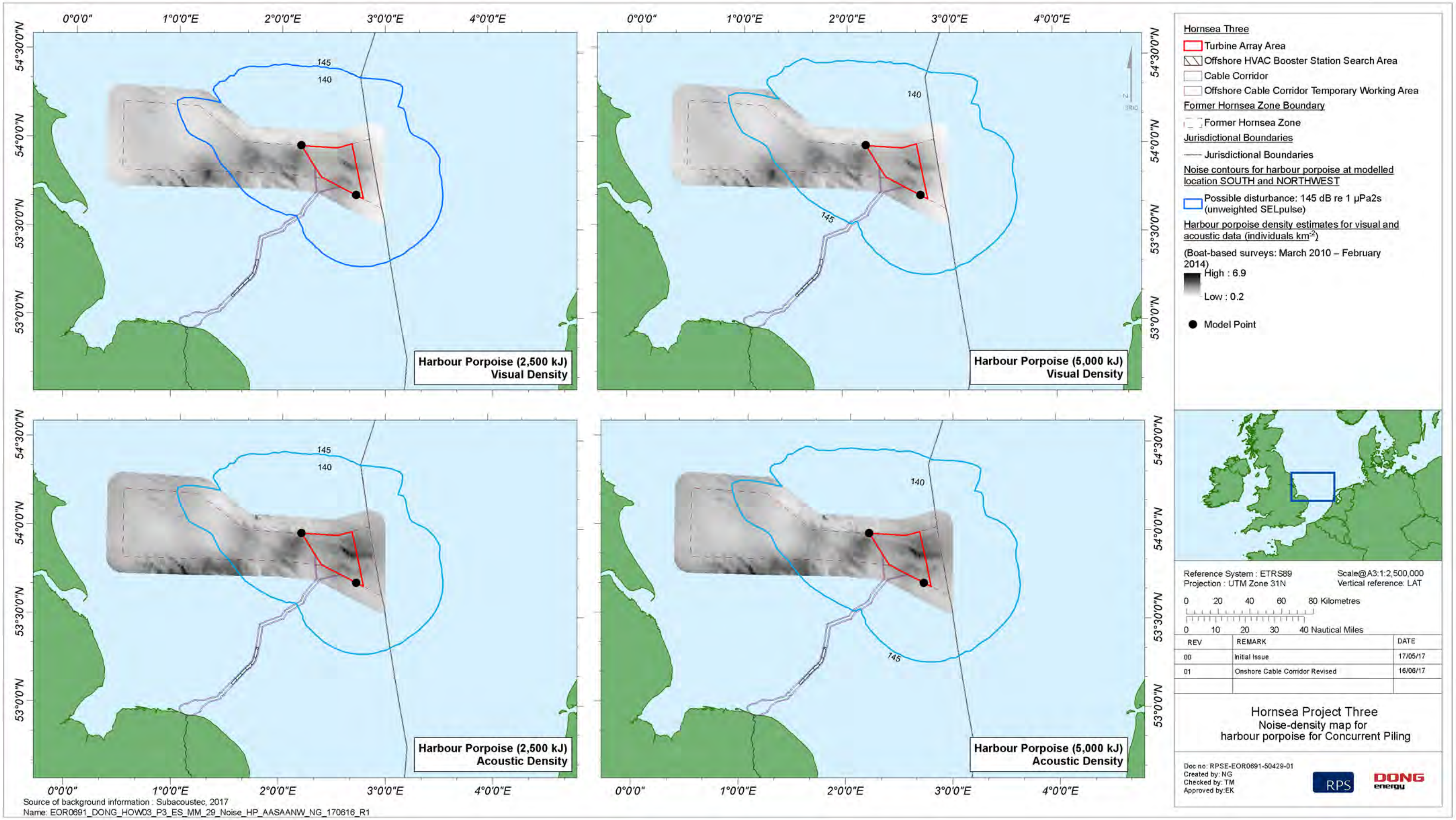

Figure 4.11: Noise density map for harbour porpoise for concurrent piling in the Hornsea Three array area.

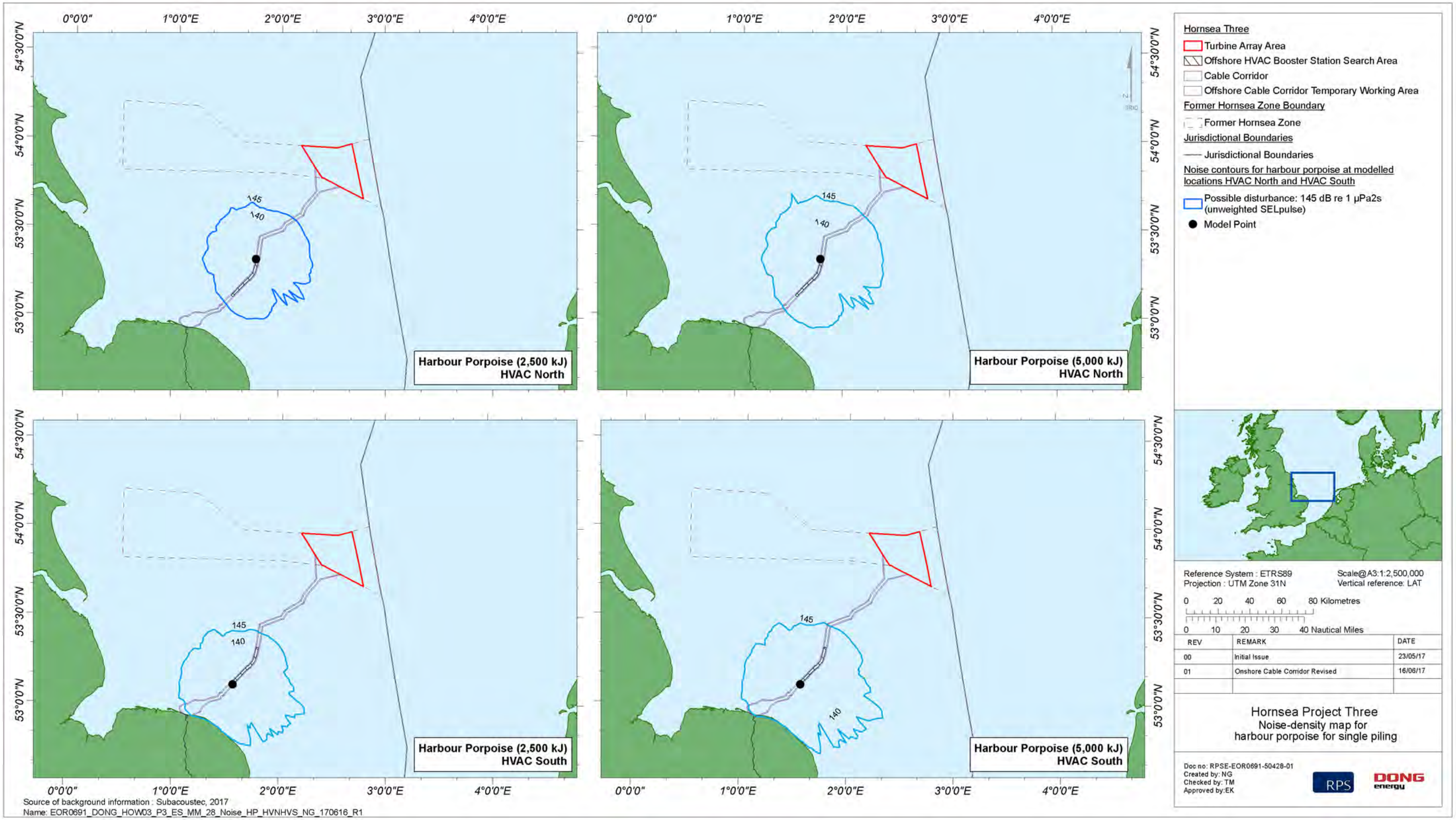

Figure 4.12: Noise density map for harbour porpoise single piling in the Hornsea Three offshore cable corridor.

White-beaked dolphin

4.11.1.52 Displacement could be expected over ranges of 22 to 71 m for white-beaked dolphin (Table 4.24 and Table 4.25) depending on the maximum hammer size and location (Hornsea Three array area or offshore HVAC booster station search area). Possible and likely avoidance is predicted to occur over 11 and 36 km respectively for the maximum spatial design scenario, with behavioural effects occurring within an area of up 4,124 km^2 during concurrent piling (Figure 4.13 and Figure 4.14). As described previously for harbour porpoise, this is likely to be very precautionary as it assumes the maximum spacing between concurrent piling vessels and the maximum hammer energy at all locations (paragraph 4.11.1.48).

4.11.1.53 Piling duration is estimated as 604.8 days (temporal worst case) phased over 2.5 years, equivalent to ~7% of the species lifespan; piling would occur intermittently over this period (i.e. four to eight hours per 24 hour period) but could overlap with key life stages, potentially affecting up to four breeding cycles. Again, this is considered to be very precautionary for reasons described earlier (paragraph 4.11.1.49).

4.11.1.54 The magnitude of impact is smaller for piling within the offshore HVAC booster search area compared to within the Hornsea Three array due to the shorter duration of piling.

4.11.1.55 No magnitude evaluation has been undertaken for white-beaked dolphin for the reasons outlined in paragraph 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the magnitude evaluation for white-beaked dolphin prior to the submission of the Environmental Statement in Quarter 2 of 2018

Minke whale

4.11.1.56 Displacement could be expected over ranges of 170 to 840 m for minke whale (Table 4.24 and Table 4.25) depending on the maximum hammer size and location (Hornsea Three array area or offshore HVAC booster station search area). Possible and likely avoidance is predicted to occur over 66 and 105 km respectively for the maximum spatial design scenario, with behavioural effects occurring within an area of up 19,427 km^2 during concurrent piling (Figure 4.15 and Figure 4.16). As described previously for harbour porpoise, this is likely to be very precautionary as it assumes the maximum spacing between concurrent piling vessels and the maximum hammer energy at all locations (paragraph 4.11.1.48).

4.11.1.57 Piling duration is estimated as 604.8 days (temporal worst case) phased over 2.5 years, equivalent to ~4% of the species lifespan; piling would occur intermittently over this period (i.e. four to eight hours per 24 hour period) but could overlap with key life stages, potentially affecting up to four breeding cycles. Again, this is considered to be very precautionary for reasons described earlier (paragraph 4.11.1.49).

4.11.1.58 The magnitude of impact is smaller for piling within the offshore HVAC booster search area compared to within the Hornsea Three array due to the shorter duration of piling.

4.11.1.59 No magnitude evaluation has been undertaken for minke whale for the reasons outlined in paragraph 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the magnitude evaluation for minke whale prior to the submission of the Environmental Statement in Quarter 2 of 2018.

Grey seal and harbour seal

4.11.1.60 Displacement could be expected over ranges of 250 to 1,000 m for grey and harbour seal (Table 4.24 and Table 4.25) depending on the maximum hammer size and location (Hornsea Three array area or offshore HVAC booster station search area). There are no criteria available for predicting the ranges for behavioural disturbance for pinnipeds, however, it is likely that behavioural effects could extend beyond the 1 km modelled for TTS/fleeing and potentially up to 10 km or more, based on the available scientific evidence.

4.11.1.61 Piling duration is estimated as 604.8 days (temporal worst case) phased over 2.5 years, equivalent of up to ~13% of the species lifespan; piling would however occur intermittently over this period (i.e. four to eight hours per 24 hour period) but has the potential to overlap with key life stages, including up to four breeding cycles. As described for harbour porpoise, this is considered to be very precautionary as it assumes the maximum hours of piling at each location and the maximum days on which piling could occur will be required (paragraph 4.11.1.49).

4.11.1.62 The magnitude of impact is much smaller for piling within the offshore HVAC booster search area compared to within the Hornsea Three array area due to the short duration of piling.

4.11.1.63 No magnitude evaluation has been undertaken for grey seal and harbour seal for the reasons outlined in paragraph 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the magnitude evaluation for white-beaked dolphin prior to the submission of the Environmental Statement in Quarter 2 of 2018.

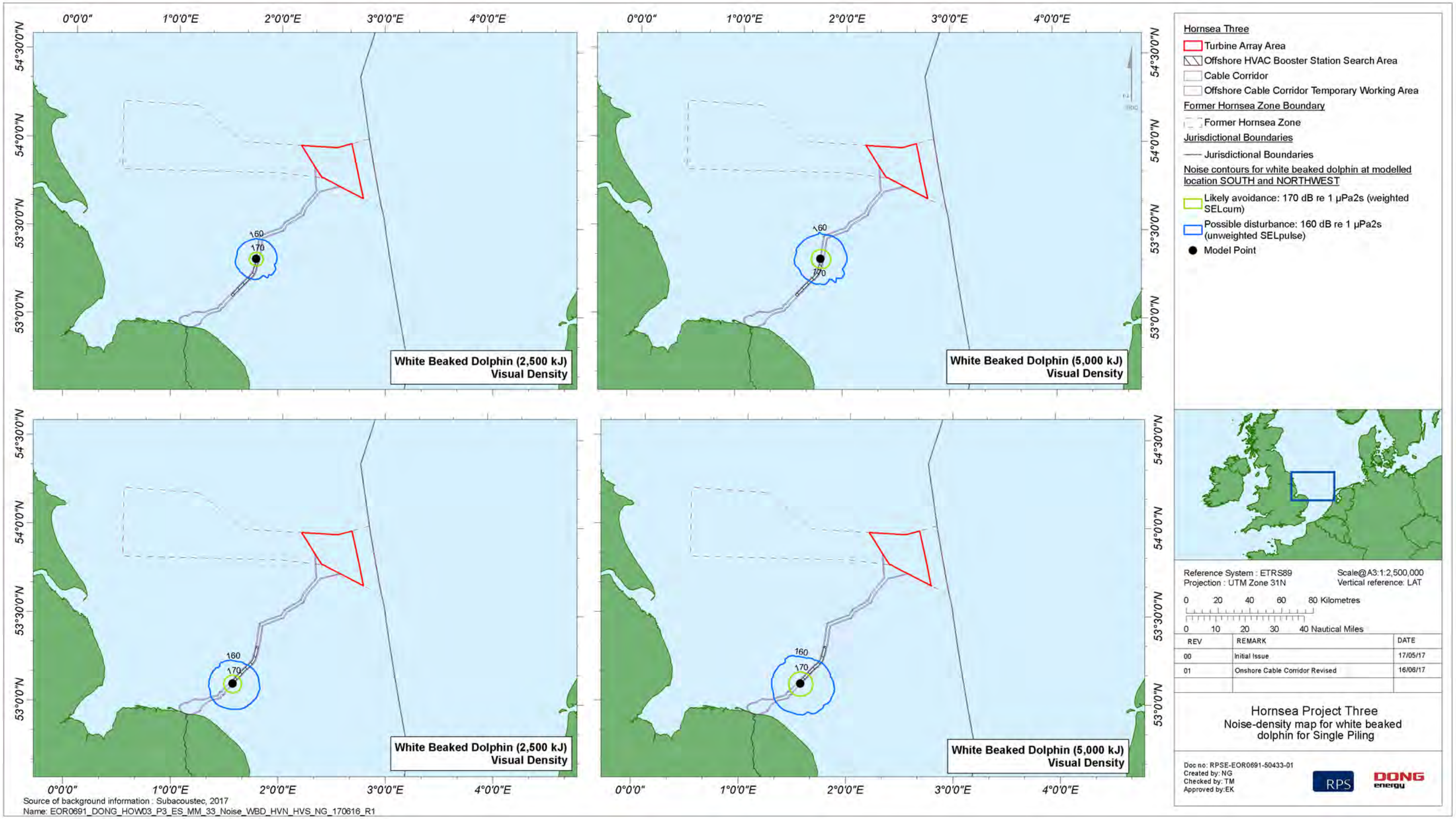

Figure 4.13: Noise density map for white-beaked dolphin for single piling in the Hornsea Three offshore cable corridor.

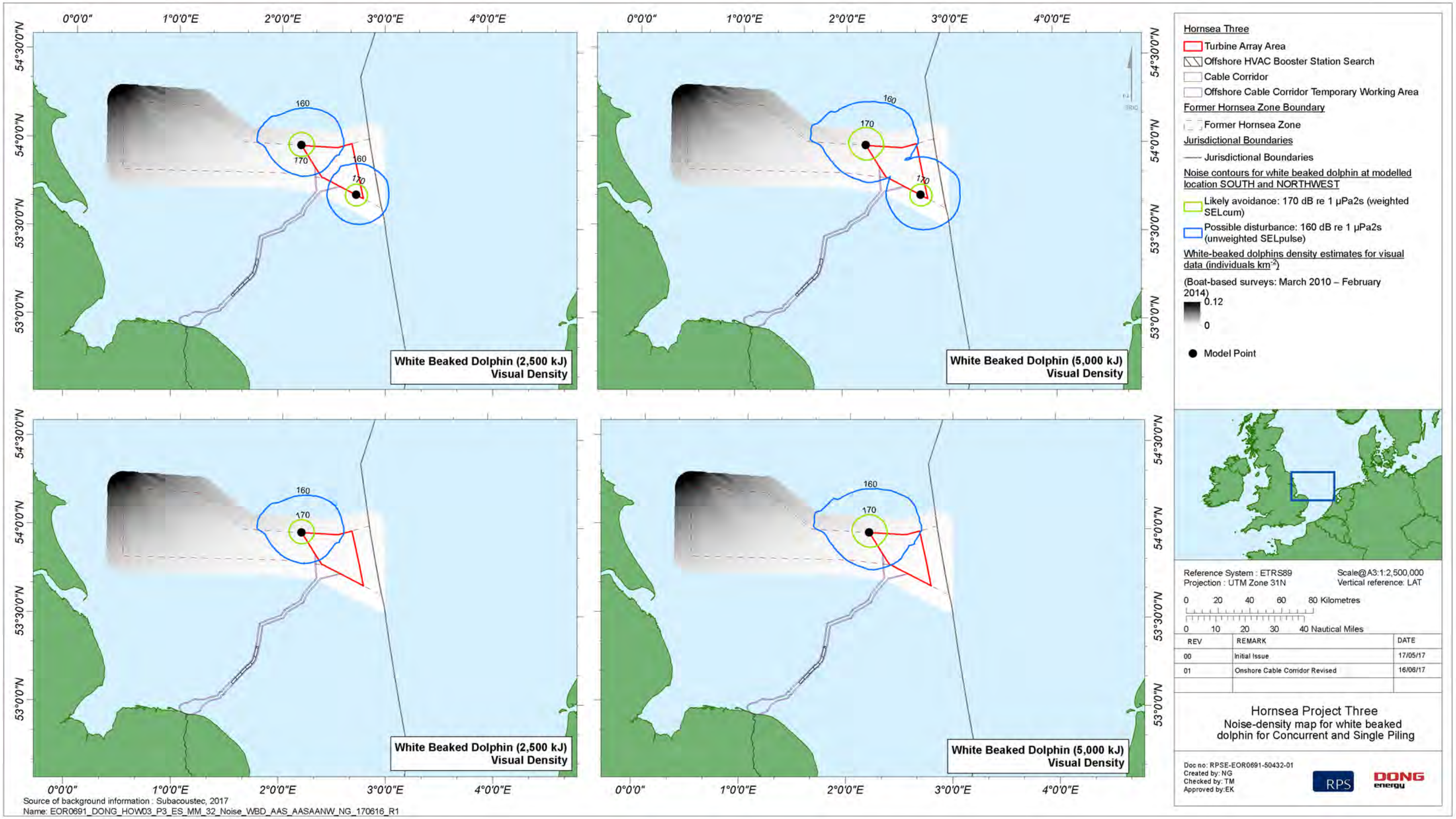

Figure 4.14: Noise density map for white-beaked dolphin for concurrent and single piling in the Hornsea Three array area.

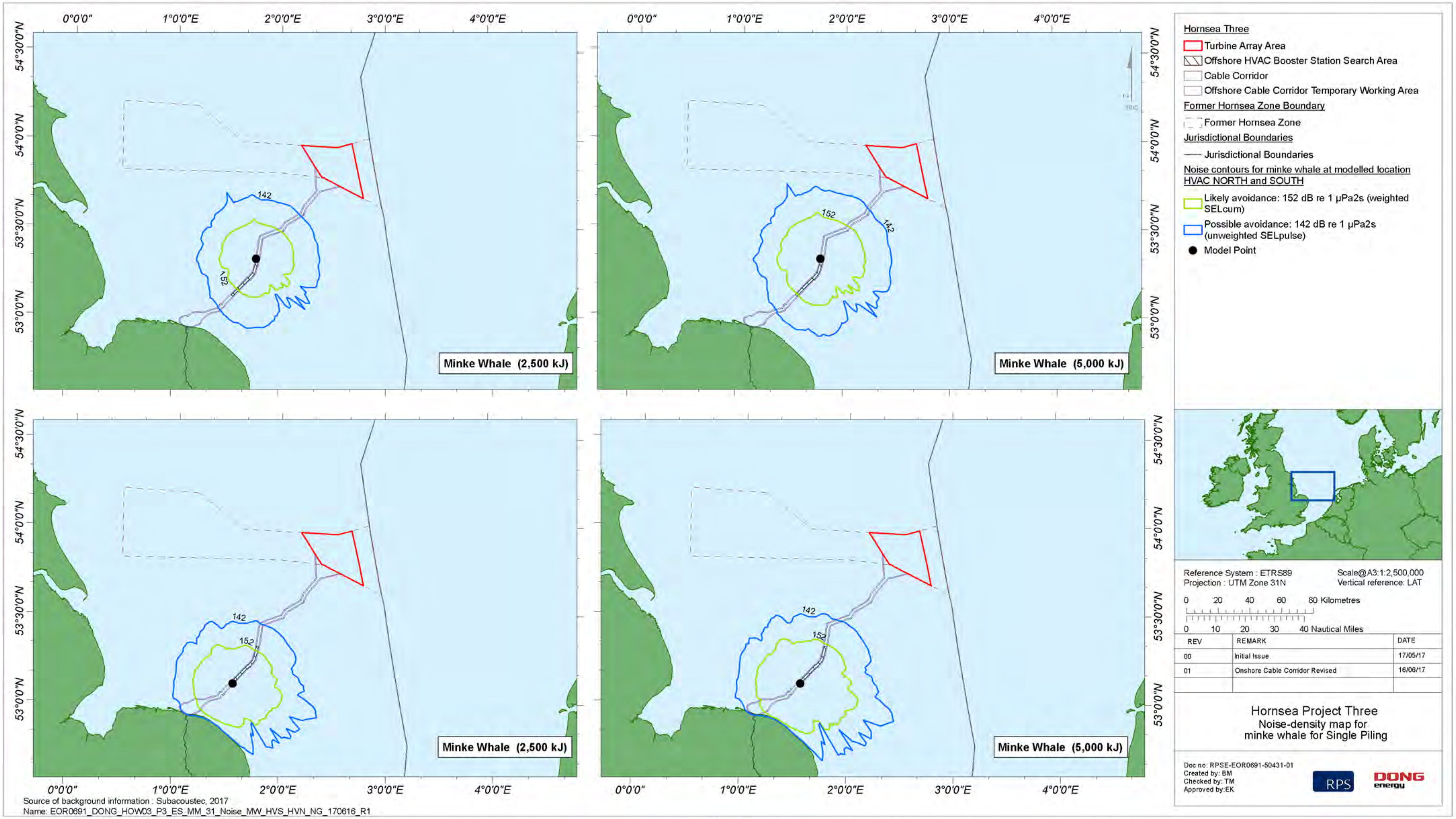

Figure 4.15: Noise density map for minke whale for single piling in the Hornsea Three offshore cable corridor.

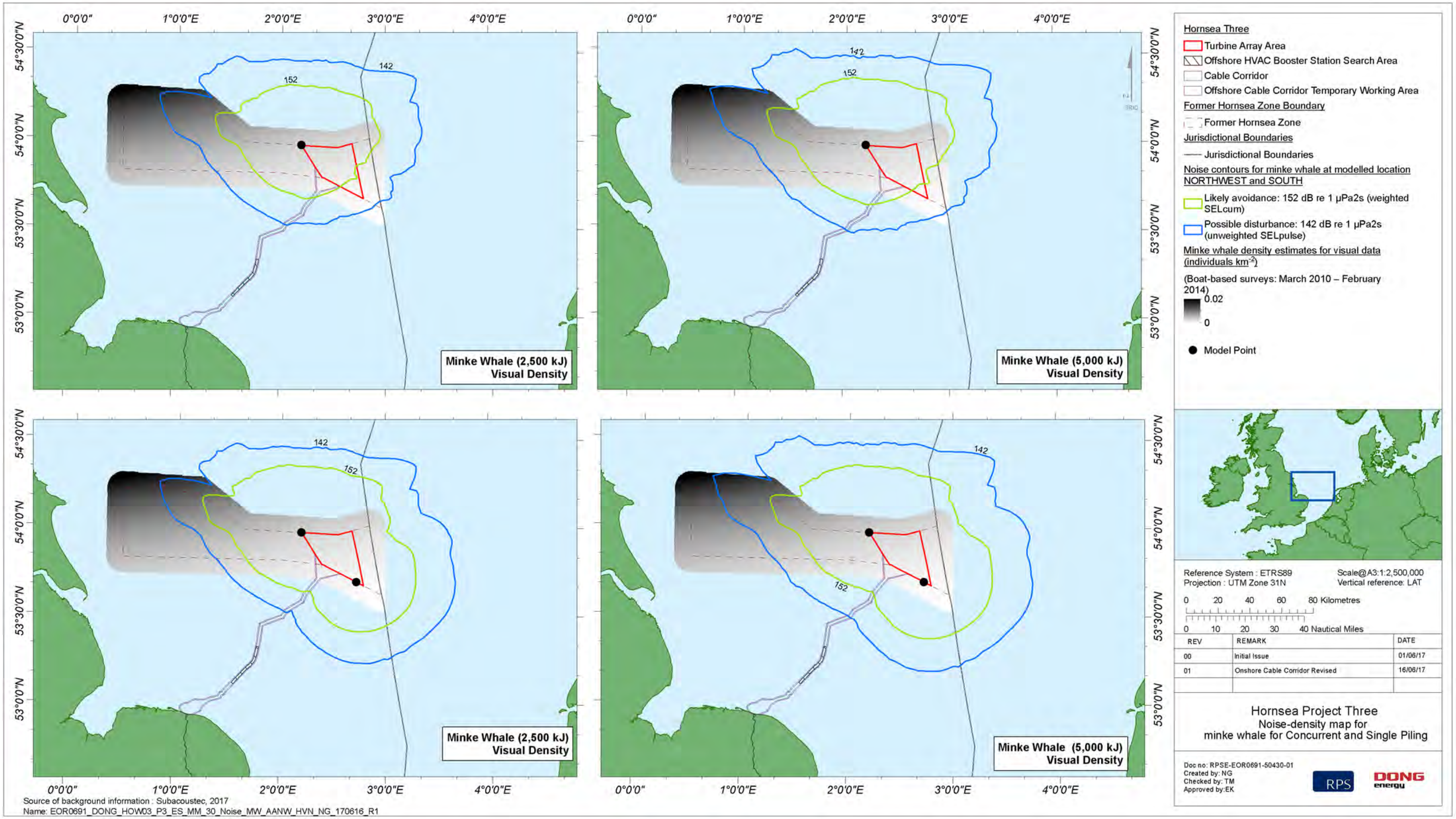

Figure 4.16: Noise density map for minke whale for concurrent and single piling in the Hornsea Three array area.

Sensitivity of the receptor

4.11.1.64 Whilst it is widely acknowledged that hearing sensitivity of the animal is a key factor (Finneran and Schlundt, 2011; Terhune, 2013 and Nedwell *et al*., 2007b), the context of the exposure is also likely to have an influence on behaviour, in addition to the level of the underlying ambient noise (i.e. the perceived signal-to-noise ratio).

4.11.1.65 Background noise levels in the southern North Sea are dominated by anthropogenic activities, including those from vessel activity (heavy shipping, fishing and passenger vessels), oil and gas activity (drilling etc.), military activities, and UXO clearance. Ambient noise levels contribute to the background noise level, and will increase in higher sea states. Measured background levels within the former Hornsea Zone in 2011, prior to installation of the met mast gave the range of noise as 112 to 122 dB re. 1μPa (RMS over two days). This snapshot of data suggested that noise levels are within the same range as baseline levels sampled elsewhere in the North Sea, although noting that this does not provide information on the frequency of the source (volume 4, annex 3.1: Subsea Noise Technical Report). In a study comparing noise levels in the southern North Sea, northern North Sea and Celtic Sea, Merchant *et al*. (2016) found that the North Sea sites had the highest noise levels in the frequency range 63 to 500 Hz (the same frequency range as the dominant third octave bands produced by piling) and that the Celtic Sea, in comparison, had much lower levels in this frequency spectrum. This suggests that marine mammals in the North Sea are likely to be acclimatised to certain level of noise in the same spectrum that is predicted to arise from piling.

4.11.1.66 As discussed previously, the sensitivity of marine mammals depends on the frequency range over which they hear and communicate and therefore understanding the characteristics of the source will determine whether there is any overlap with biologically important frequencies. For marine mammal receptor the sensitivity has been assessed in relation to each of the noise thresholds: auditory injury (PTS), TTS/fleeing, and behavioural effects (where available).

4.11.1.67 As marine mammals rely heavily on their underwater auditory sense, it may be assumed that auditory injury (PTS) would affect an individual's long-term fitness and survival. Similarly, since onset of TTS triggers a fleeing response in marine mammals, there are potential consequences for fitness if displacement leads to reduced foraging, either due to lower quality of foraging habitat elsewhere or increased competition for resources over reduced habitat. For behavioural effects the implications are less clearly understood. In this assessment, it has been assumed that within the behavioural effect contour there are a wide range of responses. At the upper end of the scale animals may actively avoid the noise source and the degree to which this occurs is likely to vary greatly between individuals depending on age, gender, previous exposure history or motivation to stay in an area (e.g. for good foraging opportunities). This response is likely to be ecologically important as it could lead to reduced fitness of those animals affected. For example, Thompson *et al*. (2013b) suggests that even if broad-scale displacement does not occur, the focus should be on understanding the potential for sublethal effects arising from changes in foraging performance of animals within impacted areas. Other potential behavioural responses (as listed by Southall *et al.* 2007) include changes in speed, direction, dive profile, vocalisations or respiration rate. At the lower end of the behavioural response scale, there may be some short term effects on, for example, energy expenditure of individuals, but the responses are likely to be short lived, with animals quickly returning to previous activities following cessation of piling.

4.11.1.68 Traditionally noise impact assessments for offshore wind projects have assumed that all animals within each noise contour may be affected to the same degree to ensure a precautionary assessment of impact. For example, assessments would have assumed that all animals exposed to noise levels that induce likely avoidance will move away from the affected area, and similarly all animals exposed to noise levels that are modelled as inducing auditory injury (PTS) or TTS will suffer permanent or temporary auditory injury respectively. However, evidence from the published literature suggests that this is likely to lead to predictions that are over-precautionary and therefore unrealistic. For example, a study looking at the proportion of trials at different SELs that result in TTS in exposed animals revealed that to induce TTS in just 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 auditory injury (PTS) (scaled from the Finneran *et al*., 2005 study on TTS) and for behavioural response for harbour seal. Auditory injury (PTS) was predicted to increase exponentially from a SEL of 198 dB up to 250 dB; the point at which all animals are predicted to have auditory injury (PTS). Similarly, behavioural response was modelled as a dose-response based on studies of harbour porpoise at Horns Rev (Brandt *et al*., 2011) which showed that as the distance from the source increases so the proportion of animals disturbed decreases (Thompson *et al*., 2013).

4.11.1.69 The study of harbour porpoise at Horns Rev revealed important evidence that pile driving may not necessarily lead to 100% avoidance, as is assumed in a worst case scenario (Brandt *et al.,* 2011). This study showed that at closer distances (2.5 to 4.8 km) there was 100% avoidance, however, this proportion decreased significantly moving away from the pile driving activity, such that at distances of 10.1 to 17.8 km, avoidance occurred in 32 to 49% of the population. At 21.2 km, the abundance reduced by just 2%. Although the parameters in this study differ from those considered for Hornsea Three, this is nonetheless an important finding, as it suggests that an assumption that all individuals within the zone of possible avoidance will move away is over precautionary, and that in reality the behavioural response is likely to be proportional (i.e. approximately 50% would respond at the maximum predicted level as suggested by the dose-response curve in Thompson *et al*. (2013)).

4.11.1.70 For this PEIR, as a precautionary approach, it was assumed that all animals within the auditory injury zone (PTS) have the potential to experience PTS and all animals within the fleeing (TTS onset) zone would be displaced from the affected area. For behavioural effects it is assumed that a range of behavioural responses could occur, with the more severe responses (i.e. potentially leading to reduced fitness of exposed individuals) occurring at closer ranges whilst lesser behavioural effects (i.e. brief changes in behaviour that are immediately reversible and would not affect individual fitness) would occur over larger ranges. For mid- and low- frequency cetaceans, the thresholds for 'likely avoidance' and 'possible avoidance' help to distinguish between different levels of behavioural responses, whereas for harbour porpoise (a high frequency cetacean) there is only one threshold available (possible avoidance) and therefore the sensitivity is more difficult to assess. The assessment therefore describes the range of different responses that could occur within the zone of possible avoidance for harbour porpoise.

4.11.1.71 For each marine mammal receptor, the number of animals potentially affected by auditory injury (PTS) and TTS was calculated by multiplying the area of impact in Table 4.21 to Table 4.25 by the precautionary mean density estimate in (Table 4.7). The number of animals within the noise contours for likely avoidance and possible disturbance were estimated from the noise contours overlaid onto the former Hornsea Zone plus 10 km buffer surface density maps. Where there was missing density information (i.e. because the noise contours extended beyond the former Hornsea Zone plus 10 km buffer), the number of animals within these cells was estimated using the upper 75% quartile of the cells along the boundary of the former Hornsea Zone plus 10 km buffer. This was agreed with the Marine Mammal EWG (see Table 4.22) as an appropriate and conservative approach.

Sensitivity summary by species

Harbour porpoise

Auditory Injury (PTS)

4.11.1.72 In the absence of mitigation, there is potential for a small number of individuals to experience auditory injury (PTS) up to the maximum hammer energies (2,500 kJ and 5,000 kJ) during pile-driving both within the Hornsea Three array area and offshore HVAC booster station search area (Table 4.28 and Table 4.29). Auditory injury (PTS) is likely to lead to permanent effects on marine mammals. The number of animals potentially affected by PTS is very small, particularly in relation to the size of the NS MU population (0.018% reference population).

TTS/fleeing

4.11.1.73 The number of harbour porpoise potentially affected by TTS/fleeing was also relatively small (compared to the MU population) for single and concurrent piling within the Hornsea Three array area (0.65 % single and 1.3% of reference population respectively) (Table 4.28). However, as the maximum spatial design scenario for concurrent piling will lead to a shorter piling duration, the overall impact on harbour porpoise from concurrent piling using 5,000 kJ hammer energy may be similar to single location piling using the same hammer energy.

4.11.1.74 Temporarily reduced hearing in an animal caused by TTS may affect its foraging ability, interfere with its communication, reduce its ability to detect predators, and impede orientation. As discussed previously the effect of TTS depends on factors such as magnitude and duration of exposure and the frequency range affected (paragraph 4.11.1.14). Studies of TTS in marine mammals suggest that the hearing frequencies most affected by sound exposures (in relation to the frequency of the fatiguing sound) are species-specific (Kastelein *et al*., 2012a).

4.11.1.75 Marine mammals, and odontocetes in particular (due to their echolocation ability), rely mainly on their high frequency hearing for orientation and foraging. Therefore, these high frequencies are likely to be more ecologically important to them than low frequencies. Kastelein *et al*. (2012a) exposed a harbour porpoise to a 1.5 kHz continuous tone at a mean received sound pressure level (SPL) of 136 dB re.1μPa, and found that the animal's hearing around 125 kHz was not influenced (i.e., no TTS likely to affect echolocation ability occurred). This was expected, as frequencies between 1 and 2 kHz, and echolocation signals (of approximately 125 kHz), are processed in different parts of the ear (Kastelein *et al.*, 2013). Echolocation frequencies of harbour porpoise are not affected by intense low frequency sounds, and therefore foraging efficiency is unlikely to be affected (Kastelein *et al*., 2013). Following on from this, TTS resulting from sound sources such as piling, where most of the energy occurs at lower frequencies, is unlikely to negatively affect the ability of harbour porpoise for echolocation (foraging and navigation).

Table 4.28: Number of harbour porpoise potentially affected by pile-driving within the Hornsea Three array area and proportion of the reference population affected (NS MU harbour porpoise population = 227,298).

Threshold	Number of animals within noise contour: single piling	Percentage of NS MU population	Number of animals within noise contour: concurrent piling	Percentage of NS MU population
2,500 kJ				
Auditory injury (PTS) (15% soft start)	<1	0.0003	1	0.0006
Auditory injury (PTS) (100% energy)	26	0.01	52	0.02
TTS/fleeing (displacement)	144	0.06	289	0.13
Possible avoidance [a]	15,677 to 15,722	6.90 to 6.92	27,381 to 26,424	12.05 to 11.63
5,000 kJ				
Auditory injury (PTS) (15% soft start)	20	0.009	40	0.018
Auditory injury (PTS) (100% energy)	217	0.10	434	0.20
TTS/fleeing (displacement)	1,477	0.65	2,954	1.30
Possible avoidance [a]	18,828 to 19,396	8.28 to 8.53	30,525 to 32,028	13.43 to 14.09

a Numbers and ranges presented for possible avoidance are based on estimated abundance within the plotted noise contours using visual and acoustic boat-based surface density maps.

4.11.1.76 A precautionary assumption has been made that TTS/fleeing would lead to 100% displacement of animals from the affected area and therefore harbour porpoise are considered to be vulnerable to TTS/fleeing. However, harbour porpoise range over large distances (compared to the 4.0 to 12.8 km impact ranges; Table 4.21) and the proportion of the NS MU population affected is small (0.06 to 1.3; Table 4.28). Similarly, for piling within the offshore HVAC booster search area the number of harbour porpoise potentially affected by TTS/fleeing are small compared to the wider NS MU population (Table 4.29). It should, however, be noted that the offshore HVAC booster station search area overlaps part of the Southern North Sea pSAC for harbour porpoise.

Behavioural effects

4.11.1.77 Up to 32,028 animals are predicted to show possible avoidance behaviour from concurrent piling (maximum hammer energy), which equates to 14.09% of the NS MU population (Table 4.28). Up to 19,396 animals are predicted to show possible avoidance behaviour from single location piling (maximum hammer energy) which equates to 8.53% of the NS MU population.

4.11.1.78 Studies looking at the response of harbour porpoise to pile-driving within offshore wind farms found that porpoise numbers were significantly reduced during pile-driving activity (e.g. Thompson *et al*., 2010; Scheidat *et al.,* 2011; Carstensen *et al*., 2006). A study by Brandt *et al.* (2011) found that the proportion of porpoise that avoided the area decreased as distance from the piling activity increased, suggesting that not all animals within the area of possible avoidance were displaced. In addition, the recovery time was also faster at greater distances from the source with return to baseline levels within less than 24 hours at distances of up to 4.8 km (although noting that the hammer energy used in this study was only 900 kJ) (Brandt *et al*., 2011). Other studies have also suggested that harbour porpoise activity may quickly resume following pile-driving activity, with return times ranging between a matter of hours (e.g. Thompson *et al*., 2010; Scheidat *et al.,* 2011) to up to three days (Carstensen *et al*., 2006). For multiple piling events at offshore wind farms, Dähne *et al*. (2013) found that longer piling durations led to longer periods of time between porpoise detections.

4.11.1.79 Based on Southall *et al*. (2007) it is considered likely that animals within shorter ranges from the noise source could suffer more severe behavioural effects that could lead to avoidance of the disturbed area, and therefore animals will have some vulnerability and show recoverability. At greater ranges, animals are more likely to suffer temporary behavioural effects such as reduced vocalisations, or changes in speed or direction, but the receptor is likely to be less vulnerable to such effects and recovery could occur in the short term (<1 year) once piling ceases. Thus, there is a wide range of behavioural responses that are predicted within this contour and this makes it difficult to determine the potential ecological implications of the impact on harbour porpoise.

4.11.1.80 A key consideration is whether disturbance from multiple piling events will lead to longer term effects on the integrity of the population. Although the effect of behavioural disturbance on harbour porpoise breeding is unknown, it is possible that behavioural effects that lead to avoidance of an area, particularly one that may be important for the species, may result in reduced fecundity. This is most likely to occur as a result of reduced fitness since avoidance could lead to reduced prey availability as a result of sub-optimal habitat, increased competition, or greater energy costs of finding food. This may be especially important for harbour porpoise, which is a species with a relatively low body fat content compared to other cetaceans, and therefore needs to feed frequently. Reduced feeding during lactation may also lead to an increase in calf mortality, particularly since harbour porpoise calves have a high dependency on their mothers over the first eight months of their life.

4.11.1.81 The population consequence of behavioural disturbance is difficult to determine due to a paucity of long term studies. Baseline characterisation data suggests that the Hornsea Three marine mammal study area is an important area for harbour porpoise due to the high densities found here in the context of the regional marine mammal study area. Possible avoidance could potentially lead to adverse effects on up to 14.09% of the NS MU population, which could affect animals over part of their range within the Southern North Sea pSAC. For the maximum design temporal scenario, up to 15,722 animals (6.92% of the NS MU) could be affected by possible avoidance for a total duration of up to 604.8 days over a two and a half year, two phase, piling period.

4.11.1.82 Harbour porpoise could also be affected within the zone of possible avoidance during pile-driving at the offshore HVAC booster station search area (Table 4.29) with up to 6,550 (2.88% of the NS MU population) and 7,939 (3.49% of the NS MU population) animals affected for the 2,500 kJ and 5,000 kJ hammer respectively. Subsea noise arising from piling within the offshore HVAC booster station search area could also overlap with part of the Southern North Sea pSAC for harbour porpoise. The extent of this contour also reaches the coast, however, the potential for barrier effects to occur is considered to be unlikely as the noise levels in these outer areas of possible avoidance would be unlikely to deter animals from the area (i.e. would not lead to avoidance).

Table 4.29: Number of harbour porpoise potentially affected by pile-driving (single vessel) within the offshore HVAC booster station search area and proportion of the reference population affected (NS MU harbour porpoise population = 227,298).

Threshold	Number of animals within noise contour	Percentage of NS MU population
2,500 kJ		
Auditory injury (PTS) (15% soft start)	<1	0.0002
Auditory injury (PTS) (100% energy)	26	0.01
TTS/fleeing (displacement)	104	0.05
Possible avoidance [a]	6,550	2.88
5,000 kJ		
Auditory injury (PTS) (15% soft start)	11	0.005
Auditory injury (PTS) (100% energy)	137	0.06
TTS/fleeing (displacement)	730	0.32
Possible avoidance [a]	7,939	3.49

a Numbers and ranges presented for possible avoidance are based on estimated abundance within the plotted noise contours using visual and acoustic boat-based surface density maps.

4.11.1.83 The data presented in Table 4.28 and Table 4.29 are considered to be conservative as these are based on the noise-density maps that coincide with the areas of greatest harbour porpoise density. If these numbers were compared with estimates of the number of porpoise affected using the average density derived from the recent aerial data (1.77 animals km^{-2}) or using the modelled density estimate for SCANS-II for this area (1.2 animals km^{-2}) these estimates would be shown to be highly precautionary. For example, based on the aerial data or SCANS-II data, the number of harbour porpoise affected by possible avoidance for the worst-case spatial (concurrent piling at 5,000 kJ) would be 28,508 animals km^{-2} (12.5% of the NS MU) or 19,327 animals km^{-2} (8.5% of the NS MU) respectively compared to 32,028 animals km^{-2} (14% of the NS MU) estimated by overlaying the noise contour on the acoustic surface density map. Similarly, for the worst case temporal scenario (single piling at 2,500 kJ) the estimates using the aerial or SCANS-II data would be 14,068 animals km^{-2} (6.2% of the NS MU) or 9,538 animals km^{-2} (4.2% of the NS MU) respectively compared to 15,722 animal km^{-2} (6.9% of the NS MU) using the site-specific acoustic density estimates.

4.11.1.84 Furthermore, the potential for behavioural effects to lead to an effect on ecological functioning are based on animals avoiding key feeding areas, and this leading to breeding failure or increased mortality. However, as discussed previously (paragraph 4.11.1.69), it is considered unlikely that all animals within the zone of possible avoidance will be affected to the same degree (i.e. graded effects are more likely to occur moving away from the noise source as described for the dose-response relationship). Assuming animals follow a similar pattern of dose response as shown by Thompson *et al.* (2013) (i.e. approximately 50% would actively avoid the noise), this suggests that a more realistic approach would be to halve the numbers estimated for possible avoidance and compare this adjusted figure with the MU reference population. Taking this approach, 16,014 animals (7% of the NS MU) could be affected by the spatial worst case and 7,861 animals (3% of the NS MU) could be affected by the temporal worst case, and proportionally less again when applied to the aerial or SCANS-II data for this area (i.e. 14,254 (6.3% of the NS MU) and 9,664 (4.3% of the NS MU) for aerial and SCANS-II for spatial maximum design scenario respectively, and 7,034 (3.1%) and 4,769 (2.1%) for aerial and SCANS-II for temporal maximum design scenario respectively).

4.11.1.85 In summary, the vulnerability and recoverability of harbour porpoise will depend on the degree to which an animal is affected within the area of possible disturbance, and this will vary according to the distance the animal is from the noise source, its age, gender and previous exposure history. The nature of the assessment has led to over-precautionary estimates of animals potentially being affected by pile-driving, with the potential for effects on the harbour porpoise population if ecological functioning was affected as a result of possible avoidance. Therefore, further contextual information has been provided above with respect to the likelihood that the proportion of the population affected will follow a dose-response relationship (paragraph 4.11.1.84).

4.11.1.86 In terms of longer term effects, there is evidence from the strategic study "Disturbance Effects on the Harbour Porpoise Population in the North Sea" (DEPONS) that the population could recover from the effects of subsea noise from piling (van Beest *et al.,* 2015). The DEPONS study modelled the impact of multiple piling events at up to 31 offshore wind farms in the south central North Sea over a six year period on harbour porpoise populations in the North Sea and preliminary results suggest that pile-driving would not lead to long-term population-level effects on harbour porpoise. The study suggested that subsea noise disturbance from pile-driving, possibly leading to displacement, is most likely to be a short-term occurrence with animals returning quickly to the disturbed area. The model is still in the developmental stage and therefore no firm conclusions can be drawn at this stage, however, these results do suggest that there is likely to be no long-term significant effects at the population-level for harbour porpoise.

4.11.1.87 No sensitivity evaluation has been undertaken for harbour porpoise, for the same reasons outlined in paragraph 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the sensitivity evaluation for harbour porpoise prior to the submission of the Environmental Statement in Quarter 2 of 2018.

White-beaked dolphin

Auditory injury (PTS) and TTS/fleeing

4.11.1.88 Due to the low densities of white-beaked dolphin within the Hornsea Three marine mammal study area, the risk of an animal occurring within the auditory injury (PTS) zone is very small and therefore it is unlikely that an injury would occur to white-beaked dolphin during pile driving, either within the Hornsea Three array area (Table 4.30) or offshore HVAC booster station search area (Table 4.31). Similarly, it is considered unlikely that individual white-beaked dolphin would be present within the zone of potential TTS/fleeing (71 m and 67 m respectively for array area and HVAC) and therefore white-beaked dolphin are of low vulnerability to these impacts.

Behavioural effects

4.11.1.89 Behavioural effects for white-beaked dolphin are presented as likely and possible avoidance, which provides a useful context for understanding the range of potential responses as different noise thresholds are reached.

Likely avoidance

4.11.1.90 A small number of white-beaked dolphin could occur within the zone of likely avoidance during piling within the Hornsea Three array area with only one animal potentially within the affected area for the 2,500 kJ hammer and two animals within the affected area for the 5,000 kJ hammer either for single piling or concurrent piling (Table 4.30). Similarly, for piling within the offshore HVAC booster station search area, there were only two animals predicted to occur within the zone of likely avoidance (Table 4.31).

Table 4.30: Number of white-beaked dolphin potentially affected by pile-driving within the Hornsea Three array area and proportion of the reference population affected (CGNS MU white-beaked dolphin population = 15,895).

Threshold	Number of animals within noise contour: single piling	Percentage of CGNS MU population	Number of animals within noise contour: concurrent piling	Percentage of CGNS MU population
2,500 kJ				
Auditory injury (PTS) (15% soft start)	<1	<0.00000001	<1	<0.00000001
TTS/fleeing (displacement)	<1	<0.0000001	<1	<0.0000001
Likely avoidance [a]	1	0.006	1	0.006
Possible avoidance [a]	12	0.07	16	0.1
5,000 kJ				
Auditory injury (PTS) (15% soft start)	<1	<0.0000001	<1	<0.0000001
TTS/fleeing (displacement)	<1	<0.000001	<1	<0.000001
Likely avoidance [a]	2	0.01	2	0.01
Possible avoidance [a]	18	0.12	26	0.16

a Numbers presented for likely avoidance and possible avoidance are based on estimated abundance within the plotted noise contours using visual boat-based surface density maps.

4.11.1.91 Evidence for the impacts of behavioural disturbance on white-beaked dolphin is limited as most studies at offshore wind farms have focussed on species such as harbour porpoise and harbour seal, since their greater numbers make it easier to detect change. However, observations of mid-frequency cetaceans suggest that whilst there is likely to be a behavioural response to pile driving, species within this hearing threshold are less sensitive than harbour porpoise (a high-frequency cetacean). For example, Wursig *et al*. (2000) showed that for humpback dolphin, piling did not result in any overt behavioural response and only some of the population left the area, returning immediately following cessation of the activity. Mullin *et al*. (1989) reported displacement of bottlenose dolphin during pile driving activities at shallow depths and attraction at deeper levels. For both studies, there was insufficient evidence to suggest that any displacement was directly in response to piling noise since other factors, such as change in prey distribution may also have had an effect. This does not negate the possibility that piling could result in medium-term displacement effects.

Table 4.31: Number of white-beaked dolphin potentially affected by pile-driving (single vessel) within the offshore HVAC booster station search area and proportion of the reference population affected (CGNS MU white-beaked dolphin population = 15,895).

Threshold	Number of animals within noise contour	Percentage of CGNS MU population
2,500 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.0000001
TTS/fleeing (displacement)	<1	<0.0000001
Likely avoidance [a]	1	0.008
Possible avoidance [a]	10	0.06
5,000 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.0000001
TTS/fleeing (displacement)	<1	<0.000001
Likely avoidance [a]	2	0.01
Possible avoidance [a]	15	0.09

a Numbers presented for likely avoidance and possible avoidance are based on estimated abundance within the plotted noise contours using visual boat-based surface density maps.

Possible avoidance

4.11.1.92 Possible avoidance occurs over the largest range from the piling source: up to 29 or 36 km from the piling activity within the Hornsea Three array area at 2,500 kJ and 5,000 kJ respectively (Table 4.27). Despite these potentially large ranges, due to the low densities of white-beaked dolphin in the area, the numbers of animals estimated to occur within these areas are small, with 12 and 18 animals for single piling at 2,500 kJ and 5,000 kJ respectively and 26 animals for concurrent piling at 5,000 kJ (Table 4.30). Similarly, for piling within the offshore HVAC booster station search area, the number of animals affected was estimated at 10 and 15 for 2,500 kJ and 5,000 kJ respectively (Table 4.31). In this zone, the behavioural effects are likely to be short-lived and reversible, with behaviour returning to baseline levels soon after cessation of pile-driving.

4.11.1.93 No sensitivity evaluation has been undertaken for white-beaked dolphin, for the same reasons outlined in paragraph 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the sensitivity evaluation for white-beaked dolphin prior to the submission of the Environmental Statement in Quarter 2 of 2018.

Minke whale

Auditory injury (PTS) and TTS/fleeing

4.11.1.94 Densities of minke whale within the Hornsea Three marine mammal study area were low and therefore the likelihood of an animal occurring within the auditory injury (PTS) zone is very small. With measures adopted as part of Hornsea Three in place (an MMMP and soft start piling) it is considered unlikely that an injury would occur to minke whale during pile driving either within the Hornsea Three array area (Table 4.32) or offshore HVAC booster station search area (Table 4.33). Similarly, it is considered unlikely that individual minke whale would be present within the zone of potential TTS/fleeing (810 m and 840 m respectively for array area and HVAC) for any of the piling scenarios (Table 4.32 and Table 4.33).

Behavioural effects

4.11.1.95 Behavioural effects for minke whale were presented as likely and possible avoidance, which provides a useful context for understanding the range of potential responses as different noise thresholds are reached.

Likely avoidance

4.11.1.96 Within the zone of likely avoidance, where animals can demonstrate strong behavioural effects, including potentially moving away from the noise source, minke whale could be affected up to a range of 66 km from each piling location for the maximum design spatial scenario (Table 4.21). The numbers of minke whale affected were estimated at up to 133 animals for the maximum design spatial scenario of concurrent piling with a 5,000 kJ hammer energy within the Hornsea Three array area (Table 4.32). This number represented approximately 0.57% of the CGNS MU population. Smaller numbers would be affected for the maximum design temporal scenario of single piling at 2,500 kJ, with up to 58 animals (0.25% of the CGNS MU population) within the affected area over a longer duration (up to 604.8 piling days in total phased over two and a half years during a nine year construction programme). Similarly, small numbers are predicted to be affected during piling within the offshore HVAC booster station search area (Table 4.33).

4.11.1.97 Empirical evidence for the effect of underwater noise on minke whale comes from studies of other baleen whales. Overt avoidance behaviour of bowhead whale was recorded over distances of 6 to 8 km in response to noise levels of 150 to 180 dB re. 1μPa, with some avoidance behaviour observed out to at least 20 km (Koski and Johnson, 1987). Migrating bowheads avoided an area out to 10 km from drilling activity in the Alaskan Beaufort Sea with animals further afield (>20 km) also diverting their course (Hall *et al*., 1994). Grey whale also showed avoidance behaviour to drilling noise and alteration in their call characteristics was also noted, suggesting adaptations to reduce masking (Dahlheim, 1987). A reduction in the abundance of grey whale in a lagoon in Mexico was attributed to playbacks of drilling noise over a duration of 120 hours (Jones *et al*., 1994). In this study, numbers were reduced up to a month following the drilling noise, but returned to normal the following winter.

Table 4.32: Number of minke whale potentially affected by pile-driving within the Hornsea Three array area and proportion of the reference population affected (CGNS MU minke whale population = 23,528).

Threshold	Number of animals within noise contour: single piling	Percentage of CGNS MU population	Number of animals within noise contour: concurrent piling	Percentage of CGNS MU population
2,500 kJ				
Auditory injury (PTS) (15% soft start)	<1	<0.00000001	<1	<0.00000001
TTS/fleeing (displacement)	<1	<0.000001	<1	<0.000001
Likely avoidance [a]	58	0.25	118	0.50
Possible avoidance [a]	183	0.78	280	1.19
5,000 kJ				
Auditory injury (PTS) (15% soft start)	<1	<0.0000001	<1	<0.0000001
TTS/fleeing (displacement)	<1	0.0005	<1	0.001
Likely avoidance [a]	79	0.33	133	0.57
Possible avoidance [a]	208	0.88	334	1.42

a Numbers presented for likely avoidance and possible avoidance are based on estimated abundance within the plotted noise contours using visual boat-based surface density maps.

4.11.1.98 McCauley *et al.* (1998) observed humpback whale (a low frequency cetacean) during seismic surveys, and experimentally exposed individuals to air gun noise off the west coast of Australia. Whilst no disruption of whale migration routes was observed, avoidance behaviour was exhibited out to a range of 5 to 8 km from the source with 100% avoidance out to a range of 3 to 4 km. Typical received noise levels at 5 km were measured as 162 dB re.1 μPa^2. Avoidance in minke whale was also noted during seismic surveys in UK waters, but spatially was more localised compared to small odontocetes (Stone, 2003; Stone and Tasker, 2006).

Table 4.33: Number of minke whale potentially affected by pile-driving (single vessel) within the offshore HVAC booster station search area and proportion of the reference population affected (CGNS MU minke whale population = 23,528).

Threshold	Number of animals within noise contour	Percentage of CGNS MU population
2,500 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.000000001
TTS/fleeing (displacement)	<1	<0.000001
Likely avoidance [a]	49	0.21
Possible avoidance [a]	113	0.48
5,000 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.00000001
TTS/fleeing (displacement)	<1	<0.00001
Likely avoidance [a]	63	0.27
Possible avoidance [a]	134	0.57

a Numbers presented for likely avoidance and possible avoidance are based on estimated abundance within the plotted noise contours using visual boat-based surface density maps.

Possible avoidance

4.11.1.99 The range of possible avoidance extends a large distance beyond the Hornsea Three marine mammal study area and could occur up to 105 km from the piling location (Table 4.26). The number of animals potentially within the area affected under the maximum design spatial scenario (concurrent piling at 5,000 kJ) is 334, representing 1.42% of the MU population (Table 4.32). For piling at the lower hammer energy (2,500 kJ), both within the Hornsea Three array area and offshore HVAC booster station search area, the numbers affected are lower, with approximately 183 (0.78%) and 134 (0.57%) animals affected respectively (Table 4.33).

4.11.1.100 No sensitivity evaluation has been undertaken for minke whale, for the same reasons outlined in 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the sensitivity evaluation for minke whale prior to the submission of the Environmental Statement in Quarter 2 of 2018.

Grey seal

Auditory injury (PTS) and TTS/fleeing

4.11.1.101 The range of effect for injury to pinnipeds is small (up to 42 m maximum during soft start) and therefore the number of animals potentially affected is very small (less than one for all scenarios). With measures adopted as part of Hornsea Three in place (an MMMP and soft start piling) it is considered unlikely that an injury would occur to grey seal during pile driving either within the Hornsea Three array area (Table 4.34) or offshore HVAC booster station search area (Table 4.35). Similarly, very small numbers of grey seal were predicted to occur within the zone of potential TTS/fleeing for any of the scenarios within the Hornsea Three array or offshore HVAC booster search area.

Behavioural effects

4.11.1.102 There were no noise criteria against which to assess behavioural effects and therefore a quantitative estimate of the number of grey seal affected was not possible. Behavioural disturbance or displacement may be particularly important for seals as they often show high levels of site-fidelity to their haul-out sites (Cordes *et al*., 2011). Foraging ranges often become concentrated around their breeding and haul-out sites (although grey seal also range widely), creating increased competition for food. For those individuals that are behaviourally affected, this could lead to greater energetic costs of foraging or reduced foraging activity.

4.11.1.103 Empirical evidence for the effect of offshore wind farm construction on seals comes from studies at Horns Rev offshore wind farm in Denmark. This study on harbour seal showed that, although the proportion of time seals spent within the wind farm boundary during construction was reduced compared to baseline levels, animals were frequently observed in the area and continued to forage at their preferred habitat (Tougaard *et al*., 2003). This corroborates findings from seismic research that demonstrates that seals may be tolerant of loud noise pulses, particularly if attracted to the area for feeding or reproduction (Richardson *et al*., 2005). However, in close proximity, grey seal are more likely to exhibit strong avoidance behaviour as demonstrated by a controlled experiment on the effects of seismic surveys whereby grey seal changed from making foraging dives to v-shaped transiting dives to move away from the source (Thompson *et al*., 1998).

4.11.1.104 No sensitivity evaluation has been undertaken for grey seal for the reasons outlined in paragraph 4.11.1.4 above. The sensitivity of grey seal will however be assessed in the Environmental Statement in the context of important areas for this species (e.g. the Humber Estuary SAC which lies 74 km from the offshore HVAC booster station search area as the nearest point from Hornsea Three). Although there is potential for grey seal from this designated site to occur within areas affected by behavioural disturbance, the population of grey seal is considered to be thriving, within annual increases in numbers shown over the last 15 years. Hornsea Three will consult with the Marine Mammal EWG on the sensitivity evaluation for grey seal prior to the submission of the Environmental Statement in Quarter 2 of 2018.

Table 4.34: Number of grey seal potentially affected by pile-driving within the Hornsea Three array area and proportion of the reference population affected (SEE and NEE MU grey seal population = 18,150).

Threshold	Number of animals within noise contour: single piling	Percentage of SEE+NEE MU population	Number of animals within noise contour: concurrent piling	Percentage of SEE+NEE MU population
2,500 kJ				
Auditory injury (PTS) (15% soft start)	<1	<0.000001	<1	<0.000001
TTS/fleeing (displacement)	<1	0.002	<1	0.003
5,000 kJ				
Auditory injury (PTS) (15% soft start)	<1	<0.00001	<1	<0.00001
TTS/fleeing (displacement)	<1	0.003	1	0.006

Table 4.35: Number of grey seal potentially affected by pile-driving (single vessel) within the offshore HVAC booster station search area and proportion of the reference population affected (SEE and NEE MU grey seal population = 18,150).

Threshold	Number of animals within noise contour	Percentage of SEE+NEE MU population
2,500 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.000001
TTS/fleeing (displacement)	<1	0.002
Auditory injury (PTS) (15% soft start)	<1	<0.00001
5,000 kJ		
TTS/fleeing (displacement)	<1	0.03

Harbour seal

Auditory injury (PTS) and TTS/fleeing

4.11.1.105 As described above (paragraph 4.11.1.101) the range of effect for injury to pinnipeds is small with a maximum of 42 m affected during soft start. With measures adopted as part of Hornsea Three in place (an MMMP and soft start piling) it is considered unlikely that an injury would occur to harbour seal during pile driving either within the Hornsea Three array area (Table 4.36) or offshore HVAC booster station search area (Table 4.37). Less than one harbour seal was predicted to occur within the zone of potential fleeing (TTS onset) for any of the scenarios within the Hornsea Three array area or offshore HVAC booster station search area.

Table 4.36: Number of harbour seal potentially affected by pile-driving within the Hornsea Three array area and proportion of the reference population affected (SEE MU harbour seal population = 3,567).

Threshold	Number of animals within noise contour: single piling	Percentage of SEE MU population	Number of animals within noise contour: concurrent piling	Percentage of SEE MU population
2,500 kJ				
Auditory Injury (PTS) (15% soft start)	<1	<0.000001	N/A	N/A
TTS/fleeing (displacement)	<1	0.005	N/A	N/A
5,000 kJ				
Auditory Injury (PTS) (15% soft start)	<1	0.0001	<1	0.0002
TTS/fleeing (displacement)	<1	0.007	<1	0.014

Table 4.37: Number of harbour seal potentially affected by pile-driving (single vessel) within the offshore HVAC booster station search area and proportion of the reference population affected (SEE MU harbour seal population = 3,567).

Threshold	Number of animals within noise contour	Percentage of SEE MU population
2,500 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.000001
TTS/fleeing (displacement)	<1	0.005
5,000 kJ		
Auditory injury (PTS) (15% soft start)	<1	<0.00001
TTS/fleeing (displacement)	3	0.07

Behavioural effects

4.11.1.106 There were no noise criteria against which to assess behavioural effects and therefore a quantitative estimate of the number of harbour seal affected was not possible. As described for grey seal, there may be energetic costs of disturbance due to increased swimming distances if seals have to deviate from their course around the zone of likely avoidance, or reduced foraging due to density-dependant competition in alternative foraging areas. However, it is important to note, that harbour seal tend to forage in close proximity to their haul-out sites (i.e. within 40 to 50 km), with evidence in the Greater Wash of some animals travelling up to between 75 and 120 km (SMRU, 2011; paragraph 4.7.2.33), with an obvious gradient of animals from the coast, offshore to Hornsea Three shown in Figure 4.9. Given the distance to the nearest seal haul-out site from the boundary of the Hornsea Three array area, at East Hornsey is 127 km, it is considered unlikely that harbour seal would be subject to these behavioural effects within the Hornsea Three array area. Harbour seal are more likely to occur across the Hornsea Three offshore cable corridor, and therefore within the offshore HVAC booster station search area, as their coastal haul-out sites are in closer proximity, and within foraging range (Figure 4.9).

4.11.1.107 Although it was not possible to quantify the number of animals affected behaviourally (other than the fleeing response) evidence from the literature suggests that any short to medium term behavioural effects would not lead to long term population effects. Thompson *et al*., 2013 modelled the changes in the population of harbour seal from an SAC arising from piling at the Moray Firth and Beatrice proposed offshore wind farms, including both potential mortality of animals exposed to noise levels that would induce auditory injury (PTS) and behavioural displacement. The results of the modelling showed that over a 25 year period, even with considerable reductions in the population during the piling phase, for all worst case spatial and temporal scenarios, and for cumulative effects from both offshore wind farms piling concurrently, the population of harbour seal would recover in the long term.

4.11.1.108 Numbers of harbour seal within the regional marine mammal study area have shown a steady increase since 2006 and it is considered unlikely that behavioural disturbance could lead to any long-term population level effects. However, it is acknowledged that historically harbour seal have been sensitive to population declines over the years, and the population in The Wash is the largest in the UK and is considered a strong-hold for the species against a background of declining harbour seal populations elsewhere in the North Sea.

4.11.1.109 No sensitivity evaluation has been undertaken for harbour seal for the reasons outlined in paragraph 4.11.1.4 above. Hornsea Three will consult with the Marine Mammal EWG on the sensitivity evaluation for harbour seal prior to the submission of the Environmental Statement in Quarter 2 of 2018.

Significance of the effect

4.11.1.110 As described previously (paragraph 4.11.1.4), no magnitude or sensitivity evaluation has been undertaken and therefore no significance of effect has been concluded. The summary below therefore discusses where there is potential for an impact that may lead to a significant effect (in EIA terms) following further assessment based on the information presented above for magnitude and sensitivity. It is important however to note that the information presented is highly precautionary and subject to amendment.

Harbour porpoise

4.11.1.111 A range of effects arising from subsea noise during piling have been examined for harbour porpoise, and this PEIR reflects the various potential impacts, from auditory injury to behavioural effects. The greatest potential for effect (in EIA terms) is considered likely to arise due to disturbance during piling, where exposure to subsea noise within the preliminary modelled zone of possible avoidance may result in impacts on the ecological functionality of animals. Such effects could result in reduced fitness of individuals, and subsequently could lead to effects at the population level for harbour porpoise. Animals are however likely to follow a dose-response relationship, and so the numbers presented in this PEIR are over-precautionary. There is also the potential for effects (in EIA terms) to arise from exposure to noise levels that induce TTS/fleeing, although this is likely to be to a lesser extent than behavioural effects (due to smaller magnitude of impact and smaller proportion of the MU population affected). Impacts are predicted to occur over the 2.5 year piling period (split into two phases with up to six years between phases) with recovery possible over the medium term. However, as discussed, the preliminary information presented here is based on levels of conservatism, and refinement of the assessment will be undertaken for the Environmental Statement.

White-beaked dolphin

4.11.1.112 A range of effects arising from subsea noise during piling have been assessed for white-beaked dolphin and this PEIR reflects the various effects from potential auditory injury to possible disturbance. Potential effects are predicted to occur during the piling phase of the offshore construction period, and would affect white-beaked dolphin directly during the periods when pile-driving activity takes place (up to 604.8 days piling over a two and a half year piling period, split into two phases with a gap of up to six years between phases for the maximum design temporal scenario), with potential for recovery to baseline levels over time. Based on the description of magnitude of the impact and sensitivity of the receptor, it is considered unlikely that subsea noise from piling would result in any significant effects (in EIA terms) on white-beaked dolphin.

Minke whale

4.11.1.113 A range of effects arising from subsea noise during piling have been assessed for minke whale and this PEIR reflects the various effects from potential auditory injury to possible disturbance. Although the range of potential behavioural effects is large for minke whale, the number of animals affected in relation to the GCNS MU population is small and therefore there is less likelihood for population-level effects to occur. The effects are predicted to occur during the piling period of the offshore construction period and would affect minke whale directly during the periods when pile-driving activity takes place (up to 604.8 days piling over a two and a half year piling period, split into two phases with a gap of up to six years between phases for the maximum design temporal scenario), with potential for recovery to baseline levels over time. Based on the description of magnitude of the impact and sensitivity of the receptor, it is considered unlikely that subsea noise from piling would result in any significant effects (in EIA terms) on minke whale.

Grey seal

4.11.1.114 A range of effects arising from subsea noise during piling have been assessed for grey seal and this PEIR reflects the various effects from potential auditory injury to possible disturbance. The effects are predicted to occur during the piling phase of the offshore construction period, and would affect grey seal directly during the periods when pile-driving activity takes place (up to 604.8 days piling over a two and a half year piling period, split into two phases with a gap of up to six years between phases for the maximum design temporal scenario), with potential for recovery to baseline levels over time. Based on the description of magnitude of the impact and sensitivity of the receptor, it is considered unlikely that subsea noise from piling would result in significant effects (in EIA terms) on grey seal as a result of exposure to noise levels that could induce PTS or TTS/fleeing.

4.11.1.115 There is, however, uncertainty as to the extent of behavioural effects on grey seal since there is no available threshold to assess this impact. Therefore, given that grey seals are likely to occur within the Hornsea Three marine mammal study area (including animals from Natura 2000 sites designated for this species), there may be the potential for impacts to arise from exposure to levels of subsea noise that elicit a behavioural response. However, against a background of increasing numbers of grey seal within the regional marine mammal study area it is considered unlikely that behavioural disturbance could lead to any population level effects due to the small proportion of the SEE and NEE MU population affected.

Harbour seal

4.11.1.116 A range of effects arising from subsea noise during piling have been assessed for harbour seal and this PEIR reflects the various effects from potential auditory injury to possible disturbance. The effects are predicted to occur during the piling phase of the offshore construction period, and could affect harbour seal directly during the periods when pile-driving activity takes place (up to 604.8 days piling over a two and a half year piling period, split into two phases with a gap of up to six years between phases for the maximum design temporal scenario), with potential for recovery to harbour seal baseline levels over time. Based on the description of magnitude of the impact and sensitivity of the receptor, it is considered unlikely that subsea noise from piling would result in significant effects (in EIA terms) on harbour seal as a result of exposure to noise levels that could induce PTS or TTS/fleeing.

4.11.1.117 The greatest potential for effects (in EIA terms) to arise is due to disturbance during piling, where affected animals may show responses such as reduced foraging or avoidance of the noise source, which could lead to reduced fitness. As described in paragraph 4.11.1.106, harbour seal would be unlikely to be exposed to subsea noise from piling in the Hornsea Three array area due to the large distances from haul-out sites; harbour seal are more likely to be exposed to the more limited piling proposed in the HVAC booster station search area, although, due to the limited duration and extent of the proposed piling within the offshore HVAC booster station search area, behavioural effects for harbour seal alone are not anticipated to be significant (in EIA terms). There is however, currently uncertainty as to the extent of behavioural effects on harbour seal, since there is no available threshold to assess this impact.

Increased vessel traffic during construction may result in an increase in disturbance, collision risk, or injury to marine mammals

4.11.1.118 Increased vessel movement has the potential to result in a range of impacts on marine mammals, including:

- Masking of vocalisations or changes in vocalisation rate;
- Avoidance behaviour or displacement; and
- Injury or death due to collision with vessels.

<u>Magnitude of impact</u>

4.11.1.119 The magnitude of impact from vessel noise or risk of collision with marine mammals is likely to be affected by vessel type, speed, and ambient noise levels. Laist *et al.* (2001) predicted that the most severe injuries from collision with vessels travelling at over 14 knots.

4.11.1.120 Disturbance from vessel noise is likely to occur only where increased noise from vessel movements associated with the construction of Hornsea Three is greater than the background ambient noise level. The Greater Wash is a relatively busy shipping area (see paragraph 4.11.1.124), and therefore background noise levels are likely to be high.

4.11.1.121 Though impacts of increased vessel movement have the potential to occur at times during the 11 year construction period, these are likely to occur in phases throughout this period depending on construction build out programme. Current maximum design scenario would be all construction vessel movements spread throughout two construction phases within the 11 year construction period, with a six year gap between the same construction activity in different phases (Table 4.14). In addition, the conservative assumption has been made that all marine mammal species will react to increases in vessel movement to the same extent, however this is unlikely to be true as some species, for example minke whale and white-beaked dolphin, may be habituated to vessel traffic and therefore may be less sensitive to disturbance. In reality, the distance over which effects will occur will vary according to the species and the ambient noise levels but it has been assumed that masking and potential for avoidance behaviour may occur several kilometres from the noise source for all species.

4.11.1.122 Comparative analysis undertaken by Subacoustech Ltd (volume 4, annex 3.1: Subsea Noise Technical Report) of potential noise sources during construction ranked noise from construction vessels as least noisy when compared to other construction activities. For example, impact piling of monopile or pin pile options was estimated to produce noise levels of 244 dB re 1 µPa @ 1 m (Peak) and 241 dB re 1 µPa @ 1 m (Peak) respectively, and cable laying and dredging as 171 dB re 1 µPa @ 1 m (root-mean-square (RMS)) and 186 dB re 1 µPa @ 1 m (RMS) respectively. Vessel movements from large vessels and small vessels are predicted to produce noise at 171 dB re 1 µPa @ 1 m (RMS) and 164 dB re 1 µPa @ 1 m (RMS) respectively; much less than pile driving. During piling marine mammals could potentially be displaced from the zone within which the onset of TTS occurs, with likely avoidance and possible disturbance occurring for a proportion of the exposed animals over a larger area (see paragraph 4.11.1.3 *et seq.*). Although the frequency components of the noise produced by vessels are different to those from piling, and the noise is a continuous sound as opposed to impulsive, vessels transiting the areas affected by subsea noise during piling may not elicit the same reactions in marine mammals since animals could potentially be responding first and foremost to the greater noise levels produced by piling. Individuals have greater potential to be impacted by increased vessel movements during periods when piling is not taking place.

4.11.1.123 Table 4.14 details the type of construction vessels predicted to be used, and the number of vessel movements (return trips) associated with the construction of Hornsea Three. Assuming a maximum design scenario where vessel movements are spread over two construction phases during the 11 year offshore construction period, this would equate to a potential increase in vessel movements of approximately 5,888 per construction phase, or 2,356 per year/78 per month/6.45 per day during each 2.5 year construction phase within the 11 year offshore construction period. These numbers are based upon an assumption that the same (maximum) number of vessels transits would occur to/from port for each foundation installed. It is highly likely, however, that a proportion of vessels will be stationary or slow moving throughout construction activities for significant periods of time, particularly smaller vessels, therefore the actual increase in vessel traffic moving around the site and to/from the port to the site will occur over short periods of offshore construction activity. The likelihood is therefore that actual increased vessel movements within offshore construction periods will be lower than stated above. Vessels operators will follow the code of conduct (Table 4.19) to avoid any abrupt changes in speed and therefore increasing their predictability of movement to marine mammals.

4.11.1.124 The current level of vessel activity passing through the Hornsea Project One, Hornsea Project Two and Hornsea Three array areas, plus a 10 NM buffer (shipping and navigation study area) is on average24 vessels per day (chapter 7: Shipping and Navigation). This is equal to 725 vessel movements per month or 8,700 vessel movements per year, within a 10 NM radius of Hornsea Project One, Hornsea Project Two and Hornsea Three. The future baseline (within 20 years of current baseline and not vessel traffic associated with Hornsea Project One, Hornsea Project Two or Hornsea Three) is expected to show an increase in vessel activity within the same study area to 9,600 vessels per year, which equates to on average 800 per month, or 26 per day.

4.11.1.125 Vessel traffic associated with Hornsea Three has the potential to lead to an increase in vessel movements within the Hornsea Three shipping and navigation study area. This area does not equate exactly to either the Hornsea Three marine mammal study area or the Regional marine mammal study area, however as a conservative assumption it has been taken to be more similar to the Hornsea Three marine mammal study area. This increase in vessel movement could lead to an increase in interactions between marine mammals and vessels during offshore construction.

4.11.1.126 A maximum of four turbine installation vessels, 24 support vessels, and 12 transport vessels are assessed to be required on site in Hornsea Three at any one time. Impacts are predicted to be reversible except in the case of a vessel strike in which case the impact would be irreversible (i.e. could lead to mortality in the receptor). However, due to the likelihood of animals showing some degree of habituation to vessel noise other than in very close proximity, the potential for more than a minor shift from baseline is considered unlikely. The likelihood of a strike occurring is considered to be very low due to avoidance behaviour, particularly where vessels follow defined routes, and strikes do not necessarily lead to mortality (paragraph 4.11.1.134).

4.11.1.127 The impact is predicted to be of local spatial extent, short to medium term duration (11 year overall offshore construction period with a six year gap between the same construction activity in different phases), intermittent, and both reversible (in the case of increased noise), and irreversible (in the case of a collision). It is predicted that the impact will affect the receptor both directly (collision) and indirectly (disturbance from vessel noise). The magnitude is therefore, considered to be **minor** (taking into account low likelihood of a strike occurring (paragraphs 4.11.1.126 and 4.11.1.134).

<u>Sensitivity of the receptor</u>

4.11.1.128 The main source of noise from vessels comes from propeller cavitation and Senior *et al.* (2008) found that vessel noise increases with speed and loading for all vessel sizes. Reactions and are often linked to changes in the engine and propeller speed (Richardson *et al.*, 1995).

4.11.1.129 Studies have shown that unless the received vocalisation and masking noise come from the same direction, masking is unlikely to occur at significant levels (Richardson *et al*., 1995). This is because directional hearing, coupled with the strong directional nature of echolocation pulses, is an important adaptation in echolocating marine mammals.

4.11.1.130 Hastie *et al*. 2003 observed changes in surface behaviour, and Palka and Hammond (2001) reported animals avoiding vessels. Dolphins and porpoises may be more sensitive to high frequency noise such as those associated with high-speed engines, and baleen whales are likely to be more sensitive to slower moving vessels emitting lower frequency noise. However Watkins (1986) reported avoidance behaviour in baleen whales from loud or rapidly changing noise sources, particularly where a boat approached an animal. Pirotta *et al.* (2015) found that transit of vessels in the Moray Firth resulted in a reduction (by almost half) of the likelihood of recording bottlenose dolphin prey capture buzzes. They also suggest that vessel presence, not just vessel noise, resulted in disturbance. There is however likely to be rapid recovery from disturbance from vessel presence and vessel noise, as they recorded little pre-emptive disturbance or recovery time following disturbance. There is evidence of habituation to boat traffic, particularly in relation to larger vessel types (Sini *et al.,* 2005). Lusseau *et al*. 2011 (Scottish Natural Heritage (SNH) commissioned report), predicted that increased vessel movements associated with offshore wind development in the Moray Firth did not have a negative effect on the local population of bottlenose dolphin.

4.11.1.131 Richardson *et al*. (2005) reported avoidance behaviour or alert reactions in harbour seal when vessels approach within 100 m of a haul-out (Richardson *et al*., 2005), however seals are known to be curious and have been recorded approaching tour boats that regularly visit an area, and may habituate to sounds from tour vessels (Bonner, 1982).

4.11.1.132 Studies have reported that noise levels from large vessels have not caused damage to marine mammal hearing ability, though local disturbance to marine mammals may result (Malme *et al.,* 1989, Richardson *et al.,* 1995). This however will be dependent on individual hearing ranges and background noise levels within the locality.

4.11.1.133 Marine mammals can both be attracted to, and avoid, vessels. Harbour porpoise are particularly sensitive to high frequency noise and are more likely to avoid vessels, whereas other species such as white-beaked dolphin are regularly sighted near vessels and may also approach vessels (e.g. bow-riding). Dolphins are however also known to show behaviours such as increased swimming speed, avoidance, increased group cohesion and longer dive duration (Miller *et al.,* 2008) as a result of vessel presence. Sensitivity to vessel noise is most likely related to the marine mammal activity at the time of disturbance (Senior *et al*., 2008, ICW, 2006). For example, resting dolphins are likely to avoid vessels, foraging dolphins will ignore them and socialising dolphins may approach vessels (Richardson *et al*., 1995).

4.11.1.134 Vessel strikes are known to be a cause of mortality in marine mammals (Pace *et al.,* 2006), but it is possible that mortality from vessel strikes is under-recorded (David, 2006). Laist *et al.* (2001) reported that collisions between vessels and large whales tended to lead to death, but non-lethal collision has also been reported by Van Waerbeek *et al.* (2007). Collisions between vessels and marine mammals are not necessarily therefore lethal.

4.11.1.135 As marine mammals depend on hearing for location of prey, migration and communication they are sensitive to increased noise from vessel movement, and potentially to disturbance from the presence of vessels during construction of Hornsea Three. Collision with vessels could also cause death or injury to marine mammals. The baseline review (volume 5, annex 4.1: Marine Mammal Technical Report) showed that numbers of animals (apart from harbour porpoise) were relatively low in the Hornsea Three array area when compared to the regional marine mammal study area.

4.11.1.136 It is considered that there is a high likelihood of avoidance from both increased vessel noise and collision risk, with both a high potential for recovery (< 1 year) for increased noise, and medium potential for recovery for collision risk (reflecting the low likelihood of collision and potential for non-lethal collision to occur).

4.11.1.137 All marine mammals considered in this PEIR are either of international or national importance.

4.11.1.138 Marine mammals are deemed to be of low vulnerability, both high recoverability (increased noise) and medium potential for recovery (collision risk), and high to very high conservation value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of the effect

4.11.1.139 Overall, it is predicted that the sensitivity of the receptor is considered to be **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

4.11.1.140 Due to the **medium** sensitivity of receptors and the **minor** magnitude of effect (due to the likelihood that animals will show some degree of habituation), and the availability of alternative foraging areas, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Increased suspended sediment arising from construction activities, such as cable and foundation installation, may reduce water clarity and may impair the foraging ability of marine mammals

4.11.1.141 Marine mammals use vision to navigate in their environment, detect prey and avoid obstacles. Increases in SSC arising from construction activities may affect marine mammals through visual impairment.

Magnitude of impact

4.11.1.142 The southern North Sea has a naturally moderate to high turbidity, especially during the winter when the East Anglian Plume leads to increased sediment levels approximately 50 km to the south of Hornsea Three (see Figure 1.9 in volume 2, chapter 1: Marine Processes). SSC within the Hornsea Three array area was typically found to be in the range 10 to 30 mg/l although slightly higher values were experienced during spring tides and storm conditions (section 1.7 in volume 2, chapter 1: Marine Processes).

4.11.1.143 Against this background of natural variability, potential impacts have been considered in relation to an increase in suspended sediment arising from: a) drilling operations for monopile foundations, b) seabed preparation for installation of gravity base foundations and c) array, interconnector and export cable installation using a mass flow excavator (Table 4.14). Associated deposition of sediment is unlikely to directly affect marine mammals and therefore has been considered later in this chapter as one of the potential indirect effects that could lead to a change in the fish and shellfish prey resources of marine mammals (e.g. from habitat loss).

4.11.1.144 During drilling operations, SSC has the potential to increase by tens to hundreds of thousands mg/l at the point of sediment release (near the water surface). The Hornsea Three array area and offshore cable corridor is characterised by the presence of coarse grained sediments with both sand and sandy gravel prevalent. Sediment released during drilling will be carried as a narrow plume (up to a few hundred metres wide), aligned with the tidal stream, over a range of between 3.5 to 7.0 km from the point of release. Within this area the increase is likely to be in the low tens of mg/l and beyond this, finer sediments may be carried in much lower concentrations of <10 mg/l. Fine sediment concentrations may persist in suspension for hours to days, but will become diluted to concentrations indistinguishable from the background levels within around one day (chapter 1: Marine Processes).

4.11.1.145 An increase in SSC arising from seabed preparation for installation of gravity base foundations is related to the passive phase of the plume comprised of finer sediments which are likely to stay in suspension and therefore will affect a larger area. Sand particles could remain in suspension for up to approximately 15 minutes and therefore may be transported up to approximately 0.5 km, with increases in SSC in excess of natural ranges over a short timescale (chapter 1: Marine Processes). Finer sediment fractions would remain in suspension for a longer period, affecting a larger area for a longer period. Elevations in SSC above background levels at distances of hundreds of metres to a few kilometres are predicted to be relatively low (i.e. less than ~20 mg/l) and within the range of natural variability. After 24 hours, elevations in SSC are predicted to typically be less than 5 mg/l, i.e. well within the range of natural variability.

4.11.1.146 Disturbance of medium to coarse sand and gravels during cable installation using a mass flow excavator are likely to result in a temporally and spatially limited plume affecting SSC levels (and settling out of suspension) in close proximity to the point of release. SSC will be locally elevated within the plume close to active cable burial up to tens or hundreds of thousands of mg/l, although the change will only be present for a very short time locally (i.e. seconds to tens of seconds) before the material resettles to the seabed. Depending on the height to which the material is ejected and the current speed at the time of release, changes in SSC will be spatially limited to within metres downstream of the cable for gravels and within tens of metres for sands. Finer material will be advected away from the release location by the prevailing tidal current. High initial concentrations (similar to sands and gravels) are to be expected but will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within hundreds to a few thousands of metres of the point of release. Only a small proportion of the material disturbed is expected to be fines, with a corresponding reduction in the expected levels of SSC (volume 5, annex 1.1: Marine Processes Technical Report).

4.11.1.147 The impact of construction activities leading to an increase in SSC is predicted to be of local spatial extent, short to medium term duration (11 year overall offshore construction period with a six year gap between the same construction activity in different phases), intermittent and reversible. It is predicted that the impact will affect marine mammals directly (visual impairment). The magnitude is considered to be **negligible**.

<u>Sensitivity of the receptor</u>

4.11.1.148 Marine mammals regularly occur in turbid environments and therefore are adapted to finding prey in such conditions. Marine mammals forage through the diel cycle and can therefore successfully forage in low light conditions, including at night. Most marine mammals rely on vision to some extent: the large forward pointing eyes of seals gives them binocular vision and suggests that this is an important sense for detecting prey.

4.11.1.149 The use of echolocation by harbour porpoise and white-beaked dolphin enables these species to locate prey that is out of sight. Prey capture may be more difficult for non-echolocating species, such as seals, in turbid environments. Most marine mammals, however, have an acute sense of touch. Seals possess sensitive muzzles with vibrissae or sensory whiskers that these species use to detect prey items either through direct contact or due to receiving vibrations in the water column (Denhardt *et al*., 2001). Minke whale also use vibrissae to sense their prey and olfactory receptors may also be important in detecting prey. These senses are also used to navigate in the marine environment, allowing animals to avoid obstacles if undetected using their visual sense.

4.11.1.150 In general, since light is limited in the marine environment, marine mammals use their hearing, instead of sight, as their primary sense to gain information about their environment. It is therefore considered that marine mammals, VERs of national to international importance, are of low vulnerability and will show high recoverability. The sensitivity of marine mammals to increased SSC is therefore considered to be **low**.

<u>Significance of the effect</u>

4.11.1.151 The sensitivity of marine mammals is considered to be **low** and the magnitude is assessed as being **negligible**. The effect will therefore be of **negligible** significance and not significant in EIA terms.

4.11.1.152 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect and the availability of alternative foraging areas, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **negligible** significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Accidental pollution release during construction (including construction activities, vessels, machinery, and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals

4.11.1.153 Accidental release of pollutants from installation vessels during construction and offshore fuel storage tanks may have a negative effect on marine mammals, including avoidance of affected areas and in the case of chemical spills, the potential for sub-lethal or lethal effects, depending on the concentrations of toxins and the extent of exposure.

Magnitude of impact

4.11.1.154 The potential sources of pollution during the construction phase include vessel movements, use of drilling muds and storage of chemicals including lubricants, coolant, hydraulic oil and fuel on offshore platforms (Table 4.14). The magnitude of the impact is dependent on the nature of the pollution incident but the Strategic Environmental Assessment (SEA) carried out by DECC (2011; paragraph 5.13.2.1) recognised that, "*renewable energy developments have a generally limited potential for accidental loss of containment of hydrocarbons and chemicals, due to the relatively small inventories contained on the installations (principally hydraulic, gearbox and other lubricating oils, depending on the type of installation)*". Any spill or leak within the offshore regions of Hornsea Three would be immediately diluted and rapidly dispersed.

4.11.1.155 Throughout construction there will be the requirement to store fuel offshore for the purposes of refuelling crew transfer vessels (CTVs) and/or helicopters with fuel storage assumed to be placed on offshore accommodation platforms (see Table 4.14). An impact upon marine mammal receptors would only be realised if an incident occurs where the fuel is accidentally released.

4.11.1.156 The historical frequency of pollution events in the southern North Sea is low considering the density of existing marine traffic in the area. As part of the project design, an MPCP will be developed (Table 4.19) which will include measures to follow published guidelines and best working practice for the prevention of pollution events. Therefore, accidental release of contaminants will be strictly controlled and an emergency plan will also be put in place in the unlikely event of an incident. Provided that the MPCP is followed, there are unlikely to be any pollution events, and those that do occur would be very small scale and short lived, due to rapid dispersal and dilution.

4.11.1.157 The impact is predicted to be of local to regional spatial extent, short to medium term duration (11 year overall offshore construction period with a six year gap between the same construction activity in different phases), intermittent and reversible. It is predicted that the impact has the potential to affect marine mammal receptors both directly and indirectly. The magnitude is therefore, considered to be **negligible.**

Sensitivity of the receptor

4.11.1.158 Release of contaminants into the water column may lead to direct impacts on marine mammals through ingestion, inhalation or absorption through the skin, and potentially longer-term indirect impacts from bioaccumulation in the food chain. Seals are likely to be more vulnerable to the effects of surface pollution than cetaceans because of their reliance on terrestrial sites for resting, moulting and pupping. Of particular concern would be the contamination of the coastal waters of North Norfolk and Lincolnshire, where grey and harbour seal haul-out in large numbers. Seal pups entering the water would be particularly vulnerable as oil residues can reduce the thermal properties of neonate animals, increasing their susceptibility to hypothermia (Jenssen, 1996).

4.11.1.159 Waterborne hydrocarbon contaminates could adhere to and foul the baleen plates of minke whale as these animals surface. Fouling is likely to be short-term but ingestion of contaminated food may have longer term consequences for the health of individuals. The release of oils is also a serious concern for all marine mammals as the inhalation of toxic, volatile compounds could lead to mortality.

4.11.1.160 Whilst seals and cetaceans are highly mobile, and capable of detecting surface slicks in open water, the more extensive the slick, the more likely it is that an animal will surface within it (Geraci and St. Aubin, 1990).

4.11.1.161 Marine mammals, VERs of national to international importance, are likely to avoid any minor events and therefore are of low vulnerability with the potential for high recoverability. Their sensitivity is therefore considered to be **low**.

Significance of the effect

4.11.1.162 The sensitivity of marine mammals to accidental pollution during construction is considered to be **low** and the magnitude is assessed as being **negligible**. The effect will therefore be of **negligible** significance and not significant in EIA terms.

4.11.1.163 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **negligible** significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Changes in the fish and shellfish community resulting from impacts during construction may lead to loss of prey resources for marine mammals

4.11.1.164 Fish and shellfish receptors are vulnerable to a number of impacts during construction including temporary habitat loss during installation works, increased SSC and sediment deposition, underwater noise as a result of installation of foundations and subtidal cables, and accidental pollution (chapter 3: Fish and Shellfish Ecology).

4.11.1.165 The key prey species for marine mammals include a number of clupeids (e.g., herring), gadoids (e.g., cod, whiting), flatfish and sandeels. These species have been identified as important components of the fish community within the Hornsea Three fish and shellfish study area and subsequently negative effects on the fish assemblages identified in the Hornsea Three impact assessment may have indirect negative effects on marine mammal receptors.

Magnitude of impact

4.11.1.166 Temporary habitat loss could potentially affect spawning, nursery or feeding grounds of fish and shellfish receptors, with demersal fish and shellfish, and demersal spawning species the most vulnerable (chapter 3: Fish and Shellfish Ecology). During seabed preparation for foundation installation and cable burial, suspended sediments will be released into the water column, which will subsequently be deposited in mounds of tens of centimetres to several metres deep. The resulting temporary habitat loss is predicted to affect an area of 22.42 km^2, equating to 0.01% of the total seabed area within the southern North Sea fish and shellfish area and 2.23% of Hornsea Three array area and offshore cable corridor. Due to the localised nature of the effects and the small proportion of the southern North Sea fish and shellfish study area affected, temporary loss of habitat was considered unlikely to diminish ecosystem functions for fish and shellfish species. The magnitude of the impact was assessed as being minor and the sensitivity of fish and shellfish receptors ranged from low to medium; consequently, the effects of temporary habitat loss was of negligible to minor adverse significance.

4.11.1.167 An increase in SSC may lead to short term avoidance of affected areas by sensitive fish and shellfish species, although many species are considered to be tolerant of turbid environments and regularly experience changes in the SSC due to the natural variability in the southern North Sea. Fish and shellfish species that are likely to be affected by sediment deposition are those that feed or spawn on or near the seabed (chapter 3: Fish and Shellfish Ecology). Most species known to have spawning grounds within the Hornsea Three fish and shellfish study area are pelagic spawners, except for sandeel and herring, which are both demersal spawners. The assessment considered the effects of sediment deposition on these two species and it was concluded that due to the small elevations in sediment deposition expected, particularly in relation to the locations of the key spawning areas, detrimental effects are considered unlikely to occur. Given that the impact of SSC and sediment deposition is likely to be temporary and localised, and that any increase will be in the range of natural variability (see paragraph 3.11.1.24, chapter 3: Fish and Shellfish Ecology), the magnitude of effect was deemed to be minor and the sensitivity of fish and shellfish receptors was considered to be low (medium for herring only). The effect was therefore assessed as being of minor adverse significance.

4.11.1.168 Subsea noise from pile driving and other construction activities could negatively affect fish and shellfish communities as a result of mortality, injury or behavioural effects (chapter 3: Fish and Shellfish Ecology). Subsea noise modelling carried out showed that (recoverable) injury ranges extend out to a mean distance of 1 km (maximum 4 km) from the source for a 5,000 kJ hammer energy and out to a mean distance of 400 m (maximum 1.5 km) from the source for a 2,500 kJ hammer energy (volume 4, annex 3.1: Subsea Noise Technical Report). The project designed soft start (Table 4.19) is considered likely to deter sensitive species from occurring within the range of potential mortal injury and recovery is expected for species beyond this range. Subsea noise from construction activities could also result in behavioural effects ranging from startle responses through to strong avoidance behaviour and the responses will differ depending on the hearing sensitivity of the species. Behavioural effects on demersal and shellfish species were predicted to occur within 1 km of the piling operations, whilst gadoids (e.g. cod and whiting), herring and sprat could be affected over tens of kilometres from the source (although not necessarily as a strong avoidance reaction). The magnitude of subsea noise effects was considered to be minor and the sensitivity of the receptors was assessed as low to medium, therefore, the effect was of minor adverse significance.

4.11.1.169 As for marine mammals, the potential for an accidental pollution event is very low provided that the MPCP is followed. Fish eggs and larvae are likely to be of medium sensitivity due to their lack of mobility, and potential effects include abnormal development, delayed hatching and reduced hatching success (chapter 3: Fish and Shellfish Ecology). Adult fish of most species are of low sensitivity due to their mobility and ability to avoid polluted areas, although bioaccumulation may occur in flatfish exposed to pollutants. Any impacts are likely to be of limited spatial extent, short term duration, intermittent and reversible and potential effects are predicted to be of low magnitude. Therefore, the assessment concluded that the effects would be of minor adverse significance.

4.11.1.170 In summary, potential effects of changes in prey resources on marine mammals is of short to medium term duration (11 year overall offshore construction period with a six year gap between the same construction activity in different phases) and would be temporary, intermittent, and reversible. It is predicted that the impact will affect marine mammals indirectly. The magnitude of effect is therefore predicted to be **minor**.

Sensitivity of the receptor

4.11.1.171 Marine mammals exploit a suite of different prey items and can travel great distances to forage. It is likely that the effects described for fish and shellfish will occur over a similar, or lesser, extent and duration as those for marine mammals. For example, avoidance behaviour of fish during piling works will lead to displacement over potentially smaller ranges than those given for most marine mammals. In addition, as prey moves out of the areas of potential impact, so marine mammals are likely to follow in order to exploit these resources.

4.11.1.172 The communities found within the Hornsea Three fish and shellfish study area were characteristic of the fish and shellfish assemblages in the wider southern North Sea and therefore, due to the highly mobile nature of marine mammals, it is likely that these animals will be able to exploit similar resources elsewhere. There could, however, be an energetic cost if animals have to travel further to a preferred foraging ground. For example, a tagging study conducted by SMRU showed that both grey and harbour seals regularly transit between their haul-out locations on the Norfolk and Lincolnshire coasts to the west of the Hornsea Three array area and are regularly found within the Hornsea Three offshore cable corridor (Figures 4.26 and 4.32 of volume 5, annex 4.1: Marine Mammal Technical Report). Grey seal also pass through the Hornsea Three array area, most likely on route to foraging grounds further afield. The subsea noise assessment predicted that, for the largest hammer energy (5,000 kJ), there is potential for avoidance of fish species over a range of 31 to 37 km for piling within the Hornsea Three array area and over 19 to 21 km within the Hornsea Three offshore cable corridor (volume 4, annex 3.1: Subsea Noise Technical Report). Subsequently, this displacement of the fish and shellfish resources could lead to detrimental effects on seals through loss of prey items, although it is likely that marine mammals would be displaced, potentially over larger ranges, at the same time (paragraph 4.11.1.3 *et seq*.).

4.11.1.173 Given the potential for a loss of a small proportion of available foraging habitat, marine mammals, VERs of national to international importance, are of low vulnerability with the potential for high recoverability. The sensitivity of the marine mammals is considered to be **low**.

Significance of the effect

4.11.1.174 The sensitivity of marine mammals is considered to be **low** and the magnitude is assessed as being **minor**. The effect will therefore be of **minor** adverse significance and not significant in EIA terms.

4.11.1.175 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect, the **minor** magnitude of effect the absence of barrier effects, and the availability of alternative foraging areas, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Future monitoring

4.11.1.176 A marine mammal monitoring plan, forming part of the CoCP, will be devised in consultation with the SNCBs.

4.11.2 Operational and maintenance phase

4.11.2.1 The impacts of the offshore operation and maintenance of Hornsea Three have been assessed on marine mammals. The environmental impacts arising from the operation and maintenance of Hornsea Three are listed in Table 4.14 along with the maximum design scenario against which each operation and maintenance phase impact has been assessed.

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

Noise and vibration arising from operational turbines may cause disturbance to marine mammals

4.11.2.3 Marine mammals use hearing as their primary sense in the marine environment and therefore may be affected by noise and vibration arising from operational turbines.

Magnitude of impact

4.11.2.4 Subsea noise is predicted to occur as a result of the operation of up to 342 turbines within the Hornsea Three array area (Table 4.14). Turbine operation mainly produces a low frequency, low level noise originating from the internal mechanics of the turbine such as the gearbox and generator. Operational noise is generally broadband and low levels, with some narrower band, tonal noise produced (Madsen *et al*., 2006; Tougaard and Henriksen, 2009; Tougaard *et al*., 2009). Noise levels generated above the water surface are low enough that no significant airborne sound will pass from the air to the water (volume 4, annex 3.1: Subsea Noise Technical Report).

4.11.2.5 There is considerable variation in the reported noise levels from operating wind turbines, which may be in part due to different wind speeds, recording conditions and sound radiation patterns (Madsen *et al.,* 2006). The relationship between wind speed and noise production is of particular importance for operating wind turbines, as the vibration and noise produced by wind turbines increases with wind speed (Madsen *et al.,* 2006).

4.11.2.6 Early measured data are mainly for smaller capacity wind turbines ranging from about 0.2 to 3 MW (summarised in Wahlberg and Westonberg, 2005; Madsen *et al*., 2006, Nedwell *et al*., 2007, Tougaard and Henriksen, 2009) and although there are currently no published data for wind turbines with a rated capacity of 3.6 MW or above, the overall broadband level may not be significantly higher. Nedwell *et al*. (2007), for example, found little observable difference between operational noises measured for a 2 MW and a 3 MW turbine and suggested that a 3.6 MW turbine may not be significantly noisier either.

4.11.2.7 To determine the possible noise levels arising at Hornsea Three, subsea noise modelling was carried out for three turbine sizes, 7 MW, 10 MW and 15 MW, based on measured noise levels of operational turbines at existing wind farms (3 MW to 6 MW) taken by Subacoustech. The predicted levels were extrapolated as SEL_{cum} values and adjusted for the criteria given for non-impulse and continuous noise (NMFS, 2016). The modelled effect ranges for TTS/fleeing (i.e. displacement) based on the marine mammal criteria given in NMFS (2016) were found to be less than 10 m, even for the largest turbine (volume 4, annex 3.1: Subsea Noise Technical Report).

4.11.2.8 This result is supported by a published study which demonstrated that a behavioural response is only likely within close proximity to the turbine. For harbour porpoise this may be limited to just a few metres, whilst for seals the response may be up to a few hundred metres (Tougaard and Henriksen, 2009). However, this study also showed that operational noise is unlikely to result in auditory masking of either seals or harbour porpoise, due to the low levels and low frequencies produced. A detailed literature review of the potential magnitude of effects of subsea noise from operational turbines on marine mammals is presented in volume 4, annex 3.1: Subsea Noise Technical Report. In summary, elevations of subsea noise were found to be only slightly above ambient noise levels (Cefas, 2010) and no detectable effects were found on marine mammals (e.g. Madsen *et al.*, 2006; Teilman *et al.*, 2006a and 2006b; Brasseur *et al*., 2010).

4.11.2.9 Behavioural effects are therefore considered to be localised to within tens of metres of each of the operational turbines (up to 342 (Table 4.14)). Since the actual areas where behavioural disturbance may be likely are expected to be small compared to the turbine separation distances (1,000 m or more) these areas would not be expected to overlap spatially. The magnitude of the impact is predicted to be very localised, long-term and continuous (during the operational life-time of the offshore wind farm), and reversible. It is predicted that the impact will affect marine mammals directly. The magnitude is considered to be **negligible**.

<u>Sensitivity of the receptor</u>

4.11.2.10 Peak sound pressure and sound exposure levels from operational noise may be audible to marine mammals above ambient levels (Koshinski *et al.,* 2003). It is generally believed that noise from operational wind turbines will not cause injury to marine mammals, even at a distance of a few metres, and avoidance is only likely to occur in the vicinity of a turbine (e.g., Madsen *et al*., 2006; Wahlberg and Westerberg, 2005; Tougaard and Henriksen, 2009). There are a wide range of model predictions regarding the potential ranges at which species could be affected by operational noise. For the most part, marine mammals could hear the noise arising from operational turbines (i.e. within the range of audibility), with ranges varying according to species, turbine size, wind speed and ambient noise levels. Tougaard and Henriksen (2009) recorded noise at three types of turbines and comparison with marine mammal audiograms suggested that the zone of audibility is within 20 to 70 m for harbour porpoise and a few hundred metres to several kilometres for harbour seal. They hypothesise that behavioural reactions are unlikely to extend more than a few hundred metres for either species. In contrast, Marmo *et al.* (2013) used noise models to predict the range of audibility for harbour porpoise and minke whale out to 18 km, although possible avoidance is likely to be more localised with only a small proportion of animals affected (Marmo *et al.,* 2013). Despite the variation in predictions, the studies imply that generally the area between adjacent turbines is unlikely to pose a disturbance threat to marine mammals and the noise resulting from the offshore wind farm will likely decay to ambient levels within a few hundred metres beyond the boundary of the offshore wind farm.

4.11.2.11 Evidence that there is unlikely to be any significant behavioural response from operational noise comes from experiments and studies of other offshore wind farms. Koshinski *et al.,* (2003) observed the response of harbour porpoise and harbour seal to playbacks of underwater sound recordings that simulated an operating wind turbine. Neither species showed aversive behaviour resulting from the noise; with harbour porpoise appearing curious of the sound source, approaching the playback equipment and investigating it with echolocation clicks. Whilst the approach distance to the sound source did increase slightly for both species, there was generally a weak behavioural response and numbers within the study area remained unchanged during the experiment.

4.11.2.12 These findings were supported by more observations in the field. At the Horns Rev and Nysted offshore wind farms in Denmark, long-term monitoring showed that both harbour porpoise and harbour seal were sighted regularly within the operational offshore wind farms, and within two years of operation, the populations had returned to levels that were comparable with the wider area (Diederichs *et al*., 2008). Similarly, a monitoring programme of the Egmond aan Zee offshore wind farm in the Netherlands showed that during operation, significantly more porpoise activity was recorded within the offshore wind farm compared to the reference area (Scheidat *et al*., 2011). The findings from this study, together with similar results from other Dutch and Danish offshore wind farms (Lindeboom *et al*., 2011), suggest that harbour porpoise may be attracted to increased foraging opportunities within operating offshore wind farms (Scheidat *et al*., 2011). Indeed, recent tagging work by Russell *et al*., (2014) found that harbour and grey seals showed striking grid-like movement patterns as these animals moved between individual turbines and these data strongly suggest that the structures were used for foraging.

4.11.2.13 Marine mammal receptors are deemed to be of low vulnerability, high recoverability and of national to international importance. The sensitivity of the receptor is therefore considered to be **low**.

Significance of the effect

4.11.2.14 Overall, it is predicted that the sensitivity of the receptor is considered to be **low** and the magnitude is deemed to be **negligible**. The effect will, therefore, be of **negligible** adverse significance, which is not significant in EIA terms.

4.11.2.15 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **negligible** significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Increased vessel traffic during operation and maintenance may result in an increase in disturbance to and collision risk with marine mammals

4.11.2.16 The potential impacts of increased vessel movement have been detailed in paragraph 4.11.1.118 and have not been reiterated here.

4.11.2.17 In summary the potential impacts of increased vessel movement during the operation and maintenance phase of Hornsea Three are:

- Masking of vocalisations or changes in vocalisation rate;
- Avoidance behaviour or displacement; and
- Injury or death due to collision with vessels.

Magnitude of impact

4.11.2.18 Table 4.14 details the type and number of operation and maintenance vessels predicted to be used over the 25 year duration of the operational lifetime of Hornsea Three.

4.11.2.19 The current level of vessel activity passing through the Hornsea Three marine mammal study area is 12,775 vessel movements per year. Over the expected 25 year operation and maintenance phase of Hornsea Three, there is expected to be an increase of 2,832 vessel movements (return trips) per year. There will therefore be an increase in vessel movement and consequently potential for interactions between marine mammals and operation and maintenance traffic throughout this period.

4.11.2.20 A maximum of four offshore supply vessels and up to 20 CTVs are expected to be on site at Hornsea Three at any one time. Impacts are predicted to be reversible except in the case of a strike in which case the impact would be irreversible (i.e. could lead to mortality in the receptor). However due to the likelihood of animals showing some degree of habituation to vessel noise, the potential for more than a minor shift from baseline is considered unlikely.

4.11.2.21 The impact is predicted to be of local spatial extent, long term duration (25 year operational and maintenance period), intermittent, and both reversible (in the case of vessel noise), and irreversible (in the case of a collision). It is predicted that the impact could affect the receptor both directly (collision) and indirectly (disturbance due to vessel noise). The magnitude is therefore, considered to be **minor** overall.

Sensitivity of the receptor

4.11.2.22 It is considered that there is a high likelihood of avoidance from both increased vessel noise and collision risk, with both a high potential for recovery (< 1 year) for increased noise, and medium potential for recovery for collision risk reflecting the low likelihood of collision and potential for non-lethal collision to occur).

4.11.2.23 As all marine mammals are of either international or national importance, they are deemed to be of low vulnerability, and both high recoverability (increased noise) and to have medium potential for recovery (collision risk). The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of the effect

4.11.2.24 Though there is predicted to be an increase of vessel movement during the 25 year operation and maintenance period of Hornsea Three, this presents a maximum design scenario and does not reflect the fact that most vessels will be stationary or slow moving within Hornsea Three during this period, and will avoid any abrupt changes in speed. Habituation to vessel traffic and predictability of vessel use in relation to speed and direction will lead to maximum avoidance of operation and maintenance vessel traffic by animals.

4.11.2.25 The baseline (volume 5, annex 4.1: Marine Mammal Technical Report) showed that numbers of animals (apart from harbour porpoise) were relatively low in the Hornsea Three array area when compared to the regional marine mammal study area.

4.11.2.26 Overall, it is predicted that the sensitivity of the receptor is considered to be **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

4.11.2.27 Due to the **medium** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse significance, which is not significant in EIA terms.

4.11.2.28 A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Electromagnetic Fields (EMF) emitted by array and export cables may affect marine mammal behaviour

4.11.2.29 During transmission of electricity along the array, interconnector and export cables, low-frequency EMF are emitted. Marine mammals, particularly those species that undertake long distance migrations, may be magneto-sensitive and hence EMF could affect the sensory mechanisms of marine mammals and lead to effects on large-scale movement, small-scale orientation, feeding or mate finding.

Magnitude of impact

4.11.2.30 Electromagnetic fields could arise from up to 850 km of alternating current (AC) array cable, up to 225 km of interconnector cables and up to 1,083 km of HVDC or HVAC export cable (Table 4.14).

4.11.2.31 Electromagnetic fields comprise both the electric (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in tesla (T). Background measurements of the magnetic field are approximately 50 μT in the North Sea, and the naturally occurring electric field in the North Sea is approximately 25 μV/m (Tasker *et al*., 2010). It is common practice to block the direct electrical field (E) using conductive sheathing meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resultant induced electrical field (iE). A key misconception in the understanding of the effects of EMF has been the assertion that cable burial will work to mitigate E and B field effects and that there will be no externally detectable electric fields generated by industry standard subsea power cables. The conclusion of the Collaborative Offshore Wind Research into the Environment) COWRIE 1.5 EMF study (Gill *et al.,* 2005) and subsequent clarification in the Phase 2 COWRIE EMF report (Gill *et al.,* 2009) highlights the fact that there are no burial depths practically achievable that will reduce the magnitude of the B field, and hence the sediment-sea water interface induced E field, are below that at which these fields could be detected by certain marine organisms.

4.11.2.32 A variety of design and installation factors affect EMF levels in the vicinity of the cable, these include current flow, distance between cables, cable orientation relative to the earth's magnetic field (direct current (DC) only), cable insulation, number of conductors, configuration of cable and burial depth. Project design mitigation includes setting minimum separation distances between adjacent cables based on the risks and practicalities of construction and maintenance. In shallower areas, such as the intertidal zone, a minimum separation of 40 m may be expected but this is likely to increase to 100 m in deeper waters. In addition, cables are designed with a protective sheathing to reduce magnetic and electric fields. Clear differences between AC and DC systems are apparent; the flow of electricity in an AC cable changes direction (as per the frequency of the AC transmission) and creates a constantly varying electric field in the surrounding marine environment (Huang, 2005). Conversely, DC cables transmit energy in one direction creating a static electric and magnetic field.

4.11.2.33 Average magnetic fields of DC cables are higher than those of equivalent AC cables (Table 4.38). Induced electric fields emitted from AC and DC cables are not directly comparable, though modelling studies have shown average iE fields from submarine DC cables of 194 μV/m at 0 m horizontal distance from the cable (assuming cable burial to 1 m below seabed and a 5 knot current), with field strength decreasing with horizontal and vertical distance from the cable. The modelling of induced electrical fields for AC cables requires consideration of the size of an organism and its distance from the cable. Ultimately, the effects would depend on site specific and project specific factors related to both the magnitude of EMFs and the ecology of local populations including spatial and temporal patterns of habitat use.

4.11.2.34 The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source. Modelling studies have indicated that the range of the field is in the order of 10 m each side of the cable (assuming 1 m burial) (see Table 4.38; Normandeau *et al*., 2011).

Table 4.38: Average magnetic fields (μT) generated for AC and DC export cables at horizontal distances from the cable (assuming cable burial to a depth of 1 m; source; modified from Normandeau *et al*., 2011).

Distance above seabed (m)	Magnetic field (μT) measured at horizontal distance from cable					
	0 m AC	*0 m DC*	*4 m AC*	*4 m DC*	*10 m AC*	*10 m DC*
0	7.85	78.27	1.47	5.97	0.22	1.02
5	0.35	2.73	0.29	1.92	0.14	0.75
10	0.13	0.83	0.12	0.74	0.08	0.46

4.11.2.35 The orientation of the cable in relation to the earth's geomagnetic field and the distance between buried cables can influence the change in magnetic field. Modelled results show that DC cables that are buried touching can emit a magnetic field of 20 μT less than if separated by 20 m (Normandeau *et al*., 2011). Similarly, cables that run roughly parallel to the earth's geomagnetic field in some locations may cause an increase in the intensity of the magnetic field whereas cables running perpendicular to the earth's geomagnetic field will cause a decrease in magnetic field below ambient levels (Normandeau *et al*., 2011).

4.11.2.36 The impact is predicted to be of local spatial extent (i.e. restricted to within Hornsea Three but of very limited extent where cables are buried), long term duration (i.e. the lifetime of the project), continuous and irreversible (during the lifetime of the project). It is predicted that the impact has the potential to affect marine mammals directly. The magnitude is therefore, considered to be **negligible**.

<u>Sensitivity of the receptor</u>

4.11.2.37 The effects of EMF on marine mammals are not fully understood and assessment of sensitivity is based on conclusions drawn from theoretical studies, rather than empirical evidence. It is not thought that marine mammals are electro-sensitive; however, these species may be sensitive to magnetic fields produced by the current flow on the cable. Theoretical evidence suggests that some species of cetacean may use the Earth's magnetic field to aid with long distance migration (Kirschvink *et al*., 1986). In addition, cetaceans may use ambient magnetic stimuli for several life-history dependant functions including determination of feeding locations, reproduction, and refugia (Normandeau *et al*., 2011).

4.11.2.38 Research suggests that the magnetic impact of subsea cables is unlikely to affect many magnetically sensitive species to any great extent and would likely be perceived as a variation to the Earth's natural field (Normandeau *et al*., 2011). In addition, magneto-sensitive species are unlikely to respond to magnetic fields from AC cables because the rate of change of the field (polarity reversal) would be too rapid for a behavioural response to occur (Normandeau *et al*., 2011).

4.11.2.39 Magnetic fields may only be minimally attenuated by the cable sheath and seabed and therefore the ambient magnetic fields in the vicinity of the cable are likely to be altered only slightly. Likely effects would be seen as changes in behaviour, including sharp exhalations, acoustic activity and slight deviations in their swimming route (Normandeau *et al*., 2011). Sensitivity of a species depends on the water depth that it generally inhabits, such that species that are known to inhabit relatively shallow water and those that feed near the bottom (e.g., harbour porpoise) may be more exposed to EMF than species found in the pelagic zone in deeper water.

4.11.2.40 Normandeau *et al*. (2011) found insufficient information with which to extrapolate their results to baleen whale. There is, however, some evidence that baleen whale use natural geomagnetic field patterns to navigate long-distance migration routes (Walker *et al*., 1992). There are also indications that disruption of background variation in geomagnetic fields (Klinowska, 1986) or local anomalies could cause cetaceans to strand (Klinowska, 1986; Mazzuca *et al*., 1999). Others dispute this conclusion (Brabyn and Frew, 1994). No information exists on the detection or use of either magnetic fields or electric fields by pinnipeds. This highlights the uncertainty associated with assessing the sensitivity of marine mammals to this impact.

4.11.2.41 Evidence from the literature suggests that even for DC cables, which are more likely to affect marine mammals than AC cables (Normandeau *et al*., 2010), there is no evidence to suggest an effect may occur on magneto-sensitive species, other than perhaps very localised behavioural effects. For example, an assessment of the impact of installing HVDC power cables across the Bass Strait, southern Australia, noted that there is no evidence that establishes HVDC cables have affected migratory or other aspects of cetacean behaviour elsewhere (Westerberg *et al.,* 2007). Migration of the harbour porpoise in and out of the Baltic Sea necessitates several crossings of HVDC cables in the Skagerrak and western Baltic Sea without any apparent effect on its migration pattern (Walker, 2001).

4.11.2.42 It is therefore considered that marine mammals, VERs of national to international importance, are of low vulnerability to EMF over the lifetime of the project, with the potential for high recoverability. The sensitivity of marine mammals is assessed as **low**.

<u>Significance of the effect</u>

4.11.2.43 Overall, it is predicted that the sensitivity of the receptor is considered to be **low** and the magnitude is deemed to be **negligible**. The effect will, therefore, be of **negligible** adverse significance, which is not significant in EIA terms.

4.11.2.44 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **negligible** adverse significance, which is not significant in EIA terms.

4.11.2.45 A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017)

Accidental pollution released during operation and maintenance (including maintenance activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals

4.11.2.46 The potential impacts of accidental pollution on marine mammals have been outlined in paragraphs 4.11.1.153 to 4.11.1.155 and have not been re-iterated here.

Magnitude of impact

4.11.2.47 Each turbine within the Hornsea Three array area will also contain components which will require lubricants and hydraulic oils in order to operate; maximum quantities are provided in Table 4.14 and volume 1, chapter 3: Project Description. The nacelle, tower and hub of the turbines will be designed to retain any leaks should they occur.

4.11.2.48 A MPCP will be produced and implemented to cover the operation and maintenance phase of Hornsea Three with the aim of preventing any accidental spills (Table 4.19). As described previously (paragraph 4.11.1.156) in the unlikely event of a spill this MPCP will include mitigation measures, address all potential contaminant releases and include key emergency contact details.

4.11.2.49 The impact is predicted to be of local to regional spatial extent, short term duration, intermittent and reversible. It is predicted that the impact has the potential to affect marine mammal receptors both directly and indirectly. The magnitude is considered to be **negligible.**

Sensitivity of the receptor

4.11.2.50 The sensitivity of marine mammals to accidental pollution has been described previously (paragraph 4.11.1.158 *et seq*.). In summary, release of contaminants into the water column may lead to direct impacts on marine mammals through ingestion, inhalation or absorption through the skin, and potentially longer-term indirect impacts from bioaccumulation in the food chain.

4.11.2.51 Marine mammals, VERs of national to international importance, are likely to avoid any minor events and therefore are of low vulnerability with the potential for high recoverability. Their sensitivity is therefore considered to be **low**.

Significance of the effect

4.11.2.52 The sensitivity of marine mammals to accidental pollution during operation and maintenance is considered to be **low** and the magnitude is assessed as being **negligible**. The effect will therefore be of **negligible** adverse significance and not significant in EIA terms.

4.11.2.53 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **negligible** adverse significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017)

Changes in the fish and shellfish community resulting from impacts during operation and maintenance may lead to loss of prey resources for marine mammals

4.11.2.54 Fish and shellfish assemblages are vulnerable to a number of impacts during the operation and maintenance phase of Hornsea Three including long term habitat loss due to the presence of turbine foundations and scour/cable protection, introduction of new habitat types in the form of hard substrates from the foundations, EMF from subsea cables, underwater noise as a result of operation of the turbines, temporary habitat loss during maintenance operations, accidental pollution, and reduced fishing pressure within the Hornsea Three array area (chapter 3: Fish and Shellfish Ecology).

4.11.2.55 Loss or disturbance to key prey species of marine mammals (e.g. herring, cod, whiting, flatfish and sandeels) may have indirect negative effects on marine mammal receptors.

Magnitude of impact

4.11.2.56 Long term habitat loss due to presence of foundations, scour protection and cable protection is estimated to be up to 5.87 km^2 which represents would affect only a small proportion (0.003%) of the habitat within the southern North Sea fish and shellfish study area. Comparable habitats are present and widespread throughout this southern North Sea fish and shellfish study area. The species most vulnerable to habitat loss are demersal spawning species, such as sandeel and herring. The key spawning grounds for herring are located off Flamborough Head and therefore herring are unlikely to be affected by long term habitat loss. The proportion of sandeel spawning habitat within Hornsea Three is very small and scientific evidence from monitoring at other offshore wind farms suggests that there are unlikely to be long term effects on sandeel (*Hyperoplus sp.*) populations. Similarly, the proportion of spawning habitats for vulnerable shellfish species, including *Nephrops*, brown crab *Cancer pagurus* and lobster *Homarus gammarus,* potentially affected by habitat loss is likely to be very small in the context of the available habitat within the wider southern North Sea fish and shellfish study area. Fish and shellfish were considered to be of low to medium sensitivity to habitat loss and the magnitude is minor. The effect was therefore considered to be of minor adverse significance.

4.11.2.57 Up to 5,046,797 m^2 of new habitat may be present in Hornsea Three during the operation phase due to the presence of turbine foundations, scour protection and cable protection. Introduction of hard substrates may incur beneficial effects as these can act as artificial reefs, allowing colonisation by benthic organisms and attracting associated fish and shellfish communities. Such structures are thought to offer a refuge and an additional food resource for fish and shellfish communities. It is considered likely that the greatest benefit at Hornsea Three will be for crustacean species, such as crab and lobster, due to the expansion of their natural habitats and creation of additional refuge areas.

4.11.2.58 Potential negative effects of the introduction of new habitat were also considered in the assessment due to the potential introduction of non-native indigenous and invasive species (chapter 3: Fish and Shellfish Ecology). Fish and shellfish may be adversely affected through competition for resources. On balance, the assessment concluded that the beneficial and adverse effects of the introduction of hard substrates would be of minor magnitude on fish and shellfish receptors of low (fish) to medium (shellfish) sensitivity. The significance of effect was considered to be minor (beneficial and adverse).

4.11.2.59 Electrical and magnetic fields emitted from subsea cables may have a localised effect on fish and shellfish along the Hornsea Three offshore cable corridor. The most sensitive species are likely to be elasmobranchs, such as rays and dogfish, which use electroreceptors to detect prey and migratory species, such as salmon and European eel, which use the earth's magnetic field to aid in navigation (chapter 3: Fish and Shellfish Ecology). Most species were considered to be of low sensitivity, with the exception of migratory fish, which were of medium sensitivity, but due to the low magnitude of the impact the significance of effect was considered to be minor adverse.

4.11.2.60 There were not considered to be any negative effects of subsea noise arising during turbine operation or temporary habitat loss from maintenance activities (e.g. cable reburial/repair works) on fish and shellfish and therefore the significance for both was negligible.

4.11.2.61 Accidental pollution arising from the release of contaminants into the marine environment during maintenance activities may represent a short term effect of minor magnitude. Provided the EMP is followed (Table 4.19) such an impact is considered unlikely to occur, and due to rapid dispersal over the tidal cycle, the impact on fish and shellfish, low to medium sensitivity receptors, is predicted to be of negligible significance.

4.11.2.62 During the Hornsea Three operational phase, the intensity of fishing activities (including trawling and potting) may be reduced from part of the offshore wind farm, in particular within the 500 m operational safety zones around manned platforms. This has the potential to enhance fish and shellfish populations by providing refuge from fishing activities for certain species targeted by commercial fisheries in the southern North Sea fish and shellfish study area, although noting that there may be an increase in fishing in areas adjacent to Hornsea Three as the fishing vessels reallocate their effort elsewhere. Species most likely to benefit from reduced fishing pressure are the commercially important species including plaice, sole, cod, whiting, herring, *Nephrops*, brown crab and lobster. Many of these species are important prey items for marine mammals within Hornsea Three. The magnitude of impact and sensitivity for fish and shellfish were both assessed as negligible and the significance of the impact was minor beneficial.

4.11.2.63 The overall impact of changes in the fish and shellfish community resulting from operational impacts is predicted to be of local spatial extent, long term (over the design life of 25 years of the project) and continuous. Marine mammal receptors will be affected indirectly. Based on the criteria in Table 4.18 the magnitude is predicted to be **minor** and could be either beneficial or adverse to marine mammal receptors.

<u>Sensitivity of the receptor</u>

4.11.2.64 Marine mammals exploit a range of prey resources and range widely to forage. Although some key prey items may be affected during operation, such as sandeels and herring, these effects are localised and unlikely to result in a significant effect on fish and shellfish assemblages. The potential for the operational offshore wind farm to provide benefits to fish and shellfish may also indirectly benefit marine mammals. For example, the increase in harbour porpoise at Egmond aan Zee offshore wind farm during operation was attributed to a possible 'reef' effect which led to an increase in prey resources in the area (Scheidat *et al.*, 2011). Another beneficial effect may also arise from reduced fishing pressure within the Hornsea Three array area, and subsequently a local increase in abundance of fish and shellfish. Sandeels in particular may benefit from a reduction in trawling activity, and as a key prey item for marine mammals, an increase in abundance would offer an increase in prey resources.

4.11.2.65 Overall, marine mammal receptors are deemed to be of low vulnerability, high recoverability and international or national value. The sensitivity of the receptor is therefore, considered to be **low**.

<u>Significance of the effect</u>

4.11.2.66 Overall, it is predicted that the sensitivity of the receptor is considered to be **low** and the magnitude is deemed to be **minor** beneficial or adverse. The effect will, therefore, be of **minor** significance, which is not significant in EIA terms.

4.11.2.67 Due to the **low** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse or beneficial significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017)

Future monitoring

4.11.2.68 No monitoring will be required to assess the effects of operation and maintenance of Hornsea Three on marine mammals since no significant impacts were predicted.

4.11.3 Decommissioning phase

4.11.3.1 The impacts of the offshore decommissioning of Hornsea Three have been assessed on marine mammals. The environmental effects arising from the decommissioning of Hornsea Three are listed in Table 4.14 along with the maximum design scenario against which each decommissioning phase impact has been assessed.

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

Underwater noise arising from turbine and cable removal within the Hornsea Three array area and the Hornsea Three offshore cable corridor and associated vessels may cause disturbance to marine mammals

4.11.3.3 Marine mammals use hearing as their primary sense in the marine environment and therefore subsea noise arising from decommissioning activities may lead to behavioural effects on marine mammals.

Magnitude of impact

4.11.3.4 Elevated noise levels during decommissioning activities are likely to be associated with increased vessel movements and removal of the turbine foundations with the resulting noise levels dependant on the method used for removal of the foundation. Potential removal methods may include high powered water jetting/cutting apparatus and grinding or drilling techniques.

4.11.3.5 Abrasive cutting, often anticipated for wind turbine removal, would not be expected to be much noisier than general surface vessel noise (volume 4, annex 3.1: Subsea Noise Technical Report). Studies of underwater construction noise (decommissioning) reported source levels which are similar to those reported for medium sized surface vessels and ferries (Malme *et al*., 1989; Richardson *et al*., 1995). The noise resulting from wind turbine decommissioning employing abrasive cutting is unlikely to result in any injury, avoidance or significant disturbance of marine mammals within the Hornsea Three marine mammal study area. Some temporary minor disturbance might be experienced in the immediate vicinity of the decommissioning activity, for example, from dynamically positioned (DP) vessels.

4.11.3.6 Based on information at the time of writing, the impact of decommissioning is predicted to be of highly local spatial extent, short term duration, intermittent and reversible. Due to the extremely localised spatial extent, the expected magnitude is considered to be **negligible**.

Sensitivity of the receptor

4.11.3.7 Given the low noise levels associated with offshore wind farm decommissioning, any risk of significant behavioural disturbance (i.e. avoidance) for marine mammals would be limited to the area immediately surrounding the decommissioning activities. These noise levels are highly unlikely to result in injury or mortality of marine mammal species for any decommissioning activities. Marine mammal receptors are deemed to be of low vulnerability, high recoverability and international or national value. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of the effect

4.11.3.8 It is predicted that, for all decommissioning activities, the sensitivity of the receptor is **low** and the magnitude is deemed to be **negligible**. The effect will, therefore, be of **negligible** adverse significance, which is not significant in EIA terms.

4.11.3.9 Due to the **low** sensitivity of receptors and the **negligible** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **negligible** significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Increased vessel traffic during decommissioning activities may result in an increased collision risk to marine mammals

4.11.3.10 The potential impacts of increased vessel movement have been detailed paragraphs 4.11.1.118 to 4.11.1.140 and have not been reiterated here.

4.11.3.11 In summary the potential impacts of increased vessel movement during the operation and maintenance phase of Hornsea Three are:

- Masking of vocalisations or changes in vocalisation rate;
- Avoidance behaviour or displacement; and
- Injury or death due to collision with vessels.

Magnitude of impact

4.11.3.12 Increased vessel movements during decommissioning of up to 361 foundations (342 turbines, 12 offshore HVAC collector substations, four offshore HVDC substations and three accommodation platforms) and up to 2,113 km of cables is estimated to require up to 11,566 round trips by decommissioning vessels during the 11 years of the decommissioning phase.

4.11.3.13 The number of vessels and duration of the decommissioning phase are predicted to be the same as for the construction period (paragraph 4.11.1.119).

4.11.3.14 The impact is predicted to be of local spatial extent, medium term duration (11 year decommissioning period), intermittent, and both reversible (in the case of vessel noise), and irreversible (in the case of a collision). It is predicted that the impact could affect the receptor both directly (collision) and indirectly (disturbance from vessel noise). The magnitude is therefore, considered to be **minor** overall.

Sensitivity of the receptor

4.11.3.15 It is considered that there is a high likelihood of avoidance from both increased vessel noise and collision risk, with both a high potential for recovery (< 1 year) from increased noise, and medium potential for recovery from collision risk (reflecting the low likelihood of collision and potential for non-lethal collision to occur).

4.11.3.16 As all marine mammals considered in this PEIR are either of international or national importance, they are deemed to be of low vulnerability, both high recoverability (increased noise) and medium potential for recovery (collision risk), and high to very high conservation value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of the effect

4.11.3.17 Though there is predicted to be an increase in vessel movements during the 11 year decommissioning period of Hornsea Three, this presents a maximum design scenario and does not reflect the fact that most decommissioning vessels will be stationary or slow moving within Hornsea Three during the construction period, and will avoid any abrupt changes in speed. Predictability of vessel movements by marine mammals is likely to lead to maximum avoidance of decommissioning vessel traffic by animals.

4.11.3.18 The baseline (volume 5, annex 4.1: Marine Mammal Technical Report) showed that numbers of animals (apart from harbour porpoise) were relatively low in the Hornsea Three array area when compared to the regional marine mammal study area.

4.11.3.19 Overall, it is predicted that the sensitivity of the receptor is **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

4.11.3.20 Due to the **low** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the regional marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse significance, which is not significant in EIA terms. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Increased suspended sediments arising from decommissioning activities such as cable and foundation removal may impair the foraging ability of marine mammals

4.11.3.21 Based on the information available at the time of writing, the effects of temporary increases in SSC associated with removal of turbine foundations and electrical cables during the decommissioning phase on marine mammal receptors are expected to be the same or similar to the effects from construction. The significance of effect is therefore **negligible** adverse, which is not significant in EIA terms (see paragraph 4.11.1.142 *et seq.)* The conclusion in relation to marine mammal notified interest features of designated sites within the North Sea (SACs and SCIs) will therefore be the same as for the construction scenario (see paragraph 4.11.1.140)

Accidental pollution released during decommissioning (including decommissioning activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals

4.11.3.22 Based on the information available at the time of writing, the effects of accidental pollution events during the decommissioning phase on marine mammal receptors are expected to be the same or similar to the effects from construction. The significance of effect is therefore **negligible** adverse, which is not significant in EIA terms (see paragraph 4.11.1.154 *et seq.*). The conclusion in relation to marine mammal notified interest features of designated sites within the North Sea (SACs and SCIs) will therefore be the same as for the construction scenario. (see paragraph 4.11.1.163)

Changes in the fish and shellfish community resulting from impacts during decommissioning may lead to loss of prey resources for marine mammals

4.11.3.23 Fish and shellfish receptors are vulnerable to a number of impacts during decommissioning including temporary habitat loss during decommissioning of foundations, substations and electrical cables, increased SSC and sediment deposition, release of sediment contaminants within the Hornsea Three offshore cable corridor, loss of hard substrates, permanent habitat alteration through structures remaining *in situ*, subsea noise from decommissioning activities, and accidental pollution (chapter 3: Fish and Shellfish Ecology).

4.11.3.24 Loss or disturbance to key prey species of marine mammals (e.g. herring, cod, whiting, flatfish and sandeels) may have indirect negative effects on marine mammal receptors.

Magnitude of impact

4.11.3.25 The total temporary loss of habitat during decommissioning is estimated at 22,433,040 m^2 equating to 0.01% of the seabed within the southern North Sea fish and shellfish study area. Impacts are likely to occur over a local spatial extent and intermittently, and the most sensitive species are considered to be commercially important shellfish (brown crab, lobster and *Nephrops*), sandeels and herring, which are known to spawn within the southern North Sea fish and shellfish study area. Sensitivity of these species was assessed as being medium and the magnitude was minor. The significance of the impacts was therefore deemed to be minor adverse.

4.11.3.26 The impacts of an increase in SSC and associated deposition and accidental release of pollutants were considered to be similar to those arising during the construction phase and therefore have been described previously (paragraphs 4.11.1.167 and 4.11.1.169 respectively). In both cases the impacts were of minor adverse significance.

4.11.3.27 There was no site-specific information on contaminant levels in subtidal sediments in the Hornsea Three offshore cable corridor and therefore the impact of the release of potentially contaminated sediments on fish and shellfish ecology could not be undertaken for the PEIR. A site-specific survey is due to take place along the Hornsea Three offshore cable corridor and therefore this information will be used to inform the Environmental Statement.

4.11.3.28 Subsea noise from decommissioning activities is as described for marine mammals (paragraph 4.11.3.4 *et seq*.). Impacts on fish and shellfish receptors were predicted to be of local spatial extent and injury to fish and shellfish species is considered to be unlikely. The magnitude of impact was assessed as negligible and the sensitivity of receptors was low to medium. The assessment concluded that the impact of subsea noise was of adverse negligible significance.

4.11.3.29 Removal of all foundations (assuming scour and cable protection is left *in situ*) is predicted to result in the loss of 1,595,791 m^2 of hard substrate. Fish and shellfish that have colonised these structures will lose a habitat and species most likely to be affected are crustaceans, including crab and lobster. It is likely that, following removal of the hard substrates, the habitat will revert to the baseline conditions and therefore will redress the balance from any shift in community structure as a result of the offshore wind farm construction. The magnitude of the impact is predicted to be minor and the sensitivity of fish and shellfish is low to medium. Therefore, the impact is considered to be of minor adverse significance.

4.11.3.30 It is likely that cable and scour protection will remain in place during decommissioning and this represents a permanent habitat alteration (or loss of baseline habitat) which is irreversible. The permanent habitat alternation is predicted to affect up to 3,592,038 m^2 of seabed, equating to 0.002% of the southern North Sea fish and shellfish study area. Species most likely to be affected are demersal spawners with specific habitat requirements e.g. *Nephrops,* sandeel and herring, and less mobile shellfish species e.g. brown crab and lobster. Given the widespread nature of spawning habitat in the wider southern North Sea fish and shellfish study area, the sensitivity of fish and shellfish is predicted to be low to medium. With the magnitude of impact assessed as minor, the impact was considered to be of minor adverse significance.

4.11.3.31 In summary, potential effects of changes in prey resources on marine mammals could occur over an 11 year decommissioning phase and would be temporary, intermittent, and reversible. It is predicted that the impact will affect marine mammals indirectly. The magnitude of effect is therefore predicted to be **minor**.

<u>Sensitivity of the receptor</u>

4.11.3.32 Marine mammals exploit a suite of different prey items and can travel great distances to forage. It is likely that the effects described for fish and shellfish will occur over a similar, or lesser, extent and duration as those for marine mammals. The sensitivity of marine mammals to changes in fish and shellfish species as a result of decommissioning activities are similar to those described for the construction phase (paragraph 4.11.1.171 *et seq*.). Therefore, given the potential for a loss of a small proportion of available foraging habitat, marine mammals, VERs of national to international importance, are of low vulnerability with the potential for high recoverability. The sensitivity of marine mammals is considered to be **low.**

<u>Significance of the effect</u>

4.11.3.33 The sensitivity of marine mammals is considered to be **low** and the magnitude is assessed as being **minor**. The effect will therefore be of **minor** adverse significance and not significant in EIA terms. The conclusion in relation to marine mammal notified interest features of designated sites within the North Sea (SACs and SCIs) will therefore be the same as for the construction scenario (paragraph 4.11.1.175).

Future monitoring

4.11.3.34 No monitoring will be required to assess the effects of the decommissioning phase of Hornsea Three on marine mammals since no significant impacts were predicted.

4.12 Cumulative Effect Assessment methodology

4.12.1 Screening of other projects and plans into the Cumulative Effect Assessment

4.12.1.1 The CEA considers the potential impacts associated with Hornsea Three together with other projects and plans. The projects and plans selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise undertaken as part of the 'CEA long list' of projects (see annex 4.5: Cumulative Effects Screening Matrix and Location of Schemes). Each project on the CEA long list has been considered on a case by case basis for scoping in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

4.12.1.2 During the initial screening exercise for marine mammals, projects were considered over the whole of the North Sea MU (Figure 4.5) as the largest CEA study area. Further to this, for each impact, the extent of the cumulative assessment was refined depending on the scale of the potential impact. For subsea noise arising from piling and disturbance from vessel movements, the effects may be far reaching and therefore were assessed over the largest CEA for each species. For potential effects on fish and shellfish as prey items for marine mammals, the extent of the cumulative assessment was based upon the screening and impact assessment undertaken for chapter 3: Fish and Shellfish Ecology.

4.12.1.3 The projects considered in the cumulative assessment are those activities which have not been included in the baseline assessment for marine mammals, and where there was the potential for impacts to arise during the construction, operation and maintenance, or decommissioning phase of Hornsea Three. These projects include:

- Offshore energy developments;
- Cables and pipelines;
- Marine aggregates;
- Military and aviation; and
- Coastal developments (i.e. ports and harbours).

4.12.1.4 Marine aggregate and dredging projects have been screened in for the impact of potential changes in the fish and shellfish community but screened out as a potential direct impact on marine mammals as direct effects are considered likely to be localised and any uplift in vessel movements very small.

4.12.1.5 Information provided in volume 4, annex 5.1: Cumulative Effects Screening Matrix on oil and gas projects, shipping and navigation, and commercial fisheries, demonstrated that there were no additional impacts likely to occur as the impacts of these activities had been included as part of the baseline assessment on marine mammals. No further consideration in the CEA is given to these projects.

4.12.1.6 In undertaking the CEA for Hornsea Three, it is important to bear in mind that other projects and plans under consideration will have differing potential for proceeding to an operational stage and hence a differing potential to ultimately contribute to a cumulative impact alongside Hornsea Three. For example, relevant projects and plans that are already under construction are likely to contribute to cumulative impact with Hornsea Three (providing effect or spatial pathways exist), whereas projects and plans not yet approved or not yet submitted are less certain to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors. For this reason, all relevant projects and plans considered cumulatively alongside Hornsea Three have been allocated into 'Tiers', reflecting their current stage within the planning and development process. This allows the CEA to present several future development scenarios, each with a differing potential for being ultimately built out. Appropriate weight may therefore be given to each Tier in the decision making process when considering the potential cumulative impact associated with Hornsea Three (e.g. it may be considered that greater weight can be placed on the Tier 1 assessment relative to Tier 2). An explanation of each tier is included below:

- Tier 1: Hornsea Three considered alongside other project/plans currently under construction and/or those consented but not yet implemented, and/or those submitted but not yet determined and/or those currently operational that were not operational when baseline data was collected, and/or those that are operational but have an on-going impact;
- Tier 2: All projects/plans considered in Tier 1, as well as those on relevant plans and programmes likely to come forward but have not yet submitted an application for consent (the PINS programme of projects is the most relevant source of information). Specifically, this Tier includes all projects where the developer has submitted a Scoping Report; and
- Tier 3: All projects/plans considered in Tier 2, as well as those on relevant plans and programmes likely to come forward but have not yet submitted an application for consent (the PINS programme of projects is the most relevant source of information). Specifically, this Tier includes all projects where the developer has advised PINS in writing that they intend to submit an application in the future but have not submitted a Scoping Report.

4.12.1.7 It is noted that Tier 1 includes projects, plans and activities that are operational, under construction, consented but not yet implemented and submitted but not yet determined. The certainty associated with other projects, plans and activities, in terms of the scale of the development and the likely impacts, increase as they progress from submitted applications to operational projects. In particular, offshore wind farms seek consent for a maximum design scenario and the parameters are subsequently refined as built offshore wind farm will be selected from the range of consented scenarios. In addition, the maximum design scenario quoted in the application (and the associated Environmental Statement) are often refined during the determination period of the application. For example, it is noted that the Applicant for Hornsea Project One has gained consent for an overall maximum number of turbines of 240, as opposed to 332 considered in the Environmental Statement. Similarly, Hornsea Project Two has gained consent for an overall maximum number of turbines of 300, as opposed to 360 considered in the Environmental Statement.

4.12.1.8 It should be noted that the CEA presented in this marine mammal chapter has been undertaken on the basis of information presented in the Environmental Statements for the other projects, plans and activities. The level of impact on marine mammal would likely be reduced from those presented here. In addition, Hornsea Three is currently considering how the different levels of certainty associated with projects in Tier 1 can be reflected in the CEA and an update, in terms to the approach to tiering, will be presented in the Environmental Statement.

4.12.1.9 For projects in Tier 2 the level of detail available is sometimes limited at this stage and therefore the assessments presented for this Tier are semi-quantitative. There were no projects in Tier 3 which provided sufficient information to allow a robust assessment of impacts on marine mammals. Therefore, all Tier 3 projects have been scoped out of the assessment.

4.12.1.10 The specific projects scoped into this CEA and the Tiers into which these projects have been allocated, are outlined in Table 4.39 and illustrated in Figure 4.17 and Figure 4.18. The projects included as operational in this assessment have been commissioned since the baseline studies for this project were undertaken and as such were excluded from the baseline assessment.

Table 4.39: List of other projects and plans considered within the CEA.

Tier	Phase	Project/Plan	Distance from Hornsea Three array (km) (nearest point)	Distance from Hornsea Three offshore cable corridor (km) (nearest point)	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
1	*Offshore wind farms*							
	Under construction	Dudgeon	87	11	168 turbines under construction	2015 to 2017	No	Yes
		Race Bank	114	28	206 turbines consented, 91 constructed.	2015 to 2017	No	Yes
		Hornsea Project One	7	7	174 turbines to be installed	2018 to 2019	No	Yes
		Beatrice	566	581	84 turbines under construction	2017 to 2018	No	Yes
		Galloper	119	79	56 turbines under construction	2017	No	Yes
		MEG Offshore I (now Merkur Offshore Wind Farm)	247	260	400 MW turbines under construction	2017 to 2019	No	Yes
		Nordergruende	353	368	18 6.15 MW under construction	2017 to 2018	No	Yes
		Sandbank 24	298	317	72 4 MW turbines under construction	2017	No	Yes
	Consented	Aberdeen demonstration	444	461	Up to 100 MW with no more than 11 turbines		No	Yes
		Blyth demo	258	273	Up to 15 turbines consented, five constructed	2017	No	Yes
		Dogger Bank Creyke Beck A and B	76	91	Up to 200 turbines consented	2021 to 2024	Yes	Yes
		East Anglia One	152	106	102 x 7 MW turbines consented	2019	No	Yes
		Hornsea Project Two	7	8	Up to 300 turbines consented	2017 to 2019	No	Yes
		Kincardine	422	438	Eight 6 MW turbines consented	2018 to 2019	No	Yes
		Triton Knoll	100	44	Up to 288 turbines consented	2017 to 2021	Yes	Yes
		Dogger Bank Teesside A and B	95	108	Up to 400 turbines consented	2023 to 2026	Yes	Yes
		Hywind Scotland Pilot Park	438	455	Five 6 MW turbines consented	2017	No	Yes
		Moray East (previously Moray Offshore Renewables Ltd Eastern Development Area)	548	565	Up to186 6 to 8 MW turbines consented (revised PD = 137 x 8.1-15 MW turbines)	2022 to 2023	Yes	Yes
		Neart na Gaoithe	372	388	Up to 64 turbines	Unknown	Unknown	Unknown
		Inch Cape	384	401	Up to 110 turbines	Unknown	Unknown	Unknown
		SeaGreen (Alpha, Bravo, Charlie, Delta, Echo, Golf, Foxtrot)	367	384	Up to 75 turbines per sub-project	Unknown	Unknown	Unknown
		Norther (Belgium)	236	163	44 8 MW turbines consented	2017 to 2018	No	Yes

Tier	Phase	Project/Plan	Distance from Hornsea Three array (km) (nearest point)	Distance from Hornsea Three offshore cable corridor (km) (nearest point)	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
		Rentel Area A (Belgium)	231	155	42 7.35 MW turbines consented	2017 to 2018	No	Yes
		Seastar (Belgium)	225	149	42 6 MW turbines consented	2017 to 2018	No	Yes
		Borkum Riffgrund 2 (Germany)	241	225	56 8 MW turbines consented	2018 to 2019	No	Yes
		Trianel Windpark Borkum (Germany)	242	255	32 6.15 MW turbines consented	2017	No	Yes
		Deutsche Bucht Offshore Wind Farm (Germany)	203	217	30 8 MW turbines consented	2017 to 2019	No	Yes
		Borssele 1 and 2 (Netherlands)	216	181	Up to 127 turbines consented (6 to 10 MW)	2017 to 2020	No	Yes
		Borssele 3 and 4 (Netherlands)	217	175	Up to 123 turbines consented (6 to 10 MW)	2018 to 2021	Yes	Yes
		Horns Rev 3 (Denmark)	373	394	49 8.3 MW turbines consented	2017 to 2018	No	Yes
		Nissum Bredning (Denmark)	461	485	4 7 MW turbines	2017 to 2018	No	Yes
	Submitted	East Anglia Three	103	87	Up to 172 turbines	2020 to 2022	Yes	Yes
	Aggregate extraction and disposal sites							
	Operational (with on-going effects)	Humber 3 – 484	43	0	Operational	N/A	N/A	Yes
		Inner Dowsing - 481/1-2	126	41	Operational	N/A	N/A	Yes
		Inner Dowsing - 481/1-2	127	38	Operational	N/A	N/A	Yes
		Inner Dowsing - 481/1-2	126	41	Operational	N/A	N/A	Yes
		Inner Dowsing - 481/1-2	127	38	Operational	N/A	N/A	Yes
		Outer Dowsing - 515/1-2	102	41	Operational	N/A	N/A	Yes
		Outer Dowsing - 515/1-2	88	38	Operational	N/A	N/A	Yes
		Humber 4 – 490	19	13	Operational	N/A	N/A	Yes
		Humber 7 – 491	4	0	Operational	N/A	N/A	Yes
		Inner Dowsing - 481	125	38	Operational	N/A	N/A	Yes
		Inner Dowsing - 481	125	38	Operational	N/A	N/A	Yes
		Humber	77	32	Operational	N/A	N/A	Yes
		West of Inner Dowsing Bank	131	48	Application for operation sought up to December 2029	N/A	N/A	Yes

Tier	Phase	Project/Plan	Distance from Hornsea Three array (km) (nearest point)	Distance from Hornsea Three offshore cable corridor (km) (nearest point)	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
	Cables and pipelines							
	Pre-commission	PL2236 – Mimas to Saturn	33	22	33 inch Pre-commission CHEMICAL pipeline operated by CONOCOPHILLIPS	2017 to 2018	No	Yes
		PL2237 - Saturn to Mimas	33	22	33 inch Pre-commission CHEMICAL pipeline operated by CONOCOPHILLIPS	2017 to 2018	No	Yes
		PLU3122 - Juliet to Pickerill A umbilical	89	50	138 mm Pre-commission MIXED HYDROCARBONS pipeline operated by ENGIE	2017 to 2018	No	Yes
		PL3088 - Cygnus to ETS gas pipelines	48	64	24 inch Pre-commission GAS pipeline operated by ENGIE	2017 to 2018	No	Yes
		PL3086 - Cygnus A to Cygnus B gas pipelines	65	78	12 inch Pre-commission GAS pipelines operated by ENGIE	2017 to 2018	No	Yes
		PL2894 - Katy to Kelvin gas export pipelines	39	53	10 inch Pre-commission GAS pipeline operated by CONOCOPHILLIPS	2019 to 2021	Yes	Yes
		PL2895 - Kelvin to Katy methanol pipelines	39	53	2 inch Pre-commission METHANOL pipeline operated by CONOCOPHILLIPS	2019 to 2021	Yes	Yes
		PL3121 - Juliet to Pickerill A gas pipelines	*89*	*50*	12 inch Pre-commission MIXED HYDROCARBONS pipeline operated by ENGIE	*2019 to 2021*	*Yes*	*Yes*
	Under-construction	PL0219 - PR K4-Z to K5-A	*20*	35	6 inch under construction gas pipeline operated by Total E&P Nederland B.V.	2017 to 2018	No	Yes
		PL0219 - UM K4-Z to K5-A	*20*	35	5 inch under construction control pipeline operated by Total E&P Nederland B.V.	2017 to 2018	No	Yes
	Proposed	PLU3087 – Cygnus A to Cygnus B umbilical	*65*	79	193.3 mm chemical pipeline operated by ENGIE	2019 to 2021	Yes	Unknown
		PL0221 - HS D18-A to D15-FA-1	*19*	45	2 inch proposed methanol pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes
		PL0221 - PR D18-A to D15-FA-1	*19*	45	8 inch proposed gas pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes
	Military operations							
	Operational	RWS Dutch military UXO clearance	Unknown	Unknown	Detonations of UXOs of unknown charge size or quantity	N/A	Unknown	Unknown

Tier	Phase	Project/Plan	Distance from Hornsea Three array (km) (nearest point)	Distance from Hornsea Three offshore cable corridor (km) (nearest point)	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
	Coastal Development (ports and harbours)							
	Approved	Yorkshire Harbour and Marina, Bridlington	157	148	Construction of a 250 berth marina, no piling	2019 to 2020	No	Yes
		Chatham Maritime Marina, Medway, N. Kent	296	177	Construction of 54 berth marina with up to 13 piles	2017 to 2018	No	Yes
		Chatham Maritime Marina extension, Medway, N. Kent	296	177	Extension to existing pontoon providing an additional 60 berths	Unknown	Unknown	Yes
		Oikos Storage Ltd, Canvey Island, Essex	284	165	Construction of a new deep water jetty	2018	No	Yes
		Convoys Wharf, London	306	181	Construction of a new river bus jetty and associated structures	Unknown	Unknown	Yes
2	**Offshore wind farms**							
	Proposed	Norfolk Vanguard	73	51	Up to 1,800 MW and between 120 to 257 turbines	2022 to 2024	Yes	Yes
		Moray West	554	570	Up to 90 8 to 15 MW turbines	2022 to 2023	Yes	
	Cables and pipelines							
	Proposed	Viking Link Interconnector	13	18	High voltage (up to 500 kV) DC electricity interconnector	TBC	TBC	Yes

Figure 4.17: Offshore wind farms and coastal development projects screened into the marine mammal CEA.

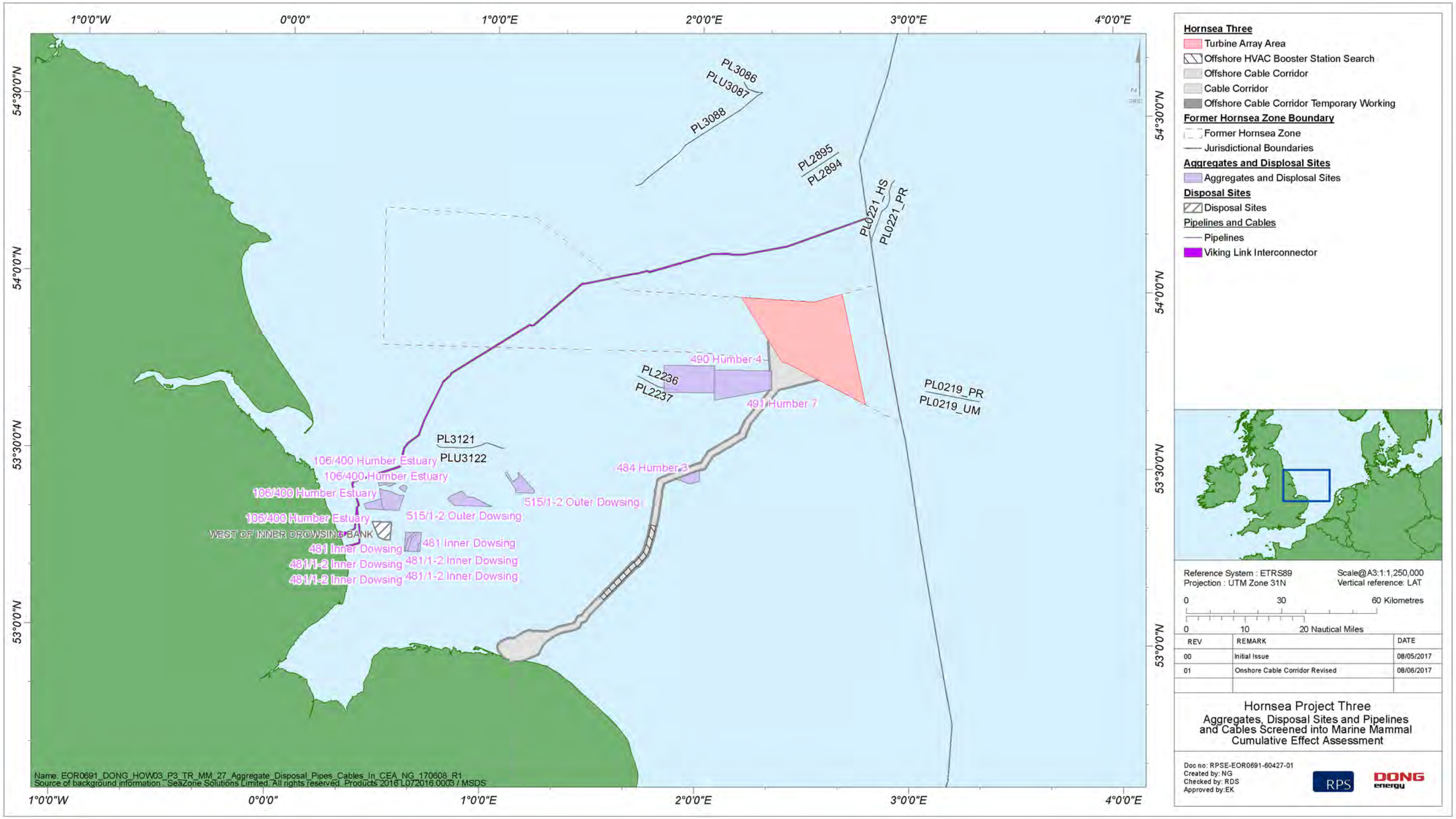

Figure 4.18: Aggregates, disposal sites, pipelines and cables screened into the marine mammal CEA.

4.12.2 Maximum design scenario

4.12.2.1 The maximum design scenarios identified in Table 4.40 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. The cumulative impacts presented and assessed in this section have been selected from the details provided in the Hornsea Three project description (volume 1, chapter 3: Project Description), as well as the information available on other projects and plans, in order to inform a 'maximum design scenario'. Effects of greater significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope (e.g. different turbine layout), to that assessed here be taken forward in the final design scheme.

4.12.2.2 The following impacts set out in Table 4.14 have not been considered in the CEA due to the highly localised nature of some of the impacts (i.e. within the Hornsea Three boundary only) and/or where the potential significance of impact has been assessed as negligible for Hornsea Three offshore wind farm alone. These impacts are:

- Construction phase:
  - Increased suspended sediments arising from construction activities, such as cable and foundation installation, may reduce water clarity and impair the foraging ability of marine mammals (significance assessed as negligible); and
  - Accidental pollution released during construction (including construction activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals (significance assessed as negligible).
- Operation and maintenance phase:
  - Noise and vibration arising from operational turbines may cause disturbance to marine mammals (significance assessed as negligible);
  - Accidental pollution released during operation and maintenance (including maintenance activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals (significance assessed as negligible); and
  - EMF arising from subsea electrical cables may affect marine mammal behaviour (significance assessed as negligible).
- Decommissioning phase:
  - Increased suspended sediments arising from decommissioning activities such as cable and foundation removal may impair the foraging ability of marine mammals (significance assessed as negligible); and
  - Accidental pollution released during decommissioning (including decommissioning activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals (significance assessed as negligible).

4.12.2.3 In addition to being screened out of the CEA due to a negligible impact for Hornsea Three alone, accidental pollution events during the construction phase resulting in potential effects on marine mammal receptors has also been screened out of the CEA due to the assumption that management measures, similar to those being employed for Hornsea Three, will also be in place for the other projects considered within the CEA. These management measures will reduce the risk of these events occurring and minimise the magnitude of the impact, should these occur (e.g. CoCP and PEMMP, see Table 4.19).

Table 4.40: Maximum design scenario considered for the assessment of potential cumulative impacts on marine mammals.

Potential impact	Maximum design scenario	Justification
Underwater noise from foundation piling and other construction activities (e.g. drilling of piles) within the Hornsea Three with underwater noise arising during construction of other projects has the potential to cause injury or disturbance to marine mammals.	The maximum design scenario as described and assessed for the construction phase impacts for Hornsea Three cumulatively with the following projects: *Tier 1* • Under construction offshore wind farms: Dudgeon; Hornsea Project One; Beatrice; and Galloper; • Consented/submitted offshore wind farm applications: Aberdeen demo; Blyth demo; Dogger Bank Creyke Beck A and B; Dogger Bank Teesside A and B; East Anglia One; East Anglia Three; Hornsea Project Two; Kincardine; Triton Knoll; Hywind Scotland Pilot Park, MORL Eastern Development Area, Inch Cape, Neart Na Gaoithe and Sea Green; • Dutch military activities – UXO clearance and mine clearance training; and • Pile-driving activities associated with ports and harbour developments including: Chatham Maritime Marina (pontoon extension); Oikos Storage Ltd, Convoys Wharf. *Tier 2* • Norfolk Vanguard; MORL Western Development Area.	Maximum design scenario includes projects whose construction phase overlaps with the construction phase for Hornsea Three, resulting in maximum design spatial scenario. Maximum design temporal scenario considers the longest duration of the piling phase for each of the projects not included as part of the baseline. Where projects do not overlap but run consecutively, it is assumed that piling could occur at any point within the construction phase therefore giving the longest duration of a potential piling phase. Maximum design scenario for Dutch military activities assumes that UXOs will be cleared via detonation of devices. Maximum design scenario for ports and harbours assumes an increase in subsea noise arising from projects that involve pile-driving activity during construction. Projects have been screened out where there is a very short piling duration (less than one month), or very few piles to be installed (less than ten), and/or the project is over 200 km distance from the nearest point in Hornsea Three. Noise impacts arising from aggregate extraction and cable and pipeline installation have been screened out on the basis that these are considered to be highly localised, short term, and of negligible magnitude. In addition, all oil and gas activities listed in the cumulative screening table are currently operational and therefore were considered to be part of the baseline and screened out for cumulative impacts of subsea noise.
Increased traffic during construction, operation or decommissioning of Hornsea Three may result in an increase in disturbance, collision risk or injury to marine mammals during construction, operation or decommissioning of other projects.	The maximum design scenario as described and assessed for the construction phase impacts for Hornsea Three cumulatively with the following projects (listed for the whole of the North Sea): *Tier 1* • Under construction offshore wind farms: Dudgeon; Beatrice; Race Bank; Hornsea Project One; and Galloper; • Consented/submitted offshore wind farm applications: Aberdeen demo; Blyth demo, Dogger Bank Creyke Beck A and B; Dogger Bank Teesside A and B; East Anglia One; East Anglia Three; Hornsea Project Two; Kincardine; Triton Knoll; Hywind Scotland Pilot Park, MORL Eastern Development Area; Inch Cape; Neart Na Gaoithe and Sea Green • All cables and pipelines listed in Table 4.46; apart from the Viking Interconnector • Ports and harbour projects including: Yorkshire Harbour and Marina, Chatham Maritime Marina (two projects). *Tier 2* • Norfolk Vanguard, MORL Western Development Area; and • Viking Interconnector.	For offshore energy developments, projects are included where the construction or operation phase overlaps with the construction or operation phase of Hornsea Three, provided that the project is not already operational and therefore part of the baseline. Projects screened in are expected to contribute to an increase in vessel traffic during construction and during operation and maintenance activities. Increased vessel activity from dredging activities and Dutch military activities have been screened out on the basis that the uplift in vessel numbers is predicted to be very small and vessel movements localised, therefore the magnitude of impact will be negligible. Cables and pipelines are included if the operational phase has not already commenced (i.e. not part of the baseline). For ports and harbours, vessel traffic during construction phase is screened out on the basis that the uplift in vessel numbers is predicted to be very small and/or vessel movements highly localised; therefore the magnitude of impact will be negligible. During operation, the impact of vessel traffic is screened in where there is an extension to an existing facility or an installation of a new facility resulting in additional berths for more than 25 vessels, therefore leading to a potential increase in vessel traffic.
Changes in the fish and shellfish community resulting from impacts during construction, operation or decommissioning of Hornsea Three with the construction, operation or decommissioning phase of other projects may lead to loss of prey resources for marine mammals.	The maximum design scenario as described and assessed for Hornsea Three cumulatively with the projects listed in chapter 3: Fish and Shellfish Ecology; Table 3.22 for each of the impacts screened into the CEA. *Tier 1* • Licensed aggregate extraction and disposal areas up to 50 km assuming 10% of the total licensed area is dredged at any one time; • Offshore wind farms under construction or operation up to 100 km; • Consented offshore wind farm projects up to 100 km; and • Cables and pipelines up to 50 km. *Tier 2* • Cables and pipelines consented (i.e. Viking interconnector) up to 50 km; and • Proposed offshore wind farms up to 100 km.	Maximum design scenarios assumed for each impact described in chapter 3: Fish and Shellfish Ecology within a 50 km buffer of the Hornsea Three array area, with the exception of piling noise, which has been assessed within a representative 100 km buffer of the Hornsea Three array area. Impacts on fish and shellfish include: • Cumulative temporary habitat loss/disturbance as a result of offshore wind farm construction, aggregate extraction and dredge disposal, and cable and pipeline installation; • Cumulative temporary increase in SSC and sediment deposition as a result of offshore wind farm construction and aggregate extraction; • Cumulative effect of underwater noise from piling operations during construction of offshore wind farms; • Cumulative long term habitat loss from offshore wind farm infrastructure and cables and pipelines; • Cumulative introduction of hard substrates from offshore wind farm infrastructure; • Cumulative effects of EMF emitted by subsea cables from offshore wind farms and subsea cables; • Cumulative displacement of fishing pressure due to offshore wind farm operation.

4.13 Cumulative Effect Assessment

4.13.1.1 A description of the significance of cumulative effects upon marine mammal receptors arising from each identified impact is given below. The scale over which the cumulative effects have been assessed for each marine mammal species is based upon the criteria of the screening exercise described above and within the relevant MU for each species, as discussed and agreed with the Marine Mammal EWG (Table 4.4).

Underwater noise from foundation piling and other construction activities (e.g. drilling of piles) within Hornsea Three with underwater noise arising during construction of other projects has the potential to cause injury or disturbance to marine mammals

4.13.1.2 An evaluation of magnitude, sensitivity and therefore overall significance has not been made for the impact of subsea noise from Hornsea Three alone, for the reasons described in paragraph 4.11.1.4. Therefore, this CEA considers any impacts where there is considered to be potential for an effect (which may be significant in EIA terms) at Hornsea Three. Where impacts have been assessed as unlikely to occur (i.e. non-significant in EIA terms), these have not been carried forward to the CEA.

4.13.1.3 During the offshore construction of Hornsea Three, the main source of cumulative increase in underwater noise is likely to occur as a result of piling operations from other projects, plans and activities. The potential impacts of increased noise due to piling at Hornsea Three on marine mammals, has been detailed fully in paragraphs 4.11.1.7 to 4.11.1.9 and has not been re-iterated here. The projects included in this cumulative impact assessment are detailed in Table 4.40 and include offshore wind farms and coastal developments within the wider North Sea MU (as agreed with the Marine Mammal EWG) where piling is considered likely to occur during construction phases of these projects, and where there is potential for direct overlap of piling phases, or where piling commences within five years of commencement or completion of piling at Hornsea Three (Figure 4.17).

4.13.1.4 Table 4.40 indicates that the maximum design scenario (temporal) for potential cumulative impact of increased underwater noise due to piling is 16 years (the total duration of piling for all projects screened into the CEA (i.e. including projects that are before Hornsea Three but screened in as not yet built/part of the baseline)), with a gap of six years where currently no piling is predicted to occur (Table 4.41). Up to 36 offshore wind farm projects are planned to be constructed within the cumulative period, and therefore may have the potential for a cumulative impact on marine mammal populations potentially affected by piling at Hornsea Three. However, within Tier 1, only five projects are currently predicted to have a directly overlapping piling period with Hornsea Three (Aberdeen Bay, Dogger Bank Creyke A & B, Dogger Bank Teesside A & B, East Anglia Three, and MORL Eastern Development Area), in Tier 2, only two projects have direct overlap of piling phases (Moray West and Norfolk Vanguard). No Tier 3 projects have been identified.

4.13.1.5 The potential for cumulative impacts of pile-driving has been assessed for Hornsea Three based on the maximum design spatial scenario of piling at two concurrent locations within the Hornsea Three array area using 5,000 kJ hammer energies, with a maximum spacing between piling activities; and where a quantitative assessment was possible and appropriate (behavioural impacts on harbour porpoise and seals) the maximum design scenario has been presented for associated CEA projects (Table 4.42). This is likely to be a highly precautionary approach to assessment as the maximum design scenario for each project is highly unlikely to occur for the majority of the time and at every project concurrently.

4.13.1.6 It should be noted that the cumulative noise assessment has been based on information and assessments, where available, as presented in the published Environmental Statements. Though Table 4.41 suggests that there may be an overlap in the timing of piling of up to eight offshore projects with the Hornsea Three piling phase, construction timescales are indicative and subject to change and it is considered highly likely that potential overlap of piling phases will vary from those presented above.

4.13.1.7 Piling at Hornsea Three is likely to occur in two short phases (each of approximately one year and a half), with a maximum duration of six years between phases where no piling will occur (Table 4.41). In addition, assessment of the potential effects on marine mammals predicted by other wind farms is not directly comparable to those presented for Hornsea Three due to different approaches to assessment taken by other offshore developers, different noise criteria and thresholds used, and differing levels of detail presented in associated Environmental Statements.

4.13.1.8 Though piling is planned for construction of Convoys Warf, Inch Cape, Neart Na Gaoithe and Seagreen Alpha and Bravo, construction timelines are currently unknown and therefore these projects have not been quantitatively assessed in this CEA.

4.13.1.9 The majority of planned developments do not have overlapping construction periods with Hornsea Three. The main potential cumulative impacts are predicted to occur during periods of overlapping piling where increased anthropogenic noise is highest, and these are the projects that are assessed quantitatively in the CEA, where possible and appropriate. A qualitative assessment has been undertaken of potential cumulative impacts of projects where there is no overlap of piling period with Hornsea Three predicted.

Table 4.41: Projected timelines of piling of CEA projects, and potential for overlap with Hornsea Three piling (2022 to 2032). Red outline denotes the periods of overlap with the two piling periods for Hornsea Three.

Tier	Project	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033 to 2038
	Hornsea Three																	
1	Aberdeen Bay Demonstrator																	
	Blyth Demo																	
	Beatrice																	
	Borkum Riffgrund 2 (Germany)																	
	Borssele 1 and 2 (Netherlands)																	
	Borssele 3 and 4 (Netherlands)																	
	Deutsche Bucht Offshore Wind Farm (Germany)																	
	Dogger Bank Creyke Beck A and B																	
	Dogger Bank Teeside A and B																	
	Dudgeon	commissioned by 2017																
	East Anglia Three																	
	East Anglia One																	
	Galloper																	
	Hornsea Project One																	
	Hornsea Project Two																	
	Horns Rev 3 (Denmark)																	
	Hywind Scotland Pilot Park																	
	Inch Cape	Unknown																
	Kincardine																	
	MEG Offshore (now Merkur offshore windfarm)																	
	Moray East																	
	Nearte Na Gaoithe	Unknown																
	Nissum Bredning (Denmark)																	
	Nordergruende																	
	Norther (Belgium)																	
	Rentel Area A (Belgium)																	

Tier	Project	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033 to 2038
	Sandbank 24																	
	Seagreen Alpha	Unknown																
	Seagreen Bravo	Unknown																
	Seastar (Belgium)																	
	Trianel Windpark Borkum (Germany																	
	Triton Knoll																	
	Chatham Maritime Marina and extension																	
	Convoys Wharf	Unknown																
2	Moray West																	
	Norfolk Vanguard																	

Tier 1

<u>Magnitude of impact</u>

4.13.1.10 The potential impacts of subsea noise from pile-driving at Hornsea Three on marine mammal receptors has been described in paragraphs 4.11.1.3 *et seq*. and have not been re-iterated here. An evaluation of magnitude, sensitivity and therefore overall significance has not been made for the impact of subsea noise from Hornsea Three alone, for the reasons described in paragraph 4.11.1.4. Therefore, this CEA considers any impacts where there is considered to be potential for an effect (which may be significant in EIA terms) at Hornsea Three. Where impacts have been assessed as unlikely to occur (i.e. non-significant in EIA terms), these have not been carried forward to the CEA. This has been detailed for each potential impact as set out below.

Auditory injury

4.13.1.11 The potential distances at which auditory injury (PTS) could occur in marine mammals during concurrent pile-driving at Hornsea Three are very small (Table 4.21). At 15% hammer blow energy, for most scenarios, the potential for auditory injury falls within the standard 500 m mitigation range recommended in the draft JNCC guidelines (2010) (Table 4.21). The exception to this is for harbour porpoise, where soft start could commence at 750 kJ (for the 5,000 kJ) hammer energy, in which case the potential injury range was estimated out to 1,500 m and therefore this is the distance over which mitigation will be carried out to reduce the risk of injury to all marine mammals (paragraph 4.11.1.33). Assuming that mitigation is implemented as set out in the MMMP (marine mammal mitigation plan), which may include use of marine mammal observers and ADDs, the risk of auditory injury (PTS) will be reduced and therefore significant effects (in EIA terms) are unlikely to occur. In addition, other projects' impact assessments for subsea noise from pile-driving have presented smaller hammer energies and are highly likely to follow good practice in implementation of mitigation measures such as use of marine mammal observers and ADDs, therefore the potential ranges for auditory injury (PTS) from other CEA projects are likely to be smaller than for Hornsea Three.

4.13.1.12 As potential impact ranges are small and significant effects (in EIA terms) are considered unlikely for Hornsea Three for the maximum design spatial scenario, no further assessment for potential cumulative impact of auditory injury has been carried out.

TTS/Fleeing (displacement)

4.13.1.13 The assessment of magnitude for Hornsea Three concurrent piling, modelled using maximum design scenario hammer energy (5,000 kJ), demonstrated that effects on minke whale, white-beaked dolphin, grey seal and harbour seal would be localised, therefore no further cumulative assessment has been undertaken for these species, however further assessment is presented below for harbour porpoise due to the longer ranges over which TTS/fleeing could occur (Table 4.24).

4.13.1.14 The magnitude of impact for Hornsea Three concurrent piling, modelled using maximum design scenario hammer energy (5,000 kJ), predicts a potential impact range of 12.8 km and total area affected of 1,028 km^2 (Table 4.24). For those projects where the piling phase may overlap with the piling phases for Hornsea Three, modelled impact ranges, as presented in published Environmental Statements, are presented in Table 4.42. Where a total area of potential impact is given, this has been calculated from range of impact provided in the associated Environmental Statement.

Table 4.42: Potential range over which TTS (fleeing) could occur in harbour porpoise due to piling at CEA projects with overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Range over which TTS (fleeing) could occur (km)	Total area of potential impact (km^2)	Source (maximum design spatial scenarios)
Aberdeen Demo	Not modelled	N/A	Jacket foundations for 11 turbines (Aberdeen Offshore Windfarm Ltd, 2013)
Dogger Bank Creyke A & B	4.5 to 5	78.54	Maximum hammer energy 3,000 kJ for jacket foundations, two concurrent vessels (Forewind, 2013).
Dogger Bank Teesside A & B	4.5 to 5	78.54	Maximum hammer energy 3,000 kJ for jacket foundations, two concurrent vessels (Forewind, 2014).
East Anglia Three	5 to 8	201	Maximum hammer energy 3,500 kJ for monopile foundation, two concurrent vessels (East Anglia Three Ltd, 2015)
Moray East	0.0316	0.003	Maximum pile diameter 2,5 m, up to six concurrent piling events (MORL, 2012).

4.13.1.15 It is not considered appropriate to add total area of potential impact for all concurrent piling operations within the harbour porpoise MU, as there is likely to be variation in timing, duration and hammer energy used throughout construction of the listed projects. The range of effects of TTS/fleeing occurs largely within the boundaries of each project area and therefore are limited in extent. For Hornsea Three, the range of effect for the maximum design spatial scenario extended just beyond the project boundary.

4.13.1.16 For animals displaced over these small ranges, there will be alternative foraging areas available within the North Sea MU. Therefore, cumulative displacement from areas where subsea noise from pile-driving could cause a TTS/fleeing response is considered unlikely to cause more than a moderate change from subsea noise baseline, with only short-term impacts on receptor species.

4.13.1.17 The cumulative impact of TTS/fleeing on harbour porpoise is predicted to be of mostly local spatial extent, intermittent occurrence and reversible. The impact will affect animals directly, however due to the relatively small areas of impact in relation to availability of alternative foraging areas (i.e. area of NS MU 516,893 km^2), the potential impact of cumulative TTS/fleeing on harbour porpoise is considered to be no greater than Hornsea Three alone when considered against the MU population.

Behavioural effects

4.13.1.18 As the potential for behavioural effects on minke whale and white-beaked dolphin due to concurrent piling at Hornsea Three is not considered likely to lead to a significant effect (in EIA terms), due to very small potential impact ranges and very small proportions of reference population affected, these receptors are not considered further for cumulative impact of behavioural effects.

4.13.1.19 The assessment for Hornsea Three identified the potential for effects (that could be significant in EIA terms) to arise in harbour porpoise as a result of exposure to noise levels from piling that could induce a behavioural response. Cumulative impact on harbour porpoise has been assessed using the threshold for possible avoidance.

4.13.1.20 For pinnipeds, due to the level of uncertainty (i.e. since there are no criteria available to assess the full extent of behavioural effects), the assessment highlighted the potential for behavioural effects (in EIA terms) to occur. In the absence of criteria for likely or possible avoidance (as given for other species) the assessment used the TTS/fleeing criteria, noting that this is considered to result in an underestimate of the potential ranges/areas of effect (see paragraph 4.11.1.44).

4.13.1.21 For those projects where piling may overlap with the piling phases for Hornsea Three, modelled behavioural impact ranges, as presented in published Environmental Statements, are presented in Table 4.43 (harbour porpoise) and Table 4.44 (seals) below. Where a total area of potential impact is not given for behavioural effects, this has been calculated from the published range of impact provided in the associated Environmental Statements.

Harbour porpoise

4.13.1.22 The maximum total extent over which possible disturbance is modelled to occur in harbour porpoise due to concurrent piling using 5,000 kJ hammer energy at Hornsea Three is 66 km, with a total potential area affected of 16,106 km^2 (Table 4.27).

4.13.1.23 For projects whose piling phase overlaps with Hornsea Three, the ranges over which possible disturbance could occur are presented in Table 4.43 (minimum and maximum modelled ranges for the largest hammer energy). The maximum extent of noise disturbance for CEA projects ranges over distances of 21 to 70 km from the source (Table 4.43). The areas of effect presented for each project in Table 4.43 are based on the maximum design spatial scenarios of concurrent piling.

Table 4.43: Potential range over which behavioural impacts could occur in harbour porpoise due to piling at CEA projects with potential overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Minimum range (km)	Maximum range (km)	Total potential area of behavioural effect (km^2)	Predicted significance of impact (from Environmental Statement) [a]
Aberdeen Demo	Not modelled	Not modelled	N/A	Not presented
Dogger Bank Creyke A	19.5	28.5	4,772	Minor adverse
Dogger Bank Creyke B	24	43	6,723	Minor adverse
Dogger Bank Teesside A	22	33	6,008	Minor adverse
Dogger Bank Teesside B	22	33.5	5,489	Minor to moderate adverse
East Anglia Three	37	70	13,469	Minor Adverse
Moray East	11	21	1,385	Not given

a Source of information for maximum spatial scenario of each project provided in Table 4.42.

Table 4.44: Potential range over which behavioural impacts could occur in seals due to piling at Tier 1 CEA projects with overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Criteria	Modelled range (km)	Total potential area of likely avoidance (km^2)	Predicted significance of impact (from Environmental Statement) [a]
Aberdeen Demo	N/A	Not modelled	N/A	Not presented
Dogger Bank Creyke A	TTS/fleeing (Southall et al.)	1.8	32	Negligible to minor (concurrent). Only grey seal assessed
Dogger Bank Creyke B	TTS/fleeing (Southall et al.)	1.9	32	Negligible to minor (concurrent). Only grey seal assessed
Dogger Bank Teesside A	TTS/fleeing (Southall et al.)	1.9	18	Minor adverse (only grey seal assessed)
Dogger Bank Teesside B	TTS/fleeing (Southall et al.)	1.9	18	Minor adverse (only grey seal assessed)
East Anglia Three	TTS/fleeing (Southall et al.)	2.5	19.6	Negligible
Moray East	dBht (Nedwell et al.)	13	531	No significant long term effect.

a Source of information for maximum spatial scenario of each project provided in Table 4.42.

4.13.1.24 It is not considered appropriate or realistic to add modelled areas over which potential behavioural effects could occur, as there is likely to be a great deal of variation in timing, duration, and hammer energy used throughout the various CEA project construction periods detailed above. Some animals are likely to exhibit avoidance of some areas over which modelled ranges of “possible avoidance” are predicted to occur. In addition, alternative foraging areas will be available to harbour porpoise throughout the North Sea MU. A qualitative CEA has therefore been undertaken, based on available literature and advice from the Marine Mammal EWG.

4.13.1.25 The cumulative impact of possible avoidance on harbour porpoise for the maximum adverse spatial scenario is predicted to affect animals indirectly by limiting availability of foraging areas, with the magnitude of impact extending beyond project boundaries and potentially affecting a proportion of international sites designated for harbour porpoise. At larger ranges within this contour the impact of subsea noise is less likely to lead to displacement from key foraging areas and the effects (e.g. disrupting communication, echolocation or threat detection) are considered to be reversible soon after cessation of the piling activity.

4.13.1.26 Temporally, piling could occur intermittently within a period of up to 16 years in total, with up to 33 Tier 1 offshore wind farm projects constructed within this cumulative period (Table 4.41). For harbour porpoise, a species that occurs widely throughout the North Sea, it is likely that piling at most of these projects could affect this species at some point over the respective piling phases. It is difficult to quantitatively assess temporal effects as this requires more detailed information on the actual piling schedules of each project. The information provided in this CEA only gives an indicative offshore construction period for each project and piling will only occur for a small proportion of the durations presented.

4.13.1.27 Considering both the spatial and temporal extent of over which behavioural effects could occur within the cumulative study area for harbour porpoise (NS MU), the magnitude of impact is predicted to be of regional spatial extent, long-term duration, intermittent, and reversible. It is predicted that the impact will affect the receptor directly (behavioural responses) and indirectly (avoidance of area). The magnitude of the impact could temporally lead to the potential for loss of foraging areas during pile-driving (some potentially within harbour porpoise SAC/SCIs in the North Sea)**.**

Pinnipeds

4.13.1.28 The maximum range over which TTS/fleeing was estimated to occur in grey seal due to concurrent piling using 5,000 kJ hammer energy at Hornsea Three is 1 km, with a total potential area affected of 6.28 km^2 (Table 4.27).

4.13.1.29 For projects whose piling phase overlaps with Hornsea Three, the ranges over which behavioural effect could occur, based on the maximum design spatial scenarios, are estimated at 1.5 to 13 km from the source (Table 4.43). Most other project Environmental Statements also use the Southall *et al.* (2007) criteria for TTS/fleeing to predict the range over which behavioural effects could occur. The exception to this was Moray East which used the Nedwell *et al.* (2007b) dBht approach to predict behavioural ranges and therefore these are not directly comparable with the TTS/fleeing ranges.

4.13.1.30 It is not considered appropriate or realistic to add modelled areas over which potential behavioural effects could occur, as there is likely to be a great deal of variation in timing, duration, and hammer energy used throughout the various CEA project construction periods detailed above. It is however assumed, as a precautionary approach, that animals within the TTS/fleeing zone will be displaced from the impacted area. During periods of displacement alternative foraging areas will be available to grey seal throughout the reference MU area.

4.13.1.31 The cumulative impact of behavioural effects on grey seal is predicted to affect animals directly (behavioural responses) and indirectly (limiting availability of foraging areas). Due to small ranges of effects in the context of the wider available habitat (i.e. area of SEE + NEE MU for grey seal is 122,508 km^2) the cumulative increase in magnitude is unlikely to lead to an assessment of greater magnitude than for Hornsea Three alone.

Sensitivity of the receptor

Harbour porpoise

4.13.1.32 Harbour porpoise are considered to be of low vulnerability with a high capacity to recover from the impact of TTS/fleeing following cessation of piling. Given the relatively small modelled impact ranges for TTS in harbour porpoise detailed in Table 4.42 for CEA projects, the number of animals affected is not predicted to lead to significant increases in the proportion of the NS MU population potentially affected above that presented for Hornsea Three concurrent piling using 5,000 kJ hammer energy (Table 4.28).

4.13.1.33 Harbour porpoise is likely to be sensitive to behavioural effects at close range within the zone of possible avoidance. Ranges for CEA projects given in Table 4.43 cover the whole suite of behavioural responses and it is unlikely that all animals affected within these ranges will suffer reduced fitness as a result of exposure. For those animals in closer proximity to the noise source, where foraging or communication is severely inhibited, it is possible that the potential cumulative impact could lead to population-level effects as a larger proportion of the NS MU population could be affected at any one time, particularly if piling occurs over the same periods at a number of key foraging areas. Temporally, piling could occur over a period of 16 years in total, with up to 30 offshore wind farm projects constructed within this cumulative period (Table 4.41). Therefore, the potential for return to baseline levels will depend on the ability of the population to recover in periods of non-piling. Although harbour porpoise range widely and would be able to exploit alternative foraging areas during the periods of pile-driving (which occur as a sequence of intermittent events) concurrent piling at North Sea offshore projects, particularly over a long timeframe, may have the potential to result in impacts at the MU population level in the short to medium term, however these are not predicted to affect the population in the long-term.

Grey seal

4.13.1.34 The potential impact ranges for behavioural effects (TTS/fleeing) in grey seal during piling at CEA projects (Table 4.44) are very small and are not considered likely to contribute cumulatively to an increased sensitivity in this species as the increase in the proportion of the MU reference population affected cumulatively would be marginal. Cumulative sensitivity to behavioural effects due to piling from CEA projects within the associated reference MU for grey seal is therefore likely to be the same as for Hornsea Three concurrent piling alone and will be assessed for the Environmental Statement following the further work described in paragraph 4.11.1.4.

It should be highlighted however, that TTS/fleeing is not considered an appropriate threshold to capture the full range of behavioural effects, and only gives an indication of the ranges out to which animals may be vulnerable to the effects of displacement. It is considered likely that behavioural effects could extend beyond this range where animals may be sensitive to sublethal effects of disturbance. This will be discussed further with the Marine Mammal EWG and assessment of the impact will be presented in the Environmental Statement.

<u>Significance of the effect</u>

Harbour porpoise

4.13.1.35 A range of effects arising from subsea noise during cumulative piling have been assessed for harbour porpoise and include TTS/fleeing and possible avoidance. Behavioural effects are predicted to occur intermittently during the piling phases of the offshore construction period for each project, with potential construction occurring at various points (spatially and temporally) during the 16 year period (Table 4.37). Based on the quantification of magnitude presented above and the sensitivity of the receptor to some behavioural effects, there is considered to be the potential for cumulative effects that could be significant in EIA terms, on harbour porpoise in the medium term.

4.13.1.36 It is expected that any effects would not adversely affect harbour porpoise population trends in the long term. As detailed in paragraph 4.11.1.86, the potential for recovery of the population in the long term is supported by the DEPONS study which modelled the impact of multiple piling events on harbour porpoise populations in the North Sea (van Beest *et al.*, 2015). Though the model is still in the developmental stage and therefore no firm conclusions can be drawn at this stage, these results do suggest that the Hornsea Three assessment presented is very precautionary, and that there are likely to be no long-term effects on harbour porpoise population trends in the North Sea.

Grey seal

4.13.1.37 The effect of subsea noise during cumulative piling leading to behavioural effects has been assessed for grey seal. The assessment has defined behavioural effects as potential displacement, based on the threshold for TTS/fleeing. Due to the small impact ranges and small proportion of the MU populations affected for either species, the effects are considered unlikely to be greater than for Hornsea Three alone. However, the assessment has highlighted the uncertainty of potential behavioural effects beyond the range over which displacement could occur and therefore this has been considered further in the CEA. Behavioural effects are predicted to occur intermittently during the piling phases of the offshore construction period for each project, with potential construction occurring at various points (spatially and temporally) during the 16 year period.

4.13.1.38 Based on the quantification of magnitude presented above and the sensitivity of the receptor to some behavioural effects, there is considered to be the potential for cumulative effect that could be significant in EIA terms, on grey seal in the medium term. However, it is predicted that these effects would not adversely affect grey seal population trends in the reference MUs in the long term.

Tier 2

Magnitude of impact

Auditory injury

4.13.1.39 As described for Tier 1 projects (paragraph 4.13.1.11) the potential impact ranges for injury to marine mammals are small, and for the maximum design spatial scenario for Hornsea Three alone, the magnitude of impact is considered to be of limited spatial extent. Hornsea Three will adhere to a MMMP to reduce the potential risk of auditory injury (PTS); therefore no further assessment for potential cumulative impact of auditory injury has been carried out.

TTS/fleeing

4.13.1.40 The cumulative assessment for Tier 1 projects demonstrated that the effects on harbour porpoise are largely localised to within each respective project area. There is no information on the TTS/fleeing ranges for the two additional Tier 2 projects – Moray West and Norfolk Vanguard – however it can be assumed that the range of effects will be similar to other projects assessed (Table 4.42).

4.13.1.41 For animals displaced over these small ranges there will be alternative foraging areas available to harbour porpoise, whose population range extends throughout the North Sea MU. Therefore, cumulative displacement from areas where subsea noise from pile-driving could cause a TTS/fleeing response are considered unlikely to cause more than a small change in harbour porpoise baseline, and the magnitude of impact is unlikely to be greater than described for Tier 1. Subsea noise from pile-driving could affect harbour porpoise directly (displacement) over relatively small spatial scales, and could occur intermittently over the duration of the 16 year cumulative period for Tier 2.

Behavioural effects

4.13.1.42 The potential for cumulative impacts of subsea noise from piling leading to behavioural effects on harbour porpoise and grey seal, has been assessed and is presented in Tier 2 of this CEA.

4.13.1.43 There are no ranges available for Tier 2 projects, although the supporting environmental information for Norfolk Vanguard states that behavioural effects could occur up to tens of kilometres for harbour porpoise and grey seal. The potential for behavioural effects is therefore assumed to be similar to those projects assessed for Tier 1 (Table 4.43 and Table 4.44).

Harbour porpoise

4.13.1.44 For harbour porpoise, the minimum behavioural effect ranges for CEA projects are 11 to 51 km and the maximum effect ranges are 21 to 70 km (based on modelled effect ranges for projects in Tier 1; Table 4.43). As described previously for Tier 1, the more severe behavioural effects are predicted to affect animals indirectly by limiting availability of foraging areas, with the magnitude of impact extending beyond project boundaries. In the outer ranges of the possible avoidance contour, behavioural effects are likely to be less severe and may result in temporary behavioural responses (e.g. brief cessation of vocalisation or reduced ability to detect predators) from which harbour porpoise will recover quickly once piling ceases.

4.13.1.45 In Tier 2, an additional two projects could overlap temporally with Hornsea Three during the construction phase: Moray West lies 554 km to the north of Hornsea Three array area and Norfolk Vanguard lies 73 km due south of Hornsea Three array area. Avoidance of key foraging areas may therefore be significant, particularly for sites closer to Hornsea Three which could cumulatively add to the areas affected within the south central North Sea region, an area of high density of harbour porpoise within the North Sea as a whole.

4.13.1.46 Temporally, the addition of two Tier 2 projects would also add to the duration of actual piling days within the 16 year cumulative period, although as described previously (paragraph 4.13.1.26) piling will only occur for a small proportion of the time during this period.

4.13.1.47 Considering both the spatial and temporal extent over which behavioural effects could occur within the cumulative study area for harbour porpoise (NS MU), the magnitude of impact for the Tier 2 assessment is predicted to be of regional spatial extent long-term duration, intermittent, and reversible. The impact will affect the receptor directly (behavioural responses) and indirectly (avoidance of area). There is potential for impacts to extend beyond the boundaries of each project area which could lead to loss of foraging areas during pile-driving (some potentially within harbour porpoise SAC/SCIs in the North Sea).

Pinnipeds

4.13.1.48 For projects, whose piling phase overlaps with Hornsea Three, the ranges over which behavioural effects could occur are estimated at up to 13 km from the source for Tier 1 projects and it is assumed that the ranges would be similar for Tier 2 projects (Table 4.43). TTS/fleeing could affect grey seal by causing displacement from key foraging areas during pile-driving, however, as the range of effects is small and likely to be localised within project areas, the magnitude of impact is unlikely to be greater than for Hornsea Three alone.

Sensitivity of receptor

Harbour porpoise

4.13.1.49 Given the relatively small modelled impact ranges for TTS in harbour porpoise, the number of animals affected is not predicted to increase significantly above those presented for Hornsea Three concurrent piling using 5,000 kJ hammer energy (Table 4.28).

4.13.1.50 As described for Tier 1 (paragraph 4.13.1.33) the cumulative impact of possible avoidance from Tier 2 projects with Hornsea Three has the potential to lead to population-level effects in the medium term, particularly if piling occurs over the same periods at a number of key foraging areas. Although, harbour porpoise range widely and would be able to exploit alternative foraging areas during the periods of pile-driving (which occur as a sequence of intermittent events), concurrent piling at North Sea offshore projects, particularly over 16 year offshore cumulative period, could result in periods of exclusion from key habitats, including sites that have been internationally designated for harbour porpoise. However it is considered that likely that the population would recover in the long term.

Grey seal

4.13.1.51 The potential impact ranges for TTS/fleeing of grey seal during piling at Tier 2 CEA projects are very small and are not considered likely to contribute cumulatively to an increased sensitivity in these species. Cumulative sensitivity to behavioural effects due to piling from CEA projects within the associated reference MU for grey seal is therefore likely to be the same as for Hornsea Three concurrent piling alone and will be assessed for the Environmental Statement following the further refinements described in paragraph 4.11.1.4.

4.13.1.52 It should be highlighted however, that TTS/fleeing is not considered an appropriate threshold to capture the full range of behavioural effects, and only gives an indication of the ranges out to which animals may be vulnerable to the effects of displacement. It is considered likely that behavioural effects could extend beyond this range where animals may be sensitive to sub-lethal effects of disturbance. It is noted that due to the complexity and variability of marine mammal behavioural responses, NOAA will continue to develop additional guidance regarding the effects of anthropogenic sound on marine mammal behaviour, (NMFS, 2016) and, where possible, these potential impacts will be considered further in the Environmental Statement.

Significance of the effect

Harbour porpoise

4.13.1.53 A range of effects arising from subsea noise during cumulative piling have been assessed for harbour porpoise and include TTS/fleeing and possible disturbance. As described for Tier 1, it is considered that there is the potential for some behavioural effects to be significant in EIA terms in the medium term as a result of exposure to subsea noise, however it is considered likely that there is potential for recovery of the population in the long term (paragraphs 4.13.1.35 and 4.13.1.36) and therefore potential for significant effect in the long term is unlikely.

Grey seal

4.13.1.54 The effect of subsea noise during cumulative piling leading to behavioural effects in grey seal has been assessed. As described for Tier 1 it is considered that there is the potential for cumulative effects that could be considered significant in EIA terms to occur in the medium term, as a result of sublethal effects at ranges greater than predicted for TTS/fleeing (paragraphs 4.13.1.37 and 4.13.1.38). Full recovery to baseline levels however is expected in the long term and therefore potential for significant effect in the long term is unlikely.

Increased traffic during construction, operation or decommissioning of Hornsea Three may result in an increase in disturbance, collision risk or injury to marine mammals during construction, operation or decommissioning of other projects

4.13.1.55 This cumulative assessment considers the effects of increased vessel noise on, and increased potential for collision with marine mammals, due to the potential increase in vessel movements from the construction, operation and maintenance, and decommissioning of the Hornsea Three offshore wind farm with other planned or existing projects, plans and activities. These are:

- Offshore wind farms where construction and/or operational and maintenance phases overlap with the construction and operational and maintenance phases of Hornsea Three;
- Operational phases of port and harbour developments where there is a potential for an uplift in vessel movements as a result of the development; and
- Cable and pipeline projects that have not yet commenced construction.

4.13.1.56 For harbour porpoise, minke whale and white-beaked dolphin, projects, plans and activities have been considered within the North Sea MU area (Figure 4.5); for grey seals, developments have been considered where they lie within the South-East England and North-East England MU (Figure 4.8), and for harbour seal, where developments are within the South-East England MU (Figure 4.8).

Tier 1

Magnitude of impact

4.13.1.57 Upon examination of data available for offshore wind, pipeline and cable, and coastal developments, it is clear that the greatest potential for cumulative increase in vessel movements arises from the development of other offshore wind farm developments (Table 4.45).

4.13.1.58 Thirteen offshore pipeline and cable projects and two coastal projects have been scoped into the CEA (Table 4.45). Vessel movements associated with cable and pipelines listed in Table 4.45 are likely to lead to only a very slight increase in vessel movements, particularly when considered against increased movements associated with offshore wind farm developments. Similarly, increased vessel movements associated with operational phases of port and harbour developments are likely to lead to only small or localised increases in vessel traffic and therefore can be considered negligible in relation to potential cumulative increased collision risk or disturbance to marine mammals due to increased vessel movement in the relevant MU.

4.13.1.59 For coastal projects scoped into the CEA, increased berthing facilities have been provided for 114 vessels at the Chatham maritime marina pontoon (total for two berthing extension projects at this location) and for 250 vessels at the Yorkshire Harbour and Marina could lead to an increase in vessel use in the North Sea. It is unlikely however that all berthing facilities will be fully occupied at any one time, and it is likely that vessel movements will be localised, short duration and intermittent.

4.13.1.60 Table 4.45 summarises the indicative vessel movements predicted to be associated with offshore wind farm developments in the North Sea over the lifetime of Hornsea Three, including the construction, operation and maintenance, and decommissioning phases. The estimated uplift in vessel movements (return trips) associated with Hornsea Three is 11,776 over the construction period (two phases over 11 years with up to six years between phases). It was assumed that a similar uplift would occur in vessel numbers during the decommissioning period. A total uplift of 2,832 per year was predicted over the operational lifetime of the project. As stated previously (paragraph 4.11.1.123) these numbers are based upon an assumption that the same (maximum) number of vessels transits would occur to/from port for each foundation installed. It is more likely that these trips will occur less frequently than assumed for the maximum design scenario. In addition, for a large proportion of time vessels will be moving slowly or stationary within the array area. Therefore, for Hornsea Three alone vessel movements are likely to be an overestimate.

4.13.1.61 Similarly, for each of the projects included in the CEA, the number of vessel movements represents a maximum design scenario (Table 4.45). Where a range of vessel movements has been provided in project documents, the maximum number of vessel movements has been presented. The numbers presented do not reflect the fact that most construction vessels associated with offshore developments will be stationary or slow moving, are likely to follow pre-determined routes to and from ports, and will adhere to best-practice guidance regarding changes of speed and not approaching marine mammals.

Table 4.45: Tier 1 cumulative impact assessment projects - vessel movements..

Project	Construction – number of vessel movements (return trips)	Operation and maintenance – number of vessel movements (return trips)
Under construction/approved offshore wind farms		
Dudgeon	Info not available	Info not available
Beatrice	Approximately 1,350 over construction period (approx. 675 per year)	Approximately 365 per year
Race Bank	~ 2,730 per year	704 per year
Hornsea Project One	6,966 over construction period (three phases over five years)	2,630 per year
Blyth demonstrator	Not available	Not available
Galloper	Not specified in Environmental Statement	Not specified in Environmental Statement
Consented/submitted offshore wind farms		
Aberdeen Bay Demonstrator	494 in total over 2 years	1,080 per year
Dogger Bank Creyke A & B	3,460 in total over 3 years	683 per year
Dogger Bank Teeside A & B	5,810 in total over 6 years	730 per year
East Anglia One	5,700 in total over 2.5 years	2,160 per year
East Anglia Three	8,000 (two phase approach) over 3.75 years	4,067 per year
Hornsea Project Two	6,200 in total over up to 7.5	2,817 per year
Kincardine	Minimal	78 per year (Minimal)
Triton Knoll	3,850 over 3 years	9,220 per year
Hywind Scotland Pilot Park	Minimal	Minimal
MORL Eastern Development Area	1,355 per construction period (4,065 total)	Not available/assessed as not significant
Inch Cape	3,500 over 1.5 years	Not available
Neart na Gaoithe	9,792 over 17 month construction period	1,550 per year
Sea Green (7 sub-projects)	4 vessels on site at any one time for each sub-project = 28 vessels in total at any one time over construction period	1,760 per year

4.13.1.62 Overall, baseline vessel use within the regional marine mammal study area which coincides with the North Sea MU is considered to be relatively high due to the presence of known shipping routes, ferry routes, and recreational boating areas (see paragraph 4.11.1.124 for current and predicted future baseline vessel movements within 10 nm of Hornsea Project One, Hornsea Project Two and Hornsea Three). Marine mammals are therefore likely to show some degree of habituation to vessel movements (Sini *et al*., 2005). Given the limited spatial extent of vessel movements from the projects considered in the CEA, with most activity confined to within the project area and transiting via existing routes, it is considered likely that marine mammals will tolerate the additional noise disturbance due to the increased vessel movements.

4.13.1.63 The impact is predicted to be of regional spatial extent, long term duration, intermittent, and both reversible (disturbance due to increased vessel noise) and irreversible (collision risk). It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

4.13.1.64 Marine mammals are particularly sensitive to increases in anthropogenic noise in the marine environment due to their reliance on sound for prey identification and capture, communication, and navigation. Potential impacts on marine mammals from increased noise due to increased vessel traffic could occur during construction, operational and maintenance, and decommissioning phases of Hornsea Three cumulatively with other projects, plans and activities.

4.13.1.65 There is also potential for a cumulative increase in collision risk between vessels and marine mammals during construction, operation and maintenance, and decommissioning of Hornsea Three with other projects, plans and activities. Marine mammals may be more vulnerable to collision risk if they are not able to detect the approach of a vessel. For example, sound produced during piling operations may mask the presence of vessels, leading to reduced detection and avoidance by marine mammals which could lead to increased potential for vessel strikes to occur.

4.13.1.66 It is considered that there is a high likelihood of avoidance from both increased vessel noise and collision risk, with both a high potential for recovery (< 1 year) for increased noise, and medium potential for recovery for collision risk. A moderate recovery rating has been given to reflect the low likelihood of collision and potential for non-lethal collision to occur.

4.13.1.67 All marine mammals considered in this PEIR are either of international or national importance.

4.13.1.68 Marine mammals are deemed to be of low vulnerability, to have both high recoverability (increased noise) and medium potential for recovery (collision risk), and high to very high conservation value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of effect

4.13.1.69 There is predicted to be a large increase in number of vessel movements within the North Sea over the construction, operation and maintenance, and decommissioning phases, of Hornsea Three cumulatively with other projects, plans and activities (Table 4.45).

4.13.1.70 Overall, the sensitivity of the receptor is considered to be **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

4.13.1.71 Due to the **medium** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the cumulative marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse significance, which is not significant in EIA terms.

4.13.1.72 Conclusions on the effect on the site integrity of European sites within the regional marine mammal study area are beyond the scope of this PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Tier 2

Magnitude of impact

4.13.1.73 The following developments have been assessed as Tier 2 projects in relation to potential for increased underwater noise from vessel traffic:

- Norfolk Vanguard offshore wind farm; and
- MORL western development area.

4.13.1.74 For Norfolk Vanguard, no details are available on the number of vessel movements associated with this development as the project is at the pre-application stage. There are expected to be crew transfers from port to the development area on a daily basis during construction and operation. As the project is expected to result in the installation of between 120 and 257 turbines, this has been estimated to result in a similar increase in vessel numbers during construction, and operation and maintenance phases as other offshore wind farms of a similar size (approximately 5,000 to 6,000 during construction and approximately 700 per year during operation and maintenance phases).

4.13.1.75 The MORL western development area is currently at scoping stage and no details for predicted vessel movements are available. However the MORL western development area Scoping Report does not predict a significant impact from increased vessel movements (Moray Offshore Renewables Ltd, 2016). Given the lack of quantitative data available, and that Tier 2 only contributes an additional two projects over and above the 16 already included in the Tier 1 assessment, the assumption has been made that impacts of Tier 2 projects will not be greater than Tier 1 projects.

4.13.1.76 The impact is therefore predicted to be of regional spatial extent, long term duration, intermittent, and both reversible (disturbance due to increased vessel noise) and irreversible (collision risk). It is predicted that the impact will affect the receptor both directly (collision risk) and indirectly (disturbance due to increased vessel movement). The magnitude is therefore considered to be **minor**.

Sensitivity of receptor

4.13.1.77 Details of marine mammal sensitivity and response to increased vessel traffic have been detailed in paragraphs 4.11.2.22; and 4.11.2.23, and have not been reiterated here. Marine mammals are deemed to be of low vulnerability, to have both high recoverability (increased noise) and medium potential for recovery (collision risk), and high to very high conservation value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of effect

4.13.1.78 Overall, it is predicted that the sensitivity of the receptor is considered to be **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

4.13.1.79 Due to the **medium** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the cumulative marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse significance, which is not significant in EIA terms.

4.13.1.80 Conclusions on the effect on the site integrity of European sites within the regional marine mammal study area are beyond the scope of this PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Changes in the fish and shellfish community resulting from impacts during construction, operation or decommissioning of Hornsea Three with the construction, operation or decommissioning phase of other projects may lead to loss of prey resources for marine mammals.

4.13.1.81 The cumulative assessment considers the effects of decreased prey availability on marine mammals due to changes in the fish and shellfish community arising from construction and operation of Hornsea Three, with other planned and operational offshore wind farms, aggregate dredging areas, and cables and pipelines within a 50 km buffer of Hornsea Three (and up to 100 km for the assessment of subsea noise from other offshore wind farms) (refer to chapter 3: Fish and Shellfish Ecology).

Tier 1

Magnitude of impact

4.13.1.82 A summary of the effects assessed in the fish and shellfish chapter is provided in Table 4.46 below. All impacts were assessed as being of minor adverse significance for Tier 1 projects. The potential effects of changes in prey resources on marine mammals could occur over the construction, operation and maintenance, and decommissioning phase and for the most part will occur over a local spatial extent. The exception to this is subsea noise arising from pile driving, where the behavioural effects on fish and shellfish may extend up to 30 or 40 km from offshore wind farms. However, it is likely that marine mammals would be behaviourally disturbed during the same period and over similar or greater distances compared to the fish and shellfish disturbance ranges.

4.13.1.83 Impacts during the construction and decommissioning phases would be temporary, intermittent and reversible whilst the magnitude of effects during operation are predicted to be long term and continuous. It is predicted that the impact will affect marine mammals indirectly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

4.13.1.84 Marine mammals exploit a range of prey resources and range widely to forage. Although some key prey items may be affected during operation, such as sandeels and herring, these effects are localised and unlikely to result in a significant effect on fish and shellfish assemblages. The sensitivity of marine mammals to changes in the fish and shellfish community is described in paragraphs 4.11.1.171 and 4.11.2.64.

4.13.1.85 Overall, marine mammal receptors are deemed to be of low vulnerability, high recoverability and high to very high conservation value. The sensitivity of the receptor is therefore considered to be **low**.

Table 4.46: Summary of cumulative impacts on fish and shellfish (as prey items for marine mammals).

Cumulative impact	Predicted effect	Impact assessment
Temporary habitat loss/disturbance during offshore wind farm construction, aggregate extraction/disposal and cable and pipelines installation.	Tier 1 Total temporary loss of: • 107.36 km² from offshore wind farms; • 165.50 km² from aggregate extraction/ disposal; and • 3.92 km² from cables and pipelines Total Tier 1: 276.78 km² Magnitude of effect is predicted to be minor.	Demersal spawning species are considered to be most vulnerable to habitat loss (paragraph 4.11.1.166). Total loss amounts to 0.14% of sandeel spawning habitat. Potential effect on brown crab and lobster populations particularly at inshore offshore wind farms and aggregate areas. Most species are considered to be of low sensitivity to this impact with the exception of brown crab, European lobster, sandeels and herring which are of medium sensitivity. Minor adverse significance.
	Tier 2 As above for Tier 1 plus Viking interconnector (1.86 km² temporary habitat loss) Total Tier 2: 278.64 km²	As above. Minor adverse significance.
Temporary increase in SSC and sediment deposition during offshore wind farm construction and aggregate extraction.	Tier 1 Plumes from aggregate extraction extend between 2 to 17 km from the source. Plumes from aggregate extraction-related dredging activity and the Hornsea Three extraction activity are generally predicted to coalesce together, creating a larger plume with concentrations similar to the alone activities, as opposed to an additive plume with a higher concentration. Additive plume only likely if cable installation at Hornsea Three took place at same time as aggregate extraction at Humber 5 and Humber 7. Plumes of high concentration would be short-lived persisting for a few hours only. Magnitude of effect is predicted to be minor.	Fish and shellfish are considered to be of low vulnerability and high recoverability to increases in SSC and sediment deposition. Sensitivity is as described previously (paragraph 4.11.1.167) as is assessed as low. Minor adverse significance.
Increase in underwater noise from piling operations at offshore wind farms	*Tier 1* Piling driving activities on a total of 1,556 days over an 11 year duration (=total temporal construction period), equating to 38.8% of the cumulative construction period. The extent of behavioural effects varied between projects and species and were in the range of 7.5 to 34 km for pelagic and demersal respectively. Triton Knoll predicted behavioural effects out to a distance of 42 km for herring, as the most hearing sensitive receptor. Magnitude of effect is predicted to be minor.	Fish and shellfish range in sensitivity depending on their hearing group (see paragraph 4.11.1.168). For the more hearing sensitive species (e.g. herring, sprat, cod, whiting, shad and European eel) the sensitivity was as assessed as medium, whilst other species were assessed as low sensitivity. Minor adverse significance.
	Tier 2 As above plus subsea noise during construction of the proposed Norfolk Vanguard offshore wind farm. No quantitative information available.	As above. Minor adverse significance.
Long term loss of fish and shellfish habitat from offshore wind farm infrastructure, cables and pipelines	*Tier 1* Cumulative long term habitat loss of: • 15.34 km² from physical presence of offshore wind farm foundations and scour protection • 0.02 km² from physical presence of cable and pipeline protection Magnitude of effect is predicted to be minor.	Demersal spawning species are considered to be most vulnerable to habitat loss (paragraph 4.11.2.56). Total loss amounts to 0.07% of the available habitat within the representative 50 km buffer of Hornsea Three. Most species are considered to be of low sensitivity to this impact with the exception of brown crab, European lobster, sandeels and herring which are of medium sensitivity. Minor adverse significance.
	Tier 2 As above plus Viking interconnector. No quantitative information available.	As above. Minor adverse significance
Introduction of hard substrates from offshore wind farm infrastructure leading to creation of reef habitat	*Tier 1* Total predicted habitat creation of: • 21.13 km² from physical presence of offshore wind farm foundations and scour protection • 21.91 km² from physical presence of cable and pipeline protection Magnitude of effect is predicted to be minor.	Habitat creation is likely to benefit crustacean species, such as crab and lobster, due to the expansion of their natural habitats and creation of additional refuge areas (paragraph 4.11.2.57). Potential negative effects could occur due to the introduction of non-native indigenous and invasive species (paragraph 4.11.2.58). Shellfish are considered to be of medium sensitivity, whilst fish are of low sensitivity. Minor adverse significance.
EMF emitted by subsea cables from offshore wind farms and interconnectors	*Tier 1* Cumulative length of array, substation interconnector and export cables: • 5,343 km from offshore wind farms • Unknown from Viking interconnector Magnitude of effect is predicted to be minor.	The most sensitive species are likely to be elasmobranchs, such as rays and dogfish, and migratory species, such as salmon and European eel (paragraph4.11.2.59). EMF from electrical cabling is likely to dissipate rapidly with distance from the cable. Fish and shellfish receptor are of medium to low sensitivity. Minor adverse significance.
	Tier 2 As above plus the proposed Viking Interconnector. No quantitative information available.	As above. Minor adverse significance.
Displacement of fishing pressure as a result of offshore wind farm operation	For the purposes of the CEA is has been assumed that there is a fishing restriction within a 500 m operational safety zone around turbines for all offshore wind farms included in the assessment. It is unlikely that there would be a fishing exclusion through entire array areas. Magnitude of effect is predicted to be minor.	Exclusion of fishing within the operational wind farms has the potential to enhance fish and shellfish populations by providing refuge from fishing activities for certain species targeted by commercial fisheries (paragraph 4.11.2.62). Due to the uncertainty associated with such benefits, sensitivity of fish and shellfish species is low. Minor beneficial significance.

Significance of effect

4.13.1.86 Overall, it is predicted that the sensitivity of the receptor is considered to be **low** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse/beneficial significance, which is not significant in EIA terms.

4.13.1.87 Due to the **low** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the cumulative marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse/beneficial significance, which is not significant in EIA terms.

4.13.1.88 Conclusions on the effect on the site integrity of European sites within the regional marine mammal study area are beyond the scope of this PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

Tier 2

Magnitude of impact

4.13.1.89 The inclusion of the Viking interconnector will add to the magnitude of effects on fish and shellfish prey resources arising from the impacts of temporary habitat loss/disturbance, long term habitat loss, and EMF from subsea cables. There was no quantitative information available to assess the extent of the impacts but any increase is likely to be negligible in the context of the Tier 1 projects. Similarly, there was no quantitative data to allow additional assessment of the subsea noise arising from the Norfolk Vanguard offshore wind farm on fish and shellfish receptors. Behavioural disturbance has therefore be anticipated to occur over similar ranges as described for Tier 1 projects.

4.13.1.90 Impacts during the construction and decommissioning phases would be temporary, intermittent and reversible whilst the magnitude of effects during operation are predicted to be long term and continuous. It is predicted that the impact will affect marine mammals indirectly. The magnitude is therefore, considered to be **minor**.

Sensitivity of receptor

4.13.1.91 Marine mammal receptors are deemed to be of low vulnerability, high recoverability and high to very high conservation value. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of effect

4.13.1.92 Overall, the sensitivity of the receptor is considered to be **low** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** beneficial significance, which is not significant in EIA terms.

4.13.1.93 Due to the **low** sensitivity of receptors and the **minor** magnitude of effect, effects on marine mammal notified interest features (harbour porpoise, grey seal or harbour seal) of designated sites (SACs/SCIs) within the cumulative marine mammal study area (Figure 4.1), are predicted to be of **minor** adverse/beneficial significance, which is not significant in EIA terms.

4.13.1.94 Conclusions on the effect on the site integrity of European sites within the regional marine mammal study area are beyond the scope of this PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform the Appropriate Assessment for Hornsea Three (DONG Energy, 2017).

4.14 Transboundary effects

4.14.1.1 A screening of transboundary impacts has been carried out and is presented in annex 5.5: Transboundary Impacts Screening Note. This screening exercise identified that there was potential for significant transboundary effects with regard to marine mammals from Hornsea Three upon the interests of other European Economic Area (EEA) States. A number of EU ministries were consulted Hornsea Three including those from Belgium, Germany, Denmark, France, Netherlands, Norway, Portugal, Republic of Ireland and Sweden and the Environmental Statement will be updated on the basis of the response received.

4.14.1.2 Based on the information available at PEIR, it is anticipated that a number of direct and indirect transboundary impacts could occur on marine mammal receptors. Direct impacts may occur due to underwater noise generated during construction, particularly pile-driving during the installation of foundations, and due to an increase in vessel movements during construction, operation and decommissioning leading to increased disturbance and collision risk to marine mammals. An indirect impact has also been identified due to changes in the availability of prey resources which could arise from transboundary impacts on fish and shellfish receptors.

4.14.1.3 For all impacts identified, with the exception of underwater noise from pile driving, Hornsea Three, both alone and cumulatively, is predicted to result in effects of **minor** or **negligible** adverse significance, and therefore are not considered further in this transboundary effects section.

4.14.1.4 Marine mammals range widely over the North Sea from UK coastal waters across to the coast of Europe and into the western Baltic, Skagerrak and Kattegat Seas. Subsea noise from pile-driving has the potential to cause injury or disturbance to marine mammal species within proximity to offshore wind farms throughout European waters. Potential injury (physical or auditory damage) generally occurs within a short range of pile-driving (10's of metres) and it is standard practice to put in place mitigation procedures that reduce the risk of injury during piling.

4.14.1.5 Behavioural disturbance could occur over much larger ranges (10's of kilometres) and therefore there is potential for transboundary effects to occur where subsea noise arising from Hornsea Three could extend into waters of other EEA states and where marine mammals are cumulatively disturbed over a greater proportion of their natural range. This has been explored in the cumulative assessment as offshore wind farm projects within the North Sea MU, including those in European waters, were included in the screening.

4.14.1.6 Similarly, the potential for an increase in vessels to lead to increased disturbance and collision risk to marine mammals from all offshore wind farm projects, including projects in European waters, was explored in the cumulative assessment. The assessment concluded that, due to the high level of vessel activity throughout the North Sea, and potential for habituation to vessel movement and noise, marine mammals are likely to tolerate increases in vessel activity. Therefore, transboundary impacts on marine mammal receptors from an increase in vessel activity are considered to be of **minor** adverse significance, and not significant in EIA terms.

4.14.1.7 Changes in fish and shellfish communities have been identified in the transboundary screening arising from habitat loss and disturbance and an increase in SSC during construction, operation and maintenance, and decommissioning of Hornsea Three. Any impacts could indirectly affect marine mammals due to loss of prey resources. The transboundary assessment in chapter 3: Fish and Shellfish concluded that the impacts will be limited in extent (to within the immediate vicinity of Hornsea Three array area and offshore cable corridor) and are not predicted to extend into the waters of other EEA states. Since marine mammals exploit a range of prey resources and range widely to forage, transboundary impacts on marine mammals are considered to be of **minor** adverse significance, and not significant in EIA terms.

4.15 Inter-related effects

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

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the project (construction, operational and maintenance, and decommissioning), to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (e.g. subsea noise effects from piling, operational turbines, and from foundation removal during decommissioning) and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on marine mammals, such as subsea noise from piling, vessel disturbance and increased suspended sediment concentrations, may interact to produce a different or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

4.15.1.2 A description of the likely inter-related effects arising from Hornsea Three on marine mammals is provided in chapter 11: Inter-Related Effects (Offshore).

4.16 Conclusion and summary

4.16.1.1 Baseline data from site-specific surveys and historical records have demonstrated that Hornsea Three and the former Hornsea Zone are important areas for a number of marine mammal species that occur regularly throughout the southern North Sea. Key species that have been identified as VERs within the Hornsea Three marine mammal study area include harbour porpoise, minke-whale, white-beaked dolphin, grey seal and harbour seal. Harbour porpoise, in particular, was found to occur in high densities within the Hornsea Three marine mammal study area, reflecting the importance of the southern North Sea for this species. The Hornsea Three offshore cable corridor intersects the Southern North Sea cSAC designated for "persistent high densities of harbour porpoise". Within the Hornsea Three marine mammal study area there were a total of 11 European sites with marine mammal interest features for one or more of the following species: harbour porpoise, harbour seal and grey seal.

4.16.1.2 The impacts of activities during the construction, operation and maintenance, and decommissioning phases of Hornsea Three, both alone and cumulatively with other plans and projects, were assessed with respect to these key marine mammal species and marine mammal features of SACs within the study area. The impact assessment has adopted a precautionary approach throughout in order to help to address any uncertainties. The effects are summarised in Table 4.47 below. Assuming successful implementation of the proposed mitigation measures, the majority of impacts from Hornsea Three alone were assessed as being of minor adverse significance or less.

4.16.1.3 This PEIR describes the magnitude of impact from subsea noise on marine mammal receptors and the sensitivity of the receptors to the range of impacts. At this stage, however, the preliminary information presented here is based on levels of conservatism, and refinement of the assessment will be undertaken for the Environmental Statement as described in paragraph 4.11.1.4. The assessment did, however, conclude that there is potential for significant effects from piling at Hornsea Three alone on harbour porpoise and grey seal, with respect to behavioural disturbance.

4.16.1.4 Cumulative impacts screened into the assessment were considered likely to arise from other offshore wind farm developments, cables and pipelines, aggregate extraction, military activities (UXO detonations) and coastal developments. The cumulative assessment was undertaken using a tiered approach, which placed the greatest emphasis on projects that had been consented or submitted (Tier 1) and lesser emphasis on projects likely to come forward and which had submitted a scoping report (Tier 2) or potentially may come forward as advised to PINS (Tier 3). The CEA considered those impacts for which an impact of minor adverse significance or greater was predicted to arise from Hornsea Three alone. Impacts that were predicted to be of negligible significance were screened out of the CEA. In this way, cumulative impacts were assessed for underwater noise arising from pile-driving and other construction activities, increased traffic during construction, operation or decommissioning leading to an increase in disturbance or collision risk to marine mammals, and changes in the fish and shellfish community during construction, operation and decommissioning.

4.16.1.5 For most of the impacts assessed in the CEA the impacts were predicted to be of minor adverse significance and not significant in EIA terms. As described above, it was not possible to draw conclusions with respect to cumulative effects of subsea noise from piling, however, the assessment highlighted the potential for significant behavioural effects to occur on harbour porpoise and grey seal.

4.17 Next Steps

4.17.1.1 Additional data collected during the ongoing aerial surveys of the Hornsea Three array area plus 4 km buffer will be analysed to provide further baseline information on harbour porpoise and other marine mammal species.

4.17.1.2 Hornsea Three are currently undertaking a review of the maximum design scenario for piling, by reviewing construction experience at other offshore wind farms. Pending the completion of this review, the Hornsea Three marine mammal noise related assessments will be revisited, including where applicable the subsea noise modelling, and this will enable a more fully developed and accurate impact assessment to be completed. Hornsea Three will consult with the Marine Mammal EWG on any changes to the marine mammal noise assessment prior to the submission of the Environmental Statement in Quarter 2 of 2018.

4.17.1.3 The impact assessment is based on criteria to assess magnitude and sensitivity of marine mammals. These criteria may be refined for the Environmental Statement and any changes will be discussed and agreed with the Marine Mammal EWG in order to provide further confidence in the assessment approach.

4.17.1.4 Hornsea Three will also look to provide more detailed quantification of the layers of precaution in the assessment for the Environmental Statement.

Table 4.47: Summary of potential environment effects, mitigation and monitoring.

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Construction Phase							
Underwater noise from foundation piling within the Hornsea Three array area or for the HVAC booster substations within the offshore cable corridor has the potential to cause injury or disturbance to marine mammals	A 30 minute soft-start will be used for all piling activities. Piling will commence at 15% hammer energy with a reduced strike rate and gradually ramp up over a 30 minute period to achieve the required hammer energy (up to the maximum specified). An MMMP will also be implemented. The MMMP will use ADDs as the primary mitigation measure prior to soft start to ensure marine mammals are deterred beyond the range at which injury could occur.	No magnitude or sensitivity evaluation has been undertaken with this PEIR and therefore no significance of effect has been predicted.					
		No magnitude or sensitivity evaluation has been undertaken with this PEIR and therefore no significance of effect has been predicted.					
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		No magnitude or sensitivity evaluation has been undertaken with this PEIR and therefore no significance of effect has been predicted.					
Increased vessel traffic during construction may result in an increase in disturbance, collision risk, or injury to marine mammals	Codes of conduct for vessel operators including advice to operators to not deliberately approach marine mammals and to avoid abrupt changes in course or speed should marine mammals approach the vessel to bow-ride	Minor	Medium	Minor adverse	None	N/A	N/A
Increased suspended sediments arising from construction activities, such as cable and foundation installation, may reduce water clarity and impair the foraging ability of marine mammals	N/A	Negligible	Low	Negligible	None	N/A	N/A
Accidental pollution release during construction (including construction activities, vessels, machinery, and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals	A CoCP will be produced and followed to prevent accidental spills.	Negligible	Low	Negligible	None	N/A	N/A
Changes in the fish and shellfish community resulting from impacts during construction may lead to loss of prey resources for marine mammals	An EMP will be produced and followed and will include a MMP (see chapter 3: Fish and Shellfish Ecology)	Minor	Low	Minor adverse	None	N/A	N/A

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Operation Phase							
Noise and vibration arising from operational turbines may cause disturbance to marine mammals	N/A	Negligible	Low	Negligible	None	N/A	N/A
Increased vessel traffic during operation and maintenance may result in an increase in disturbance to and collision risk with marine mammals	Codes of conduct for vessel operators including advice to operators to not deliberately approach marine mammals and to avoid abrupt changes in course or speed should marine mammals approach the vessel to bow-ride	Minor	Medium	Minor adverse	None	N/A	N/A
Electromagnetic Fields (EMF) emitted by array and export cables may affect marine mammal behaviour	Array, export and interconnector cables will be buried to a target burial depth of 1 m subject to a cable burial risk assessment. Where it is not possible to ensure that cables will remain buried, cable protection will be installed	Negligible	Low	Negligible	None	N/A	N/A
Accidental pollution released during operation and maintenance (including maintenance activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals	A PEMMPP will be produced and followed to prevent accidental spills.	Negligible	Low	Negligible	None	N/A	N/A
Changes in the fish and shellfish community resulting from impacts during operation and maintenance may lead to loss of prey resources for marine mammals	N/A	Minor	Low	Minor beneficial	None	N/A	N/A

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Decommissioning Phase							
Underwater noise arising from turbine and cable removal within the Hornsea Three array area and the Hornsea Three offshore cable corridor and associated vessels may cause disturbance to marine mammals	N/A	Negligible	Low	Negligible	None	N/A	N/A
Increased vessel traffic during decommissioning activities may result in an increased collision risk to marine mammals	Codes of conduct for vessel operators including advice to operators to not deliberately approach marine mammals and to avoid abrupt changes in course or speed should marine mammals approach the vessel to bow-ride.	Minor	Medium	Minor adverse	None	N/A	N/A
Increased suspended sediments arising from decommissioning activities such as cable and foundation removal may impair the foraging ability of marine mammals	N/A	Negligible	Low	Negligible	None	N/A	N/A
Accidental pollution released during decommissioning (including decommissioning activities, vessels, machinery and offshore fuel storage tanks) may lead to release of contaminants into the marine environment and subsequently result in potential effects on marine mammals	A decommissioning plan will be produced and followed to prevent accidental spills.	Negligible	Low	Negligible	None	N/A	N/A
Changes in the fish and shellfish community resulting from impacts during decommissioning may lead to loss of prey resources for marine mammals	N/A	Minor	Low	Minor	None	N/A	N/A

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