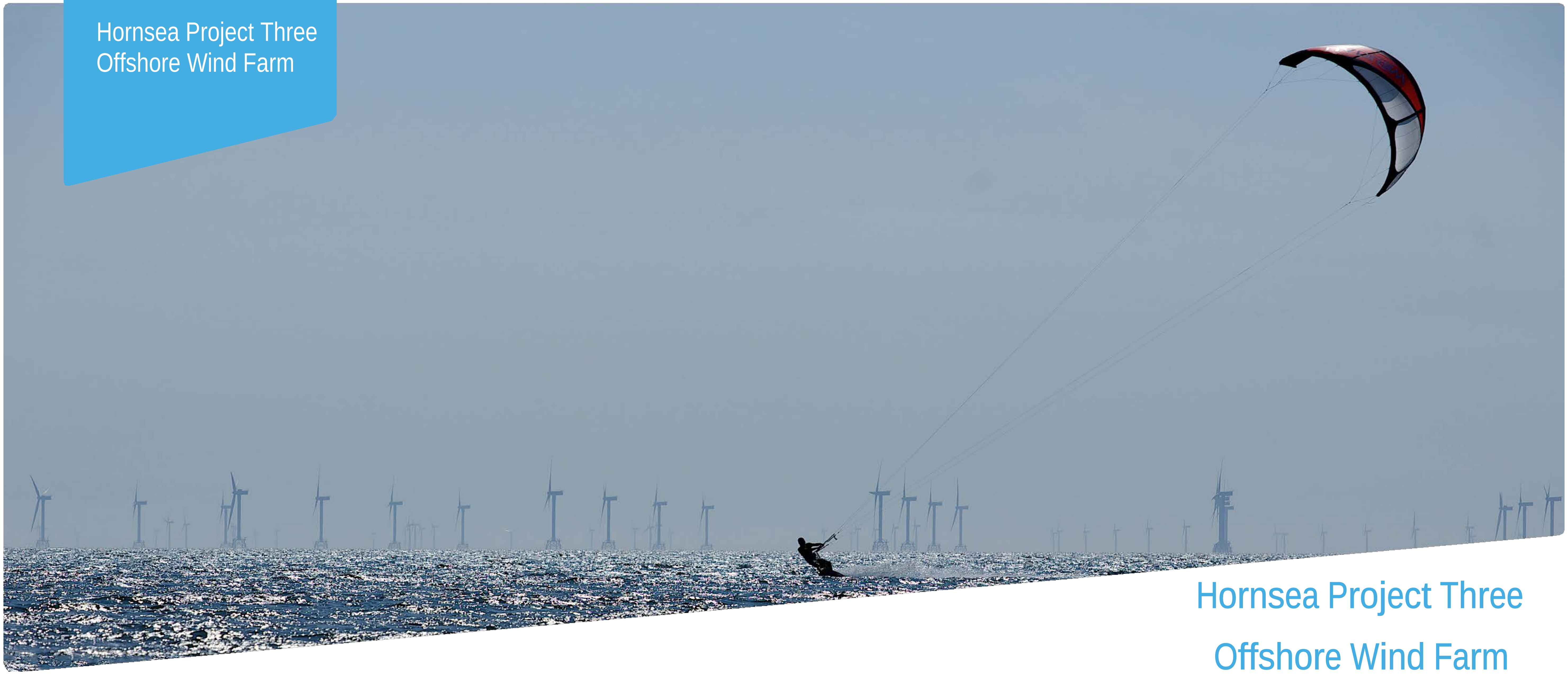
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three Offshore Wind Farm

Environmental Statement:
Volume 2, Chapter 4 – Marine Mammals

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Hornsea 3
Offshore Wind Farm

Ørsted

Environmental Impact Assessment

Environmental Statement

Volume 2

Chapter 4 – Marine Mammals

Report Number: A6.2.4

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Date: May 2018

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

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Glossary

Term	Definition
Average hammer energy	A conservative hammer energy which reflects the upper estimate of the average hammer energy expected to be achieved across all piling activity for each foundation type.
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.
Maximum design scenario piling parameters	The definition of the hammer energy profile (how the hammer energy ramps up over time) and the maximum hammer energy based on the absolute maximum expected hammer energy to be required across all locations for the installation of each foundation type.
Most likely piling parameters	The definition of the hammer energy profile and the maximum hammer energy likely to be reached on the majority of pile installations.
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, some outputs from SCANS III were published in 2017 and these have been 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
cSAC	Candidate Special Area of Conservation
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

Acronym	Description
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
$SEL/SEL_{cum}/SEL_{ss}$	Sound Exposure Level/Sound Exposure Level (cumulative)/Sound Exposure Level (single strike)
SMRU	Sea Mammal Research Unit
SNCBs	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPL/SPL_{peak}	Sound Pressure Level/Sound Pressure Level (peak)
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
dB	Decibel
GW	Gigawatt
kV	Kilovolt
kW	Kilowatt
kg	Kilogram
km	Kilometre
km^{-2}	Per kilometre squared
km	Knot
l	Litre
m	Metre
mm	Millimetre
MW	Megawatt
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 Environmental Statement presents the findings 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) and accompanies the application to the Secretary of State for Development Consent. This Environmental Statement sets out the findings of the EIA taking into consideration the consultation responses received in relation to the Preliminary Environmental Information Report (PEIR) and all other consultation undertaken to date.

4.2.1.2 It is intended that the Environmental Statement will provide statutory and non-statutory consultees with sufficient information to complete the examination of Hornsea Three and will form the basis of agreement on the content of the DCO and/or Marine Licence conditions (as required). In particular, this Environmental Statement chapter:

- Presents the existing environmental baseline established from desk studies, site specific and regional survey data, 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 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 survey extents within the Hornsea Three marine mammal study area agreed with statutory consultees (EWG meeting in April 2016 and full meeting minutes are presented in the Evidence Plan (Consultation Report Annex 1 Evidence Plan)) 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) III Block O 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.

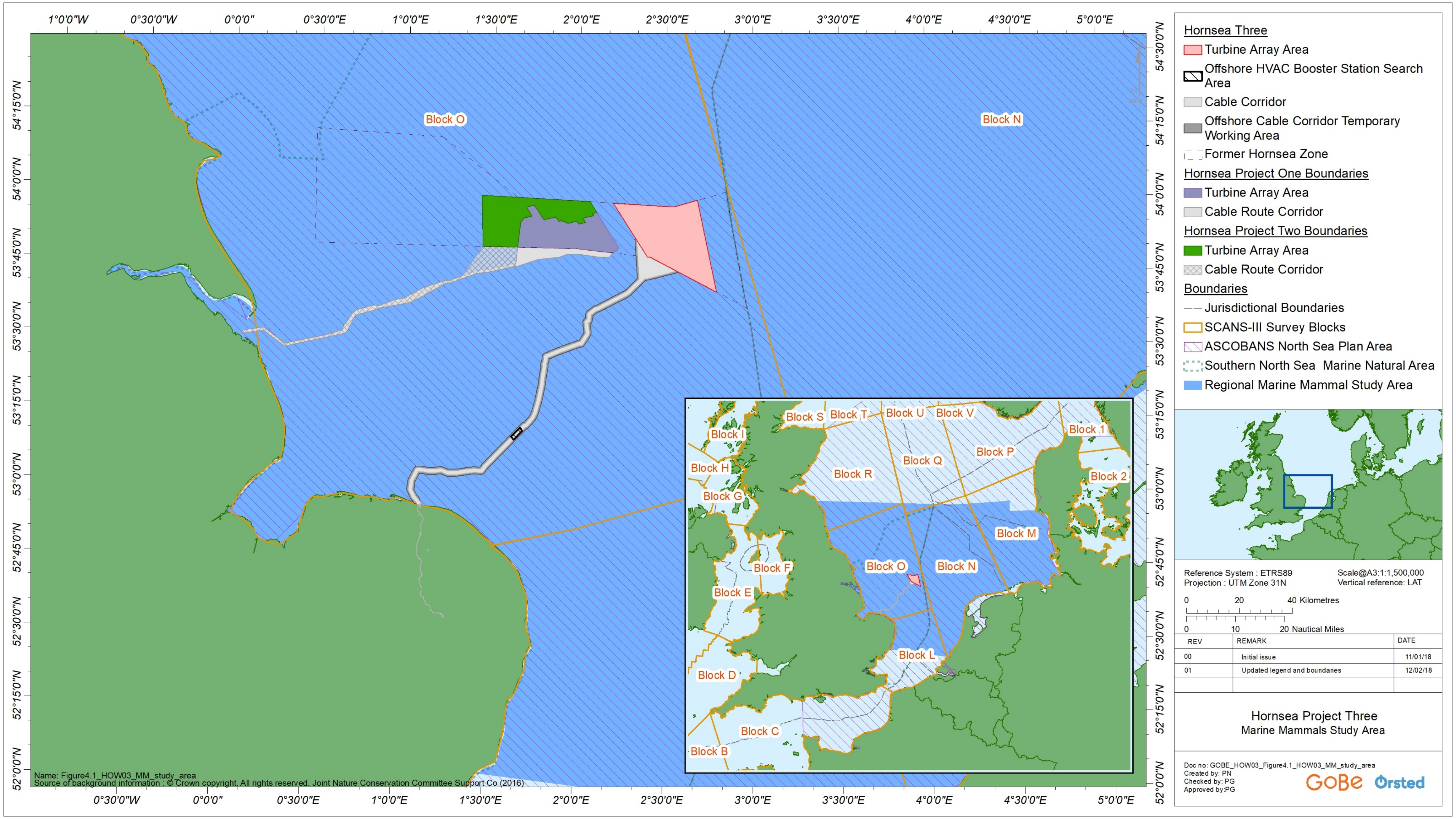

Figure 4.1: Location of the Hornsea Three marine mammal study area (within which is the Hornsea Three array area and offshore cable route corridor and the former Hornsea Zone) and location of the regional marine mammal study area.

4.4 Planning policy context

4.4.1 National Policy Statements

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) and the NPS for Renewable Energy Infrastructure (EN-3, DECC, 2011b).

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. This has been addressed with regard to the impacts on marine mammals from changes to suspended sediment concentrations (SSCs) in the water column (Section 4.11).

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.

4.4.2 Other relevant policies

4.4.2.1 A number of other policies are relevant to the marine mammal assessment. The Marine Policy Statement (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).

4.4.2.2 The assessment of potential changes to fish and shellfish and the corresponding impacts on marine mammals has also been made with consideration to the specific policies set out in the East Inshore and East Offshore Coast Marine Plans (MMO, 2014). Key provisions are set out in Table 4.3 along with details as to how these have been addressed within the assessment.

4.4.2.3 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.

4.4.2.4 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 4.4 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 Environmental Statement
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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2) 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 4.13).
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 Environmental Statement
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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).
Mitigation may be possible in the form of careful design of the development itself and the construction techniques employed (paragraph 2.6.70 of NPS EN-3).	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) will be devised following consultation with the Statutory Nature Conservation Bodies (SNCBs) and approved by the Marine Management Organisation (MMO) prior to construction commencing.
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 In Principle Monitoring Plan (IPMP) (Document Ref: A8.8) and the Project Environmental Management and Monitoring Plan (PEMMP), which includes the 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 4.15.
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 4.13).
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: East Marine Plan Policies of relevance to marine mammals.

Policy	Key Provisions	How and where considered in the Environmental Statement
East Inshore and East Offshore Marine Plans – ECO1	Cumulative impacts affecting the ecosystem of the East marine plans and adjacent areas (marine, terrestrial) should be addressed in decision-making and plan implementation.	Cumulative effects are considered within section 4.13.
East Inshore and East Offshore Marine Plans – MPA1	Any impacts on the overall marine protected area (MPA) network must be taken account of in strategic level measures and assessments, with due regard given to any current agreed advice on an ecologically coherent network.	Designated nature conservation sites of relevance to marine mammals are described in volume 5, annex 4.1: Marine Mammals Technical Report. The predicted changes to marine mammals have been considered in sections 4.11 and 4.13.

Table 4.4: 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 and where considered in the Environmental Statement
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 0, 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 4.13, 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 4.13, 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 4.13, respectively.
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 4.13, respectively.
Descriptor 10: Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	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 4.11.1.199) and in the CEA (see paragraph 4.13.1.61).

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 Environmental Statement. 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

4.5.3.1 Table 4.5 below summarises the issues raised relevant to marine mammals, which have been identified during consultation activities undertaken to date, including those received in response to the PEIR. Table 4.5 also indicates either how these issues have been addressed within this Environmental Statement or how Hornsea Three has had regard to them. Further information on the consultation activities undertaken for Hornsea Three can be found in the Consultation Report (document reference number A5.1) that accompanies the application for Development Consent.

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 Evidence Plan (document reference number A5.1.1), 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 liaised as appropriate with JNCC throughout 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 2017 and into 2018. Following Section 42 consultation on the PEIR, a further three meetings were held with the EWG, which included discussions on the updated baseline characterisation following collection of site specific survey data, amendments to the impact assessment considering Section 42 consultation responses, and presentation of outputs from the updated assessment. It is considered that many of the issues raised during the Section 42 consultation have now been resolved as detailed within the Evidence Plan (document reference A5.1.1). 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 4.5 below (see column "*response to issue raised and/or where considered in this chapter*"). Meetings were also held with the Whale and Dolphin Conservation, firstly in April 2017 to update them on Hornsea Three and discussions that were ongoing with the Marine Mammal EWG and then again in March 2018 to provide an update on the evolution of the impact assessment following PEIR.

Table 4.5: 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 4.7). 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 assessment is presented in Section 4.14.
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 4.7).
November 2016	Natural England (Scoping Opinion)	MMO should seek advice from Cefas on the noise modelling methodology.	Updated underwater noise modelling has been undertaken for the refined project description (volume 1, chapter 3) and using a revised model with increased empirical evidence underpinning it. The updated underwater noise modelling is summarised throughout this chapter and presented in full in volume 4, annex 3.1.
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 Horsey 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 the PEIR; however, it has been included in the Environmental Statement and full details are provided in volume 5, annex 4.1: Marine Mammals Technical Report.
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 4.11). In addition, it was agreed that a licence application should be made at the appropriate time (post-consent) if required for the clearance of UXO. An assessment of the impacts from UXO detonations are provided in paragraphs 4.11.1.175 *et seq*.
September 2017	MMO (Section 42)	The MMO raised concerns regarding the noise modelling that had been carried out, requesting that: Source noise levels for SPL and SEL should be provided and assessed. Further justification should be provided regarding the noise modelling and associated data sources. The noise modelling should include reference to potential cumulative effects from two piling vessels. It was noted that: The Subsea Noise Technical Report does not contain the literature review of the impacts of operational noise referred to in the text. Further evidence is required on background shipping levels and relative impacts of shipping noise from the construction of Hornsea Three.	Regarding the concerns around the noise modelling, the source levels are provided and discussed within volume 4, annex 3.1: Subsea Noise Technical Report. Updated noise modelling and associated Technical Report contains the full justification for the identified noise contours and identifies the data sources used for the modelling. Cumulative effects from two piling vessels are discussed within the impact assessment within this chapter (paragraph 4.11.1.1 *et seq*). With respect to the other concerns, volume 4, annex 3.1: Subsea Noise Technical Report has been updated accordingly to provide the literature review focusing on operational noise, including the justification for the predicted source levels and impact ranges of operational noise. The background level for shipping movements (not including the Hornsea Zone projects) is described in volume 2, Chapter 7; Shipping and Navigation and the total vessel movements per day (including the Hornsea Zone project) predicted during construction are described in paragraph 4.11.1.199 *et seq* of this document. The relative impact of shipping noise is described in detail in volume 4, annex 3.1: Subsea Noise Technical Report.
September 2017	MMO (Section 42) Natural England (Section 42)	The MMO and Natural England both raised concerns regarding the lack of any evaluation of the magnitude and sensitivity of the potential impacts from underwater noise on marine mammals. This should be addressed within the Environmental Statement. Impacts from UXO detonations were recommended to be included within the maximum design scenario for potential cumulative impacts.	This Environmental Statement chapter contains a full assessment of the potential impacts of underwater noise from Hornsea Three, with a fully detailed methodology including the appropriate magnitude and sensitivity evaluation. The magnitude and sensitivity ranges have been communicated with the relevant key stakeholders through the EWG. The impacts from UXO on marine mammals have been considered in paragraph 4.11.1.175 *et seq* of this document, with the associated noise modelling based on that undertaken for Hornsea Project One and already provided to the MMO and its advisors as discussed through the EWG and full meeting minutes are presented with the Evidence Plan (consultation Report Annex 1 Evidence Plan).
September 2017	Natural England (Section 42 Consultation Response)	Natural England raised concerns regarding the assessment of the potential impact on seals, with specific regard to the following points: Natural England originally requested that the north east England Management Unit (MU) for grey seals be included in the assessment due to the distances seals can travel, however as the PEIR scoped out all the haul out sites for this MU, Natural England consider that the north east England MU and associated reference population should be removed from the overall assessment. Consideration of haul out and pupping site at Horsey and sites at Donna Nook and the North Norfolk Coastline (Blakeney and Horsey). Status of the pupping information for seals with species regard to Blakeney and Horsey and Donna Nook. Combining these three locations in the central North Sea, it is likely that they have more pups than most other pupping sites in the UK, excepting the Outer Hebrides and Orkney (SCOS, 2016). that the need to update the numbers for the Thames seal population need updating; approximately 450 harbour seals are now present. Despite there being no disturbance thresholds for pinnipeds, current work by Hastie *et al*. (2015) mentioned in the text suggests there could be Temporary Threshold Shift (TTS)/Fleeing up to 9.8 km. Natural England queries what the distance is from the southern HVAC booster piling location to the coastline and if seals (including pups) could be prevented from reaching/leaving important haul out sites and/or foraging from these sites along the north Norfolk coast at sensitive times of the year? Where seal tracks are shown, the number of seals tagged in each location should be identified in the text accompanying figures and also noted the movement of the seals from one location does not necessary represent those that haul out elsewhere. Seal densities have been calculated using a model, please can the uncertainties inherent within the model be identified.	Regarding the use of the north east MU, it was agreed at the Marine Mammals EWG on 20 November 2017 that if the updated telemetry data showed some linkages between the north east MU and the Hornsea Three site then it would still be appropriate to use the north east MU to inform the baseline. The updated telemetry data is presented in volume 5, annex 4.1: Marine Mammals Technical Report and shows some linkages between the north east MU and the Hornsea Three site and therefore the baseline has retained the north east MU to inform the assessment. The impacts to seals have been assessed based on the ‘at sea usage’ data, which includes seal usage around the Donna Nook and north Norfolk coast haul out sites. The abundance records for seals have been updated within volume 5, annex 4.1: Marine Mammals Technical Report and are used throughout the ES chapter. The assessment includes calculation of the seal within dose-response curves and the assessment demonstrated that even piling at the most southerly potential HVAC location would not result in any barrier effects to the haul out sites along the north Norfolk coast (paragraph 4.11.1.140 *et seq*). Seal tracks are presented in the Marine Mammals Technical Report (volume 5, annex 4.1). Where models have been used to calculate densities, the uncertainties within the model are discussed in the technical report.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
September 2017	Natural England (Section 42 Consultation Response)	Entanglement impacts should be scoped into the assessment where floating turbines are proposed.	Floating turbines have now been removed from the potential options for use within the development and the Project Description (volume 1, chapter 3) has been updated accordingly, therefore, this concern is now no longer applicable.
September 2017	Natural England (Section 42 Consultation Response)	Natural England raised concerns regarding the noise modelling and piling assumptions, with specific regard to the following points: As harbour porpoise will not be outside the injury zones after the soft start period of 7.5 minutes, this soft start (hammer energy below 15% of maximum) should be extended as per discussion at EWG meeting 10 July 2017. The PTS range for marine mammals using the NOAA SEL_{cum} threshold should be presented and considered in the assessment. The additional modelling at 2 m depth is not currently presented in the marine mammal chapter. Please can this be included. Would modelling of the 15 m pile cause more issues and greater PTS/TTS/disturbance zones for low frequency cetaceans such as minke whales? Given SPL peak levels look like they are above 175 dB at the coast (or even nearer 190 dB for the HVAC south location), Natural England queries if this could constitute a barrier for hauled out seals, or impact pups? Whether values for HF cetaceans are correct for the 155 dB Weighted SEL values? Currently for 5,000 kJ, there is a maximum of 8.8 km, but for the lower energy 2,500 kJ, it is a distance of 17 km. Clarification as to why 40% blow energy for the 5,000 kJ hammer reports a maximum range of 53 km, but a mean range of 58 km?	Piling assumptions (including soft start durations and pile size) have been updated following further engineering optimisation and are detailed in volume 4, annex 3.1: Subsea Noise Technical Report and additional modelling has also been undertaken on these new assumptions. This modelling includes the PTS range requested by Natural England and is presented in section 4.11.1 and volume 4, annex 3.1: Subsea Noise Technical Report. A MMMP will be developed and agreed with the relevant organisations prior to the start of construction. This will be based on the project envelope and any soft start durations will be sufficient to ensure any impacts to marine mammals are minimised as far as is possible. Updated underwater noise modelling has been undertaken for the refined project description (volume 1, chapter 3) and using a revised model with increased empirical evidence underpinning it. The revised modelling incorporated the refinement to the area of search for the HVAC station. The updated underwater noise modelling is summarised throughout this chapter and presented in full in volume 4, annex 3.1. The revised modelling approach (change from the dBSea model to the INSPIRE model) is based on depth average predictions of sound propagation. Therefore, no depth specific noise modelling results are presented. The impacts on the relevant species of marine mammals have been reassessed based on the updated noise modelling with the full impact assessment provided in Section 4.11.1 of this chapter. The lower hammer energy modelling uses the pile diameter for the pin piles and the larger area for the 155 dB weighted SEL is considered to be a result of the increased high frequency components of the noise profile from pins piles relative to the monopiles and the consequent impacts on high frequency species such as harbour porpoise. Full details of the frequency spectrum generated by each pile type and how this relates to the hearing spectrum of each of the marine mammal species is provided in volume 4, annex 3.1: Subsea Noise Technical Report.
September 2017	Natural England (Section 42 Consultation Response)	Natural England do not agree that seismic activity from oil and gas projects can be screened out as having no impact due to being part of the baseline. Reference should be made to the BEIS Oil and Gas HRA when available or some assessment of the average number and extent of seismic surveys undertaken in the region. Natural England considers that seismic activity should be included in the Subsea Noise Technical Report.	Seismic activity has been screened into the EIA and is presented in paragraph 4.13.1.50 *et seq*. The BEIS oil and gas HRA is not currently available and therefore the average number and extent of seismic surveys over the past four years within 10 km of the Southern North Sea cSAC summer area has been used to inform the assessment. The underwater noise Technical Report has sought to undertake bespoke modelling of noise propagation from those activities associated with the project for which the application relates (namely percussive piling for Hornsea Three). Information related to seismic activity (from Oil & Gas activity) will be considered based on the information sources noted above.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
September 2017	Natural England (Section 42 Consultation Response)	Natural England raise concerns regarding the cumulative impact assessment, with specific regard to the following points: The scale for CEA was agreed as the MU for the minke whale and white beaked dolphin. Rather the harbour porpoise MU was adopted for both other cetacean species – as per paragraph 4.13.1.56. In addition, the outputs of the JCP Phase III analyses are now available and therefore should be incorporated into the final Environmental Statement. Tier 1 should possibly also include those projects at a similar stage to Hornsea Three – i.e. not submitted, but at the PEIR or similar stage. The separation of Tier 1 and 2 assessments for behaviour and TTS. The need to include construction date information for Aberdeen Bay in the table describing the other plans and projects from the CEA. The Environmental Statement assessments for the projects assessed as part of the CEA did not use the updated NOAA thresholds so there is the potential for these distances being an underestimate of the area of impact. There are limitations on data availability (and studies such as DEPONS) and as with any model there remain knowledge gaps and uncertainties which should be considered alongside the outputs. This also applies for the CEA. Although Natural England accepts why Triton Knoll and Borssele 3 and 4 were not included in the CEA, there is still the possibility that they may overlap and so should be included in the worst case envelope, unless evidence can be provided to demonstrate why not. Neart na Gaoithe, Inch Cape, Seagreen and Convoys Wharf are all unknown in terms of construction dates, so maximum design scenario would mean they would overlap. Non-UK projects should be included throughout as much as possible given that the CEA is the North Sea MU. Agreement that adding the modelled areas for TTS and disturbance from each wind farm is unrealistic. However, it would help helpful if a table containing information on numbers affected be presented as per Hornsea Project Two Environmental Statement marine mammals chapter but with a large caveat in the table title. The projects in each tier should be revisited and updated at a future date to be agreed in recognition that timescales and level of information available for these schemes will change in time.	The CEA search area has been constrained to the scale of the harbour porpoise MU for all cetaceans and the JCP III analyses have been included and are detailed within the Marine Mammals Technical Report (volume 5, annex 4.1). Tier 1 projects have been restricted only to those projects that have been submitted or have been approved due to uncertainty whether other projects at PEIR stage or similar will actually be taken forward and it is not possible to assess the final design and the ultimate associated impacts. This approach has been developed to ensure that the assessment does not consider projects that may not ultimately be taken forward or may fundamentally change and for which the parameters are not fully developed. Including these projects within Tier 1 would risk that the scale of the projects would change so that they would have a greater effect than that assessed and thus the impacts had not been fully addressed. The construction dates for Aberdeen Bay have now been included in Table 4.54 below and all dates have been checked following the most recent available information. The NOAA thresholds do not consistently result in larger impact areas than the Southall *et al*. (2007) thresholds therefore, whilst in some cases higher ranges may occur, in others lower ranges may occur. It is recognised that different Environmental Statements will have used different models and indeed potentially different threshold criteria (depending on whether they were undertaken prior to the NOAA 2016 being released). In all cases precaution will have been applied to the modelling input parameters, design scenarios and outputs assumptions and therefore, underestimations of real ranges are highly unlikely. As is the case for all other topics it is not the duty of the applicant to remodel or indeed assess other projects within the CEA, rather that information is taken at face value and fed into the assessment. However, notwithstanding this point, given the precautionary nature of the modelling and subsequent interpretation of outputs and the fact that NOAA does not always result in greater ranges means that it is highly unlikely that there will be an underestimate of real impact ranges within the projects included within the CEA. Noted. The uncertainties and knowledge gaps within the assessment are discussed alongside the results to provide context to the outputs. The updated methodology and projects included are described in the assessment presented in section 4.13. Noted. Table 4.57 provides information on the number of individuals that may be within specific noise contours representing the potential for avoidance or disturbance. It is important to note that although this table presents the maximum estimates of numbers of animals affected from each project, adding them together will significantly overestimate the level of impact. The CEA has been updated within the Environmental Statement with the Tier assigned to each project or plan checked and confirmed and therefore it represents the best available evidence at the time of writing.
September 2017	Natural England (Section 42 Consultation Response)	Natural England had some comments on the data underpinning the baseline, with specific regard to: It should be noted here that only 10% of the digital survey data was actually analysed (this being a sufficient percentage for seabirds and harbour porpoise, but not for other marine mammal species). It should be noted that in German waters 100% of data are analysed to inform the results. The ES should incorporate the SCANS III densities as this appears to show a further increase in importance of the general area for harbour porpoise. Natural England queries why the more precautionary density for the Hornsea Three marine mammal study area has not been used to calculate abundance for minke whale? Please can clarification be provided.	As part of the EWG it was agreed that 10% was sufficient and full meeting minutes are provided within the Evidence Plan (Consultation report Annex 1 Evidence Plan). The Marine Mammals Technical Report (volume 5, annex 4.1) has been updated and additional data, including further aerial survey data and the SCANS III data, has been incorporated. The baseline section of this chapter has also been updated to reflect the changes to the density estimates for the different marine mammal species where appropriate. The Marine Mammals Technical Report (volume 5, annex 4.1) has been updated to provide a comparison of the differing abundances recorded for minke whale from and demonstrates that, following correction, the abundance estimates for both the Hornsea Zone plus 10 km buffer and the Hornsea Three plus 4 km buffer are lower than that of the SCANS III data. Therefore, the SCANS III data has been used within the updated assessment presented in paragraph 4.11.1.3 *et seq* as it is deemed to be most precautionary.
September 2017	Natural England (Section 42 Consultation Response)	Natural England had the following concerns specific to transboundary impacts: Management Units (MUs) for marine mammals do not just extend to the 12 nm limit, they are transboundary and include other countries waters (as per figure 4.11 in the technical report). UK specific abundances are calculated in addition to MU abundances, but this includes all UK waters, not just territorial seas (i.e. further than 12 nm). The text should be altered to reflect this.	Section 4.7.1.2 has been updated to reflect the transboundary nature of management units for marine mammals and identify that country specific populations are based on the extent of the exclusive economic zone of a nation and not only the territorial waters (i.e. 12 nm).

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
September 2017	Natural England (Section 42 Consultation Response)	Classification of VERs need to be checked for consistency, particularly the difference between White Beaked Dolphin being defined as a VER of national importance compared to all other species which were defined as of international importance.	The Marine Mammals Technical Report (volume 5, annex 4.1) and this chapter have been updated, including with a reassessment of the importance of the white-beaked dolphin and this species has been reclassified as a VER of international importance.
September 2017	Natural England (Section 42 Consultation Response)	Natural England are concerned about the impacts from vessel presence and vessel noise. Specific concerns relate to: Why minke whale and white beaked dolphin would habituate to vessel presence while harbour porpoise would not, when they are the most numerous cetacean in the area and suggest that they may be exhibiting difference behaviours rather than habituating. The assessment of the impacts from vessel traffic during the construction and operational phases, including whether the magnitude assessments are valid (with specific reference to recovery) and request clarity on the differing levels of vessel traffic throughout the various stages of the development. The cumulative physical disturbance from vessels, not just the acoustic disturbance, should be considered. Natural England disagrees that harbour porpoises will show habituation to vessels, rather they will be temporarily disturbed away from the location and whatever they are doing. Heinanen and Skov (2015) reported that the number of ships was an important predictor of harbour porpoise density in the North Sea MU and suggested that markedly lower densities were present over a threshold of approximately over 80 vessels per day (passing through a 5 km² grid). What are the numbers reached cumulatively in the local area? The assessment should also take account of other wind farms that will be constructing/operational in other EU countries at the same time. As per comments above, it is unclear why a moderate to large increase in vessel traffic away from the baseline, over a long period of time is assessed as minor. Please can clarification be provided.	The Project Description (volume 1, chapter 3) has been updated from that provided for the PEIR and this includes a re-estimation of the vessel traffic expected throughout the different stages of the Hornsea Three development. The Marine Mammals Technical Report (volume 5, annex 4.1) has been updated and provides a more detailed discussion on the impacts of vessel presence and noise on marine mammals. The impact assessment in paragraph 4.11.1.199 *et seq* has been updated to provide more detail on the expected vessel traffic throughout different stages of the development and provides further justification for the magnitude assessments used within the impact assessments. Further detail on the uncertainties within the assessment are provided. We agree that Harbour Porpoise will move away from vessels, there is empirical evidence that small scale avoidance will occur. The number of vessels that will be visiting the site have been refined and further details have been provided of the timings when the highest densities of vessels will be present in paragraph 4.11.1.199 *et seq*. While other wind farms in other EU countries that are constructing and operating during the construction and operation of Hornsea Project Three, the overlap of disturbance arising from vessel traffic is minimal due to the ports of origin for the vessels for the relevant projects being within the waters of the respective countries and therefore the vessels will not pass throughout UK waters. The vessel impact assessment has been reassessed and the updated assessment has been presented in paragraph 4.11.1.199 *et seq* below with additional justification for the determination of magnitude and the overall assessment of effect significance.
September 2017	Natural England (Section 42 Consultation Response)	Paragraph 4.13.1.16 - Natural England considers 16 years is not a short term impact as stated in paragraph 4.13.1.27 of the PEIR (rather it is a long term impact).	We agree that a 16 year period is not a short-term impact, however, the impacts from TTS at each location over this 16 year period will be over only a few years at each site and as such will be short term at each location particularly as the impact ranges do not overlap between the different projects and alternative habitat will be available. Information has been included in the definitions of impact magnitude categories to define timescales (Table 4.17).
September 2017	Natural England (Section 42 Consultation Response)	If Hornsea Three on its own can affect 1.3% of the MU for TTS/Fleeing – any other wind farm construction at the same time will increase this value, therefore Natural England does not agree that it can be stated that cumulatively TTS will not be significant nor increase over and above what Hornsea Three alone will impact, especially given the change from Southall to NOAA being best scientific knowledge for noise thresholds. Natural England considers it is not correct to say that the impact ranges for minke whale are small. They are actually larger than for harbour porpoise. Hornsea Project Two did assess the impact for minke and white beaked dolphin. Minke whales, due to the area of ensonification came out as a moderate adverse impact. It is worth noting that wind farms further north are going to have a larger impact on both minke whales and white beaked dolphins. While this is not an issue for the assessment of the project alone, it will be a consideration in terms of the cumulative assessment. The assessment should be updated to reflect this.	The piling envelope for the project has been updated for the Environmental Statement following further engineering studies and in addition new modelling has been undertaken based on the revised project description. The results from the updated modelling are presented in volume 4, annex 3.1: Subsea Noise Technical Report and incorporated within the CEA presented in section 4.13.
September 2017	Natural England (Section 42 Consultation Response)	It should be noted that in discussing the magnitude of effect, not only disturbance will affect the receptor directly, but also TTS/Fleeing response.	The TTS threshold is not appropriate to use for the behavioural threshold of 'fleeing' for multiple pulse noise. TTS ranges have been presented as a separate impact to disturbance with the disturbance impacts assessed through a dose response curve. Significance of effect assessments have been undertaken separately for disturbance and are presented in section 4.11.1.
September 2017	Natural England (Section 42 Consultation Response)	Natural England does not agree that porpoise have a low vulnerability in terms of underwater noise.	While harbour porpoise show a high responsiveness to underwater noise, this does not necessarily imply vulnerability. A full discussion of this has taken place through the EWG and full meeting minutes are presented within the Evidence Plan (Consultation Report Annex 1 Evidence Plan).

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
September 2017	Whale & Dolphin Conservation	Whale & Dolphin Conservation raised concerns in relation the following: • Individual and cumulative impacts on cetaceans with reference to "Marine Renewable Energy: A Global Review of the Extent of Marine Renewable Energy Developments, the Developing Technologies and Possible Conservation Implications for Cetaceans" report. • Impact of region wide noise pollution across the North Sea highlighted in Heinis and De Jong, 2015. • Direct and in-combination impact of Hornsea 3 on the Southern North Sea cSAC. • The methodologies used to gain a baseline value for marine mammal populations within the project area may under-represent the actual numbers within the area. These concerns draw from issues with boat based, aerial and SCANS data used to inform the baseline figures. • Foundation types which require piling, specifically monopiles, are not recommended due to the impact of noise on marine mammals. This is practically important as the noise generated will pass into the Southern North Sea cSAC. WDC strongly recommend using foundation types which do not require piling. • The anticipated piling programme encompasses 604.8 days over 2.5 years. WDC note that this length of time covers a large portion of a harbour porpoise life span and potentially affect breeding and feeding activity. More information is needed on the implications of the impact of four breeding cycles being missed on the population. • In-combination impacts only cover other offshore wind farms. Other industries, such as oil and gas, need to be included in the assessment as well as cross boundary impacts due to the mobile nature of cetaceans. • The proposed mitigation methods including 500 m exclusion zones and soft start piling are not proven to reduce the impact on cetaceans. Real-time measures such as acoustic barriers, should be included. • The use of Acoustic Deterrent Devices (ADDs) add noise to the environment and therefore need to be included in the assessment of noise. • WDC request to be involved in the design of the MMMP. • The monitoring programme should be robust enough to demonstrate responses to construction activities, such as piling.	• The applicant has sought to use best available evidence to inform the assessment of potential impacts on marine mammal receptors (as identified throughout this chapter and its associated annex). The applicant has considered the papers identified by WDC, however it is the applicants position that no change is considered appropriate. • Matters related to the Southern North Sea cSAC are specifically discussed in the Report to Inform Appropriate Assessment (RIAA) (document reference number A5.2), which accompanies this Environmental Statement. • The limitations with individual baseline datasets are recognised (see paragraph 4.7.2.35 in Section 4.7) and these are reflective of the nature of surveying in the marine environment for a mobile species. In order to account for these limitations the full suite of data sets have been used to establish density ranges within the Study Area (rather than adopt a single density from any one data set). As such, all density estimated have been used within the assessment to prevent under-representation (see paragraph 4.7.2.35). • The Applicant notes the WDC position on use of piled foundations, and recognises that it is a position they adopt industry wide and therefore, not unique to Hornsea Three. The Applicant points WDC to those embedded measures that it has committed to (as presented in Section 4.10 of this chapter) to reduce the potential underwater noise effects on marine mammals. In light of these commitments, the applicant does not consider that it is necessary to discount piling and notes that to do so would excessively restrict commercial flexibility and potentially affect the viability and/or deliverability of the whole project. • The updated piling schedule (maximum design scenario) is presented in Table 4.15. The assessment (as presented in section 4.11) has addressed the consequence of disturbance over this time period. • Cumulative effects are presented based on best available information at the time of writing in Section 4.13 and have included the impacts from oil and gas and cable and pipeline installation activities in both the UK and those in neighbouring states where sufficient information is available. Transboundary effects are presented in Section 4.14. • The mitigation measures adopted to reduce the risk of injurious effects on marine mammals will be detailed within the Marine Mammal Mitigation Protocol (MMMP) that will be developed using best practice techniques in consultation with the statutory nature conservation body (SNCB) and approved by the MMO prior to the commencement of offshore works. The applicant considers that ADD are a mitigation measure rather than an impact and as such not subject to assessment within this chapter. • The Applicant has committed to a Plan for Marine Mammal Monitoring that will be developed in consultation with the SNCB and approved by the MMO prior to the commencement of offshore works. The Plan will be developed in line with the principles set out in the IPMP (Document Ref: A8.8 that accompanies the Hornsea Three DCO application). In addition, as set out in the IPMP, the applicant has committed to the provision of piling duration information (to the MMO following completion of construction activity) to validate the assumptions made within the impact assessment on this key concern. • The Applicant has undertaken direct consultation with WDC outside of the EWG, with all EWG meeting minutes and resources provided to WDC.

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September 2017	The Wildlife Trust (joint response from Norfolk WT and TWT)	The Wildlife Trust raised concerns regarding the following: • Suggestion that both the NOAA guidance (NMFS, 2016) and Southall *et al* (2007) are used in the assessment to reduce uncertainty, allow comparison and to test the effectiveness of the new guidance. • Mitigation is required and discussions are needed early on in the assessment to ensure that the impacts on harbour porpoises are reduced. This is based on the assessment results of injury and disturbance in the absence of mitigation. • The temporal impact of piling work due to duration and potential effect on breeding cycles of harbour porpoises. We are interested on the implications of this work on the population within the management unit. • Data validation and ground truthing are required before modelling can be realistically used to test population impacts. • We do not believe oil and gas projects, shipping and navigation, and commercial fisheries should be screened out of the cumulative assessment. TWT believe the noise levels of all activities should be assessed against a baseline noise level. • TWT suggest that East Anglia One North, East Anglia Two and Norfolk Boreas should be screened into the cumulative assessment. We expect that more information will be available on these developments before the planning application is entered for Hornsea 3, and therefore would expect these developments to be included in the cumulative assessment. • We suggest that, based on the statements made in 4.14.1.36, 4.13.1.45, 4.13.1.47 and 4.14.1.50 for the cumulative assessment for harbour porpoise, further investigation is undertaken. We suggest that mitigation is likely to be required for cumulative impacts, especially in relation to EPS. • Table 3.2 indicates that floating turbines are being considered as part of the design envelope. An assessment against entanglement and piling techniques should be undertaken for the Southern North Sea cSAC and also be included in the EIA marine mammals chapter. • In addition to the in-combination disturbance effects, the EIA alone assessment outlines that there is potential for up to 14.09% on the NS MU to be affected by disturbance impacts. As identified in 4.11.1.81 of the marine mammals chapter "Hornsea 3 marine mammal study area is important to harbour porpoise due to the high densities found here". As harbour porpoise are a mobile species, areas such as these could be important to cSAC functioning. • We would like to open discussions with the Hornsea Three project team on potential mitigation options to reduce PTS impacts. We suggest that Acoustic Deterrent Devices (ADDs) should be included in the noise assessment methodology to take account of additional noise produced as part of the MMMP. • When adding the increased vessel movements over the cumulative assessment period (table 7.30 in RIAA (document reference number A5.2)), there will be over 70,000 increased vessel movements. We suggest that the cumulative effects of vessel movements are investigated in more detail in relation to marine mammals, and the Southern North Sea cSAC in particular. • The assumptions made with regards to habituation and return times in both the marine mammals chapter and the RIAA (document reference number A5.2). For example, 4.11.1.65 in the marine mammal's chapter. We suggest that this assumption cannot be made as we do not know enough about the impacts from current baseline noise levels on the functioning of marine mammal populations within the North Sea. • There is not enough evidence to understand the true nature of harbour porpoise return behaviour following piling activity. Previous studies do highlight differing return times but we have no certainty if these are the same animals returning or new animals visiting the site. We do not know how much site fidelity relates to return times. • There is also the consideration of other noise producing activities which take place during the construction period that can affect return times. • We are interested in how any mitigation used to protect harbour porpoise may also benefit minke whales.	• The Applicant has based the updated underwater noise modelling on the NOAA guidance (NMFS, 2016) as instructed by the SNCB and agreed through the EWG process with full meeting minutes presented within the Evidence Plan (Consultation Report Annex 1 Evidence Plan). • An updated assessment of effects from underwater noise is presented in Section 4.11.1. Embedded measures that capture mitigation committed to as part of the Project's design are presented in Section 4.10. • The updated assessment of underwater noise effects (as presented in Section 4.11.1) has due regard to maximum temporal piling duration, and considers these effects at the population level for all species including harbour porpoise. • It is recognised that establishing the consequence of disturbance is a challenge and that this is being addressed at industry wide levels through initiatives such as DEPONS and the iPCoD tool. This assessment has used best available evidence to inform its assessments on the consequence of disturbance as presented in Section 4.11. • The cumulative assessment of underwater noise disturbance considers all relevant (known) plans, projects and or proposals that may come forward at the same time as Hornsea Project Three. • An updated assessment of effects from underwater noise is presented in Section 4.11.1. Embedded measures that capture mitigation committed to as part of the Project's design are presented in Section 4.10. • Floating turbines are no longer within the design envelope and therefore, this comment can now be disregarded. • An updated assessment of effects from underwater noise is presented in Section 4.11.1. Matters relating to the cSAC are presented in the Report to Inform Appropriate Assessment (document reference A5.2). • PTS effects will be controlled through the implementation of a MMMP that will be developed using best practice techniques in consultation with the statutory nature conservation body (SNCB) and approved by the MMO prior to the commencement of offshore works. The Project will not be able to proceed until the MMO is satisfied that the Project has a protocol that adequately mitigates the risk of PTS. • The updated design envelope has seen a revision to the number of projected vessels associated with the construction and operation of the project. The maximum figures are presented in Table 4.15 and these have been used to inform the subsequent assessment. • The assessment of the impact of piling noise on harbour porpoise does not explicitly consider return times in a quantitative way because of the lack of data on individual movement patterns in relation to responses to piling noise. The assumption adopted in the assessment is that the predicted level of disturbance to harbour porpoises occurs throughout the whole period of piling activity and does not distinguish between these two scenarios (a smaller number of individuals being repeatedly disturbed or a larger number of individuals being disturbed only once). • The embedded mitigation proposed (in the form of piling and UXO specific MMMPs – see Table 4.19) will be designed to cover all cetacean species under their status as EPS and therefore minke whales will benefit directly.

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 4.5). The approach involved the use of existing site-specific, boat-based survey data gathered across the former Hornsea Zone plus a 10 km buffer and re-analysed for the Hornsea Three array area, together with the use of additional site-specific aerial survey data from surveys across the Hornsea Three array area plus a 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.

4.6.2 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 4.6). A full review is provided in volume 5, annex 4.1: Marine Mammal Technical Report.

Table 4.6: 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
Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys	SCANS III	2017	Hammond *et al.*
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, 2017	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)
Draft 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2). 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 Conservation of Habitats and Species Regulations 2017 (Habitats Regulations) consolidates and updates the Conservation of Habitats and Species regulations 2010, enacting the Habitats Directive to 12 nm offshore.

4.6.3.5 In the UK water beyond 12 nm, the Habitats Directive is transposed into law through the Conservation of Offshore Marine Habitats and Species Regulations 2017 (consolidates and updates the Offshore Marine Conservation (Natural Habitats &c.) Regulations 2007) (Offshore Habitats Regulations).

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 Environmental Statement chapter.

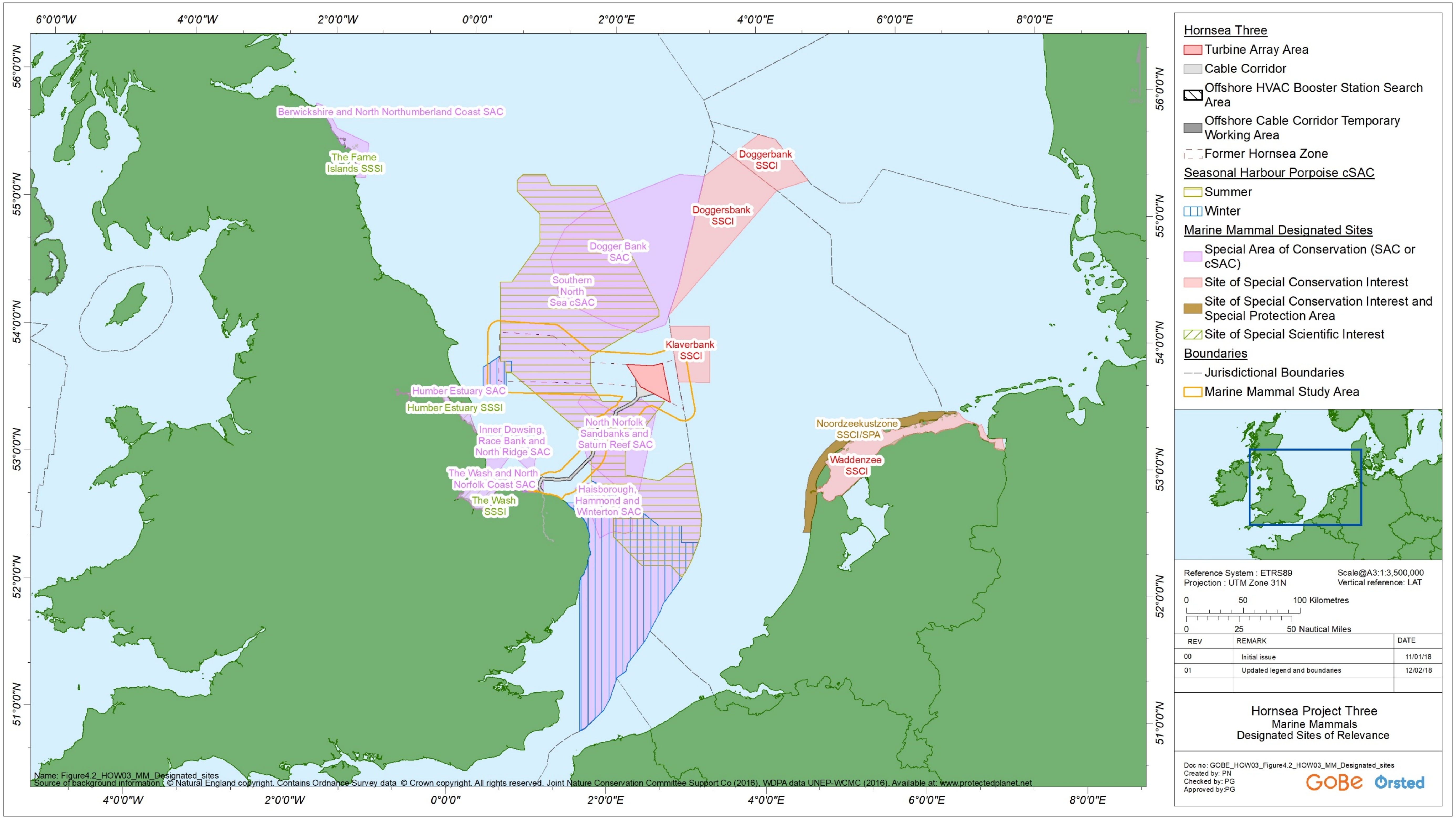

Figure 4.2: Designated sites relative to Hornsea Three.

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 2017 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 Report to Inform the Appropriate Assessment (RIAA) for Hornsea Three (document reference number A5.2).

4.6.4 European Protected Species

4.6.4.1 Under both the Offshore Habitats Regulations 2017 and the Habitats Regulations 2017, 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 2017 Regulation 45, 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 2017, Regulation 43 are as per Offshore Habitats Regulations 2017.

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 4.7 below.

Table 4.7: 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 were carried out from April 2016 until November 2017 inclusive. 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. As agreed at the EWG meeting in April 2016, only 10% of the data was analysed as this was confirmed to be sufficient to provide an estimate of densities for harbour porpoise and full meeting minutes are presented within the Evidence Plan (Consultation Report Annex 1 Evidence Plan). 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 Following examination of historic records of marine mammals in the southern North Sea, SCANS-III 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, alongside discussions with the Marine Mammal EWG, 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 Environmental Statement chapter:

- 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 are transboundary zones; the UK specific population of a species if required can be calculated based on the area of the Exclusive Economic Zone (EEZ). 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 Harbour porpoise are widespread throughout the temperate waters of the North Atlantic and North Pacific and are the most abundant cetacean in UK waters, with the whole of the coastline of the North Sea considered to be an important area for this species (Reid *et al*., 2003). Harbour porpoises normally live for approximately 12 years, although they have been recorded to reach a maximum age of 24. Harbour porpoises reach sexual maturity at between three and four years of age; reproduction is highly seasonal, with mating occurring between June and August and a corresponding peak in birth rates in June to July around the British Isles following a 10 to 11 month gestation period (Lockyer, 1995; Boyd *et al*., 1999). There is little data on the inter-birth interval of harbour porpoises, but Lockyer *et al*. (2001) reported an ovulation interval of between 1 and 2.4 years.

4.7.2.2 Visual and acoustic sightings data from surveys of the former Hornsea Zone plus 10 km show that harbour porpoises are widely distributed across the Hornsea Three marine mammal study area (Figure 4.3). Similarly, historical sightings data confirmed that harbour porpoises are 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 4.8 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 of particular importance within the former Hornsea Zone plus 10 km buffer (Table 4.8). The aerial surveys provided the lowest estimate of abundance, with the acoustic surveys giving the highest estimate (Figure 4.4).

Table 4.8: Summary of abundance and density estimates of harbour porpoises 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 (#/km^2)	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	2,165
Acoustic boat-based	1,230	2.87	3,530
Aerial video	1,230	1.019	1,253

4.7.2.4 In comparison to the regional marine mammal study area these figures suggest that the Hornsea Three marine mammal study area (Hornsea Zone plus Hornsea Three cable route plus appropriate buffers) is of relatively higher importance for harbour porpoise since the densities are higher than the average density of 0.888 animals km^{-2} (CV = 0.21, mean group size 1.31) recorded for SCANS III 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).

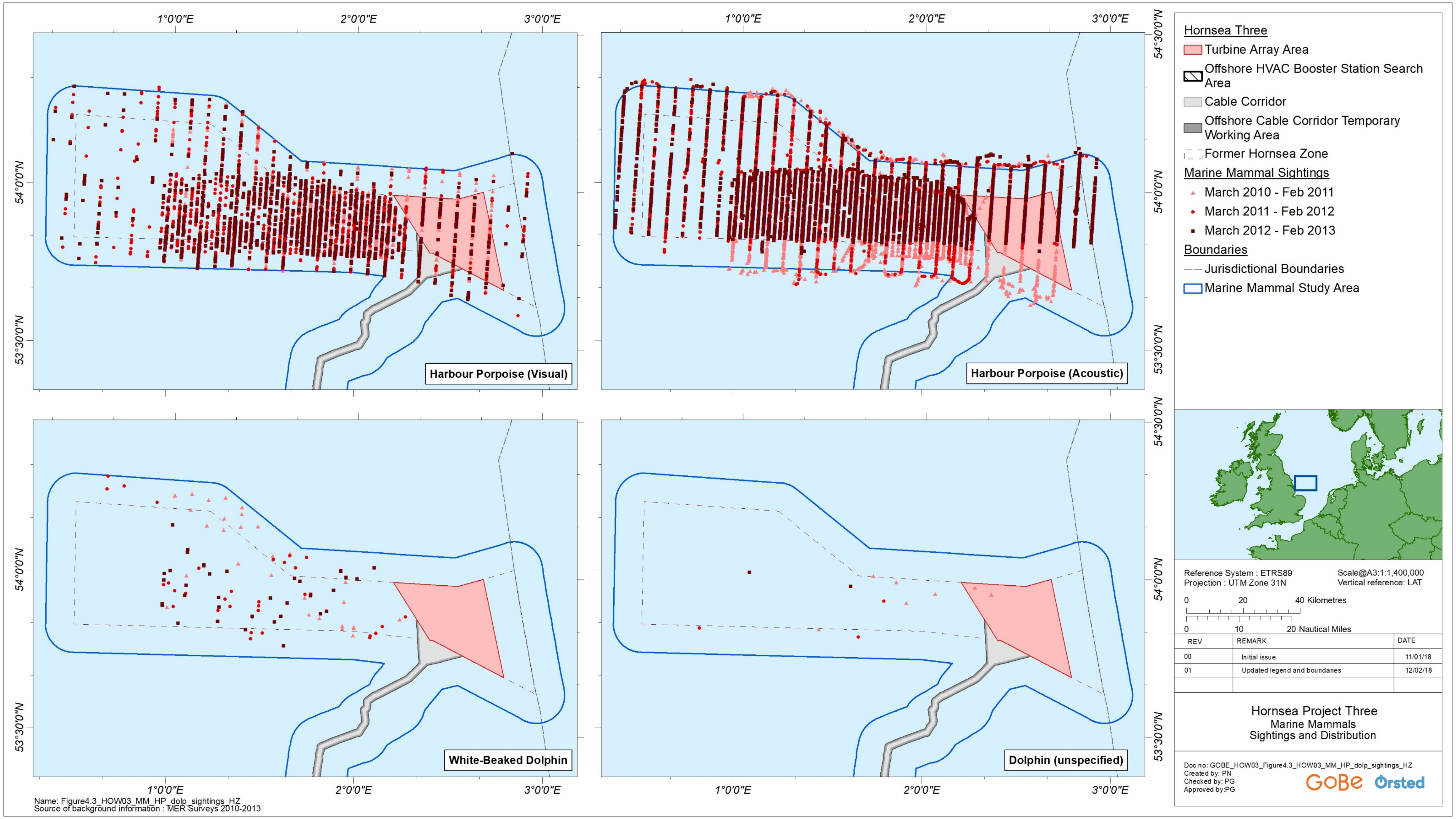

Figure 4.3: Marine mammal sighting and distribution. All data pooled across three years of boat-based surveys.

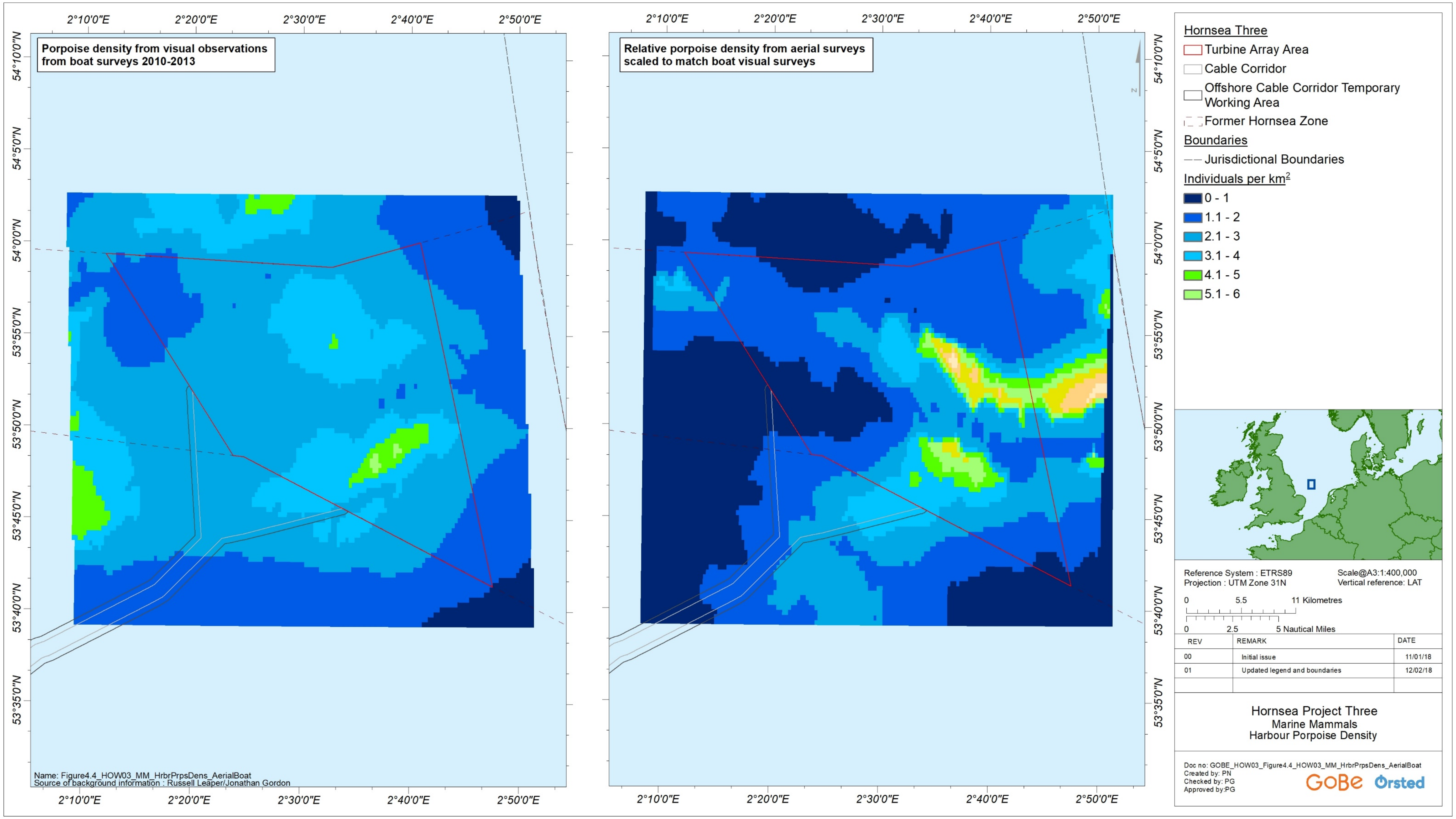

Figure 4.4: Surface density maps for harbour porpoise for Hornsea Three plus 4 km buffer with aerial data scaled to give the same mean density as the boat-based data for comparative purposes.

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 of England 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). This was updated following the SCANS III surveys to a total of 345,373 (95% Confidence Interval 246,626 to 495,752) (Hammond *et al*., 2017). Where a quantitative assessment of impact is possible, the MU abundance estimate has been used as the reference population against which to assess the impact.

4.7.2.6 Table 4.9 summarises the designated sites within the North Sea MU which have harbour porpoises listed as a qualifying interest feature (Figure 4.5). Designated sites for harbour porpoises 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 Report to Inform Appropriate Assessment (document reference A5.2).

Table 4.9: Designated sites with harbour porpoises 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 cSAC	1.6	0
Klaverbank pSCI	11	24
Noordzeekustzone II SCI[a]	138	154
a Combined with Noordzeekustzone SAC for Report to inform Appropriate Assessment (document reference A5.2).		

White-beaked dolphin

4.7.2.7 The 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, with mating occurring the warmer months and caving occurring June to September (Kinze *et al*., 1997).

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 dolphins in the North Sea are restricted to more northerly areas (Canning *et al*., 2008), with the northern North Sea now being the most important region for this species in UK waters (Figure 4.31 of volume 5, annex 4.1: Marine Mammals Technical Report).

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 4.35 of volume 5, annex 4.1: Marine Mammal Technical Report). From SCANS III surveys, relative density was estimated as 0.002 animals km^{-2} (Hammond *et al.,* 2017).

4.7.2.11 Historic Greater Lincolnshire Nature Partnership (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 4.32 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 the 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.

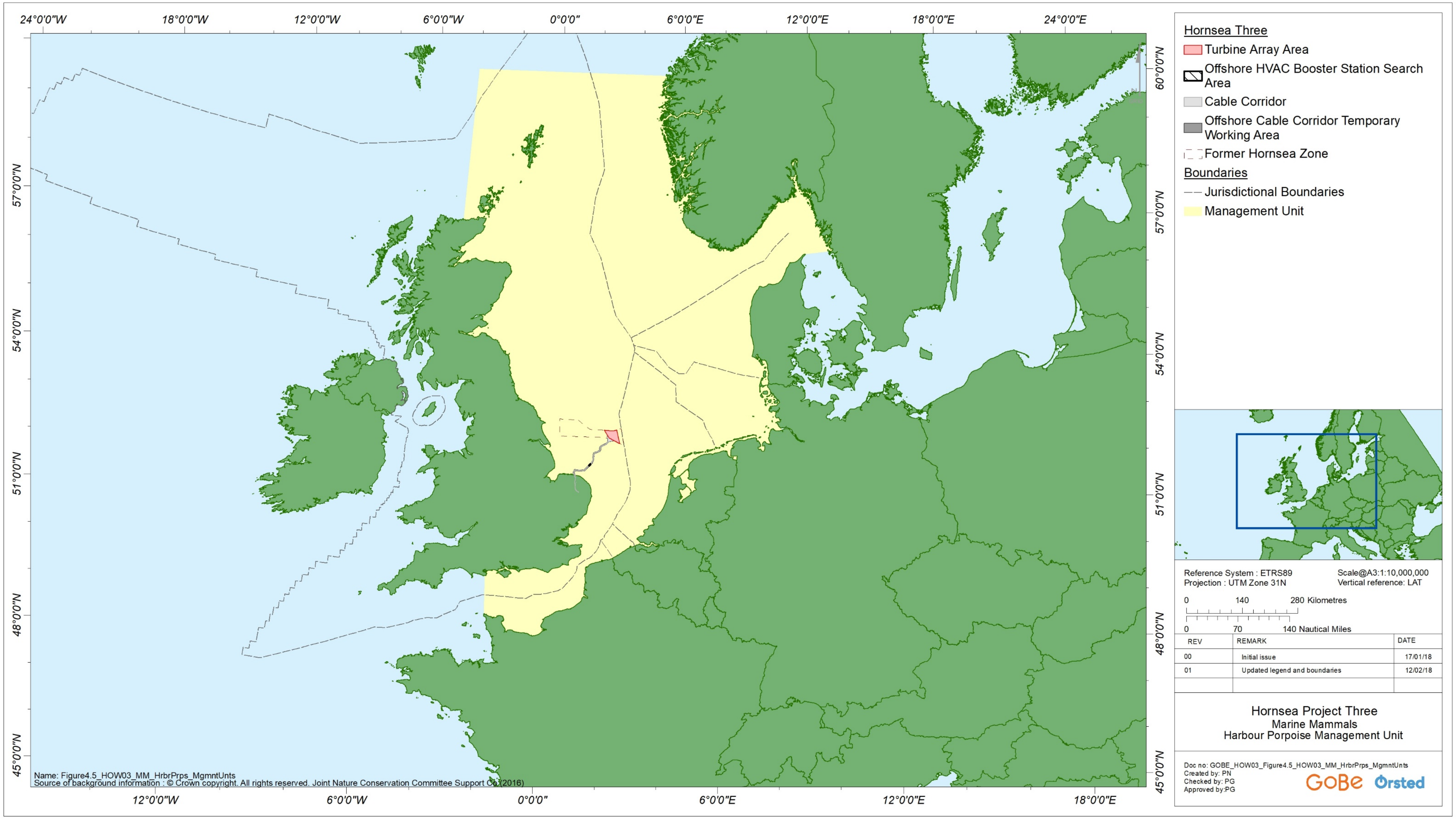

Figure 4.5: Harbour porpoise Management Unit.

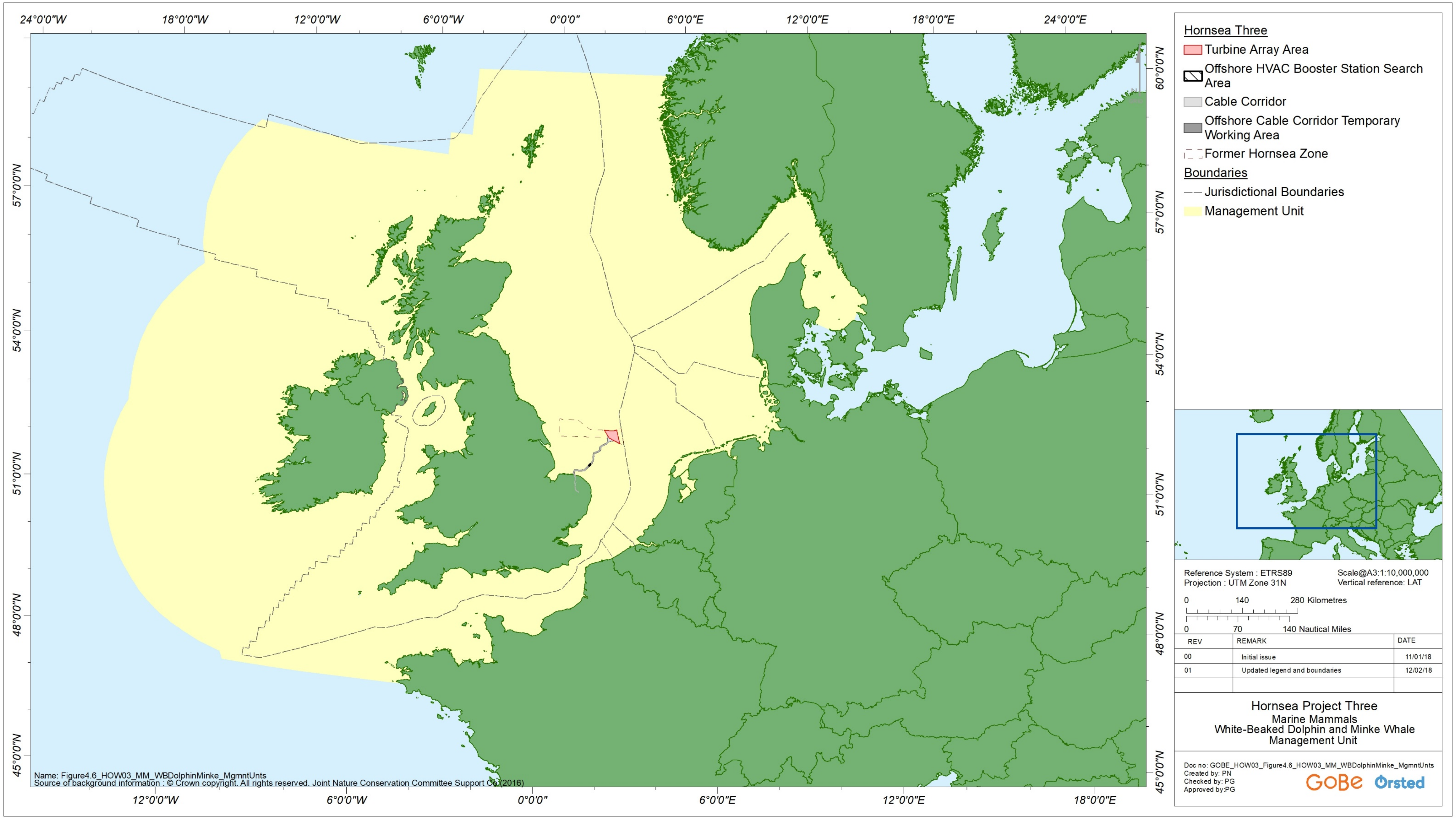

Figure 4.6: White beaked dolphin and minke whale Management Unit.

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 relative 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}). The SCANS III density estimate for minke whales in Block O was 0.010 animals km^{-2} (Hammond *et al*., 2017).

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 4.6). The total abundance of minke whale in the CGNS MU was estimated as 23,528 animals (IAMMWG, 2015) (95% Confidence Interval 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 the 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 seals breed on the sandbanks at Donna Nook, Blakeney point and Scroby Sands between September and December and are also known to haul-out at sites in the Wash. Grey seals 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 seals 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 372 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 0.30 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 seals store fat reserves prior to lactation (capital breeders), to allow reduced foraging during lactation. Grey seals are therefore 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 While grey seals are known to travel up to 2,100 km on foraging trips, most foraging trips remain 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 Hornsea Three falls within the South-East England MU, however tagging studies have demonstrated that seals hauling out in the North East England MU also travel through the Hornsea Three marine mammal study area, therefore 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 combined population size for these two MUs has been estimated as 40,040 (section 4.5.5 of volume 5, annex 4.1: Marine Mammals Technical Report). Further detail of the connectivity of the Hornsea Three site with the north east MU is provided in the Marine Mammals Technical Report.

4.7.2.27 Table 4.10 summarises the designated sites within normal (<145 km) 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 Report to Inform Appropriate Assessment (document reference A5.2).

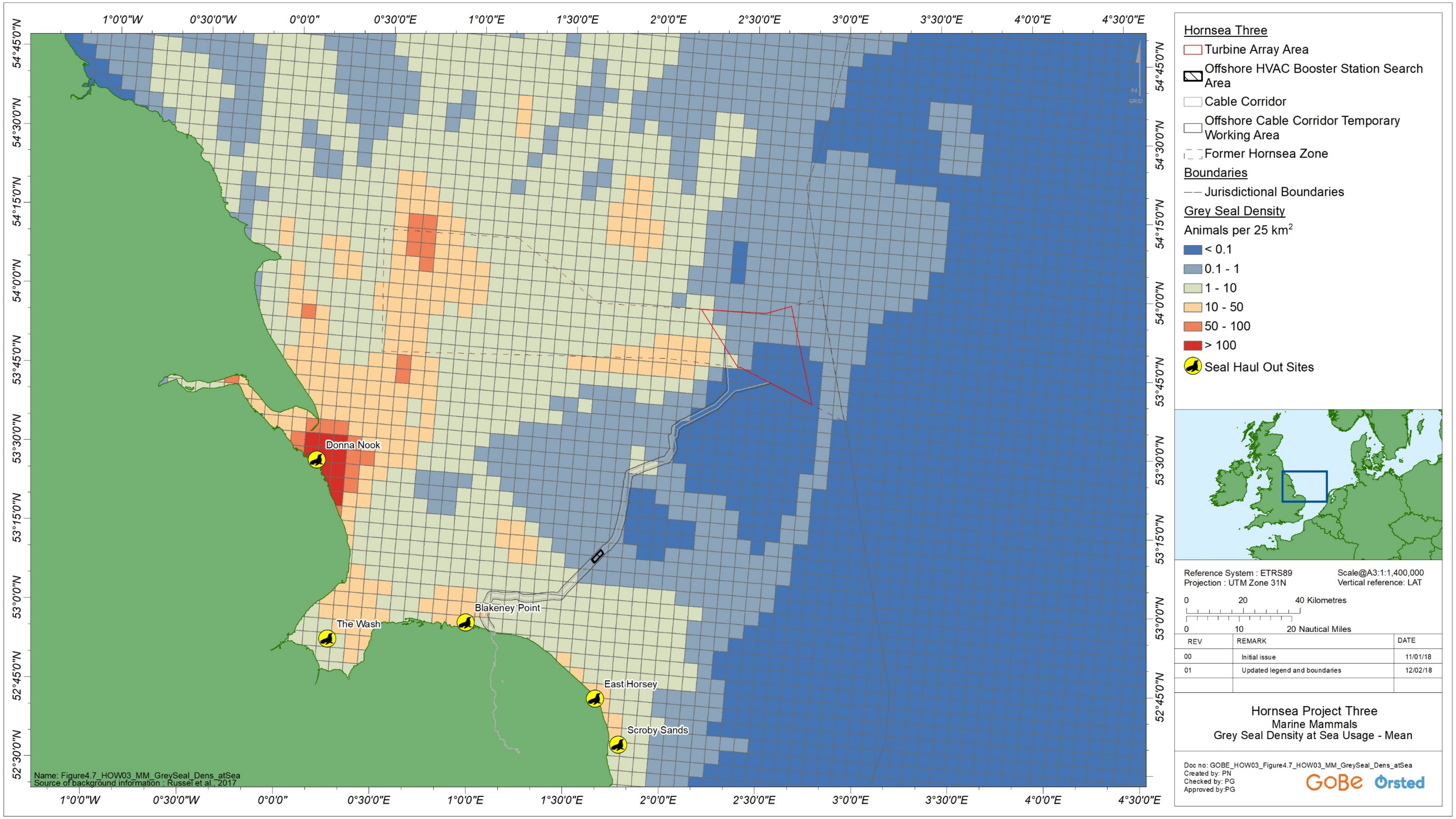

Figure 4.7: Grey seal density At-Sea usage - mean (per 25 km²) for the regional marine mammal study area based on data collected over a 15 year period up to 2015.

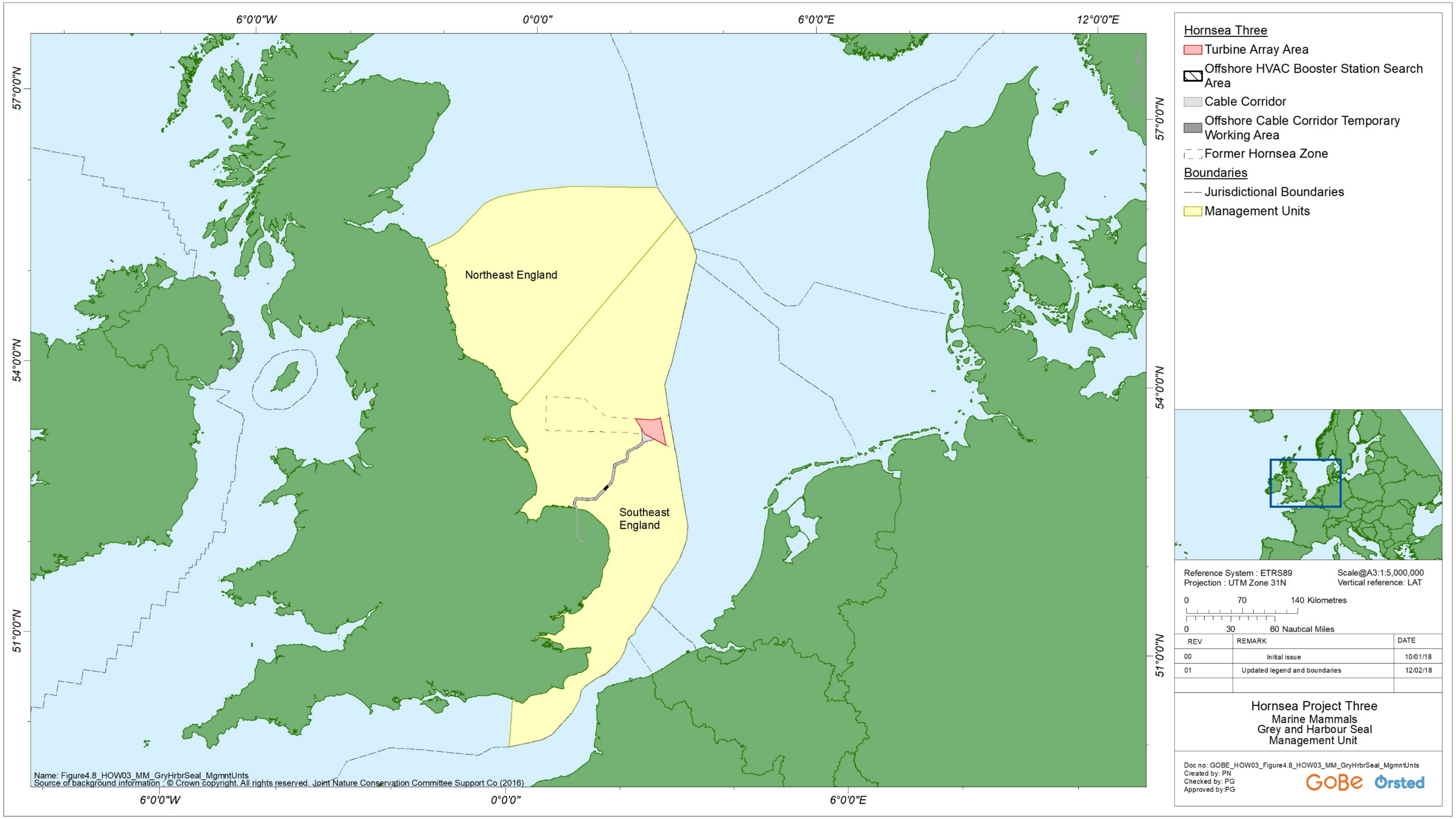

Figure 4.8: Seal Management Units.

Table 4.10: Designated sites with grey seals 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	154
Berwickshire and North Northumberland Coast SAC	286	299
Nationally designated sites		
Humber Estuary	145	74
a Combined with Noordzeekustzone SAC for Report to inform Appropriate Assessment (document reference A5.2)		

Harbour seal

4.7.2.28 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 4.36 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 seals are long-lived animals with individuals estimated to live to between 20 and 30 years (SCOS, 2016). Harbour (common) seals are the smaller of the two species of pinniped that breed in the UK, with harbour seals weighing between 80 to 100 kg (SCOS, 2016).

4.7.2.29 Boat based surveys of the former Hornsea Zone plus 10 km buffer recorded harbour seal throughout the survey area. In total, 147 harbour seals 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.

4.7.2.30 Harbour seal at sea usage data provided by SMRU, confirm that harbour seals are 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).

4.7.2.31 Using SMRU data, the average modelled surface densities across the former Hornsea zone plus 10 km buffer was calculated at 0.04 animal km^{-2} with a total 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).

4.7.2.32 Female harbour seals rely on building up fat reserves prior to lactation as their foraging range is reduced when they have pups. Therefore, harbour seals are likely to be most sensitive to disturbance during the breeding period when females are lactating since the energetic costs of reduced foraging success may reduce the survival rate of the pups (Lusseau *et al.*, 2012). Harbour seals 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 with some individuals even having been recorded as travelling as far as 220 km (SMRU, 2011).

4.7.2.33 Advice from UK SNCBs is that the assessment of impacts of Hornsea Three on harbour seals should be carried out against the South-East England MU (Figure 4.8). The population abundance estimate for this MU is 6,799 animals.

4.7.2.34 Table 4.11 summarises the designated sites within normal foraging range of Hornsea Three which have harbour seals listed as a qualifying interest feature (Figure 4.2). Sites designated for harbour seals 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 seals as a feature of these sites as well as for the Report to Inform Appropriate Assessment (document reference A5.2).

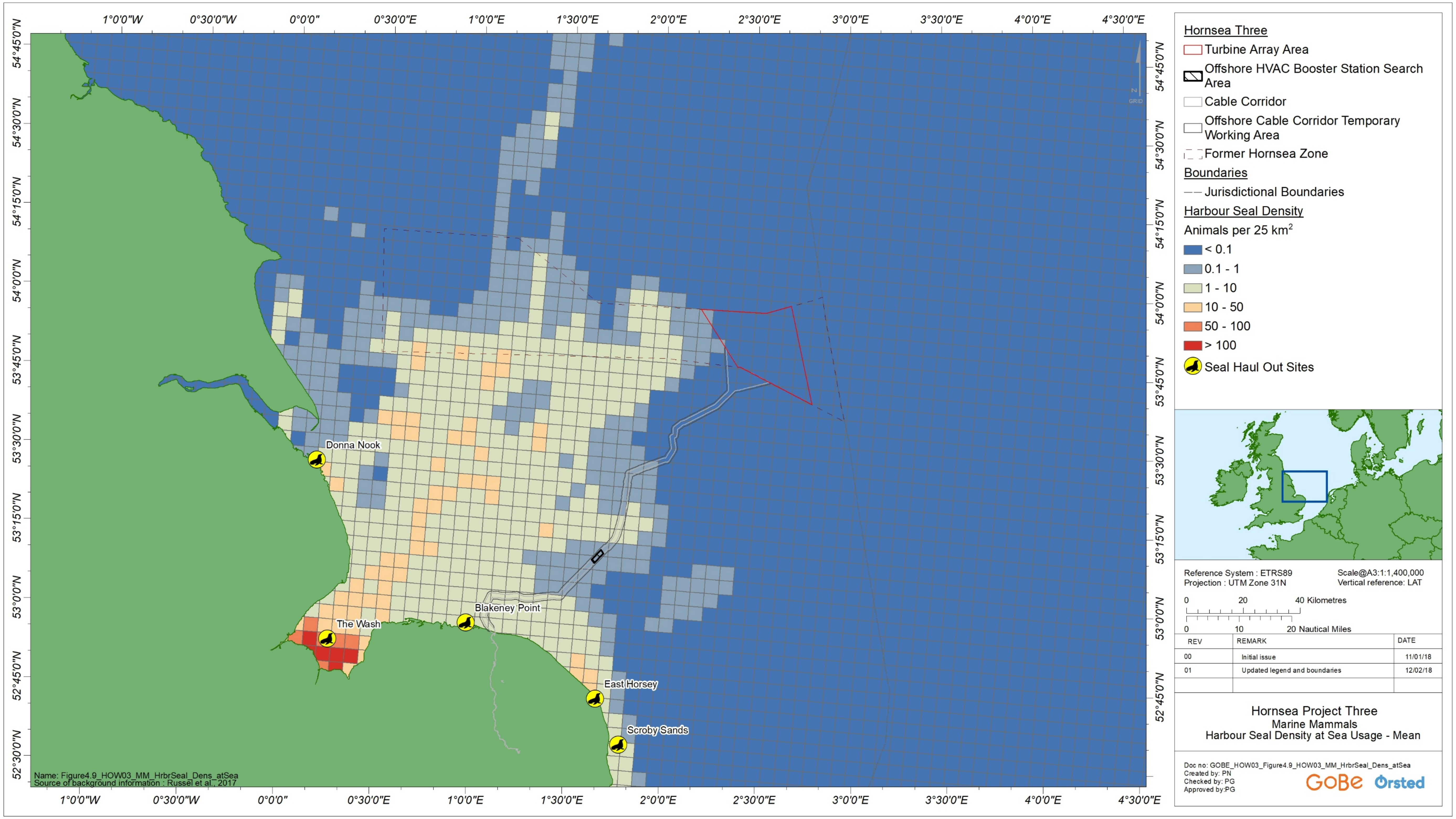

Figure 4.9: Harbour seal density At-Sea usage - mean (per 25 km²) for the regional marine mammal study area based on data collected over a 15 year period up to 2015.

Table 4.11: Designated sites with harbour seals 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	36

Summary

4.7.2.35 For the purposes of quantifying potential impacts, the following table provides a summary of the mean densities used in the assessment (Table 4.12). 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 harbour porpoises a range of estimates from a variety of surveys and data sources are described and presented in the Marine Mammal Technical Report (volume 5, annex 4.1). Although each data set has limitations, several of the recent data sources provided estimates of a similar magnitude, in the range 0.8 - 1 porpoises per km^2, including the most recent estimates from SCANS III from summer 2016 and the recent (2016 to 2017) aerial surveys of the site. The SCANS III surveys provide a very wide spatial coverage encompassing the whole of the potential impact footprint but are limited temporally as they only give an estimate for July 2016. Conversely the aerial surveys are limited to a maximum of 4 km outside of the wind farm site but provide data on a much higher temporal resolution (monthly from April 2016 to November 2017). Therefore, basing the assessment on a combination of these two data sources is considered the most appropriate approach. However, data from boat based visual and acoustic surveys from March 2010 to February 2013 suggest that in previous years the density of harbour porpoises across the site may have been higher (up to 2.9 porpoises per km^2). Given the variability in harbour porpoise abundance and distribution at this temporal and spatial scale, results are also presented using the density surface created from the three years of boat based surveys. For both the aerial survey and the boat based survey data, where impact ranges extended beyond the surveyed areas, the relevant SCANS III block data were used for all areas beyond the grid.

4.7.2.36 A similar approach was taken for minke whales and white-beaked dolphins whereby the modelled density surfaces from the boat based surveys were used in the assessment and the relevant SCANS III block data were used for all areas beyond the grid.

Table 4.12: Summary of density data for 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 (95 % Confidence Intervals)
Harbour porpoise	grid cell specific density	Modelled surface density estimates from the boat-based acoustic surveys of former Hornsea Zone plus 10 km buffer	North Sea (NS)	345,373 (246,526 – 495,752)
	0.888 individuals km^{-2}	SCANS-III Block O		
	1.019 individuals km^{-2}	Surface density estimates from the aerial video surveys of the Hornsea Three array area plus 4 km buffer		
White-beaked dolphin	grid cell specific density	Modelled surface density estimates from the boat-based visual surveys of former Hornsea Zone plus 10 km buffer	Celtic and Greater North Seas (CGNS)	15,895 (9,107 – 27,743)
	0.016 individuals km^{-2}	SCANS-III Block O		
Minke whale	grid cell specific density	Modelled surface density estimates from the boat-based visual surveys of former Hornsea Zone plus 10 km buffer	Celtic and Greater North Seas (CGNS)	23,528 (13,989 – 39,572)
	0.010 individuals km^2	SCANS-III Block O		
Grey seal	25 km^2 grid cell specific density surface	Russell *et al*., 2017	South-East England (SEE) and North-East England (NEE) combined	40,040
Harbour seal	25 km^2 grid cell specific density surface	Russell *et al*., 2017	South-East England (SEE)	6,799 (5,563 – 9,065)

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 (CIEEM, 2016). 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 4.13).

Table 4.13: 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 Table 4.14 and section 4.7.2 are considered to be International 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 4.14: 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	International	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 North Sea. 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 located in The Wash and North Norfolk Coast SAC.

4.7.4 Future baseline scenario

4.7.4.1 The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 require that "*an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge*" is included within the Environmental Statement.

4.7.4.1 In the event that Hornsea Three does not come forward, an assessment of the future baseline conditions has been carried out and is described within this section.

4.7.4.2 Marine mammal populations naturally fluctuate over space and time and therefore changes are likely to occur over the 35 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.

4.7.4.3 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.

4.7.4.4 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.

4.7.4.5 SCANS abundance data for the North Sea suggests that the population of harbour porpoise is stable or increasing with the SCANS-III abundance given as 345,373 animals (CV=0.21) (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).

4.7.4.6 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).

4.7.4.7 Grey seal populations in the North Sea have increased annually up to the most recent surveys in 2017. Between 2010 and 2016 there was a ~12% increase per annum due to the rapid expansion of newer colonies along the mainland coasts of Berwickshire, Lincolnshire, Norfolk and Suffolk coastlines (SCOS, 2016, augmented by unpublished data provided by SMRU). The largest increase (55%) was for the number of pups born at Blakeney Point between 2013 and 2014, and as a consequence this has overtaken the Farne Islands and Donna Nook as the biggest grey seal breeding colony in England (SCOS, 2016, SCOS, 2016, augmented by unpublished data provided by SMRU).

4.7.4.8 The most recent August haul-out counts of harbour seal in the period 2008-2016 shows a gradual increasing trend in numbers since the 1996-1997 counts for the southeast England colonies (SCOS, 2017). 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 2016 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). 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 4.7) 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 4.15 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.

Table 4.15: Maximum design scenario considered for the assessment of potential impacts on marine mammals.

Potential impact	Maximum design scenario	Justification
Construction phase		
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.	Maximum design scenario – Spatial extent: monopile foundations with concurrent piling Up to 319 monopiles (300 turbine foundations and 19 foundations for other infrastructure and platform foundations). • Piling of up to 300 monopile foundations of 15 m diameter for turbines; • Piling of up to 19 monopile foundations, 15 m diameter, for substations and platforms including: o Three offshore accommodation platforms; o Twelve offshore transformer substations; and o Four offshore HVAC booster stations located within the Hornsea Three offshore cable route corridor (HVAC transmission option only). • Absolute maximum design scenario 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; • Most likely maximum of 3,500 kJ (average maximum energy likely to be required at each piling location); and • Average hammer energy of 2,000 kJ (average hammer energy likely to result across all piling activity). • Absolute maximum design scenario of four hours piling duration per monopile (including 30 minute soft start); • Maximum total duration of actual piling is 1,276 (four x 319); • 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) with the maximum design spatial scenario being for concurrent piling. 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, although a concurrent scenario with one vessel piling in the HVAC booster station search area and within the Hornsea Three array area 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, maximum design spatial scenario (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 193.8 days which consists of: o Hornsea Three array area: 189 days = (157.5 days piling for 300 turbines + three accommodation platforms + 12 offshore transformer substations) plus 20% contingency; and o Hornsea Three offshore cable corridor: 4.8 days = (four days piling for four offshore HVAC booster stations) plus 20% contingency. • Foundation installation could occur over 2.5 years in up to two phases with a gap of up to three 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.	The maximum design spatial design scenario equates to the greatest area of effect from subsea noise at any one time during piling. The noise modelling used the frequency spectrum from a 7 m monopile, however, this is appropriate for also modelling 15 m monopiles as, at this scale, the overall noise output from the piling is controlled by the hammer energy used, adjusted by the length of the pile in contact with the water, rather than the size of the pile. Therefore, modelling a 7 m monopile also encompasses the extent of the noise profile from a 15 m monopile (see section 5.1.3.8 of volume 4, annex 3.1: Subsea Noise Technical Report). The monopile foundation for 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, whilst considering the degree of overlap with the areas of highest density for each species. Locations modelled for each species were therefore selected separately to reflect the maximum design scenario in terms of highest numbers potentially affected. For cetaceans this was the scenario of two vessels piling in the Hornsea Three array area and for seals this was for one vessel piling in the Hornsea Three array area and one vessel piling in the HVAC booster station search area.

Potential impact	Maximum design scenario	Justification
	Maximum design temporal: jacket foundations with single piling Up to 1,848 pin piles (1,200 for turbine foundations and 648 for other infrastructure and platform foundations) • Piling of up to 300 jacket foundations (four piles per foundation, each pin pile 4 m diameter) for turbines, with up to 1,200 piles (300 x four) in total; • Piling of up to 19 jacket foundations, up to 4 m diameter piles, for substations and platforms including: o Three offshore accommodation platforms, with up to 72 piles (three x 24) in total; o Twelve offshore transformer substations, with up to 288 piles (12 x 24) in total; and o Four offshore HVDC converter substations located in the Hornsea Three array area with up to 288 piles (four x 72 piles per foundation) in total (HVDC transmission option only). Maximum hammer energies defined as follows: • Absolute maximum hammer energy of up to 2,500 kJ (maximum that installation machinery is capable of); • Average maximum of 1,750 kJ (highest energy likely to be reached during piling events); and • Average hammer energy of 1,250 kJ (average hammer energy likely to be reached during piling). • Maximum four hours piling duration per pile (including 30 minute soft start); • Maximum total piling duration 7,392 hours of piling (four x 1,848); • 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, plus a 20% contingency; • Therefore, maximum design temporal scenario (single piling scenario for infrastructure located within the Hornsea Three array area only) is 554.4 days comprising: o 300 days piling for turbines (1,200 pin piles) o 18 days piling for accommodation platforms (72 pin piles) o 72 days for offshore transformer substations (288 pin piles) o 72 days for + for offshore HVDC converter substations (288 pin piles) o Total = 462 days plus 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 three years between phases. *Maximum design scenario* • Clearance of up to 23 UXO across the Hornsea Three array area and offshore cable corridor.	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. 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.
Underwater noise from UXO clearance within the Hornsea Three array area has the potential to cause injury or disturbance to marine mammals.	Up to 23 UXO detonations throughout the Hornsea Three array area and offshore cable corridor prior to the start of construction. may be required. It is assumed that one UXO will be cleared in any 24 hour period, resulting in up to 23 days of UXO clearance (not including weather down time).	The characterisation surveys undertaken as part of the EIA process do not include surveys for detecting UXO and therefore the number of UXO that may need to be cleared prior to the start of construction for Hornsea Three is not currently known. However, based on the Hornsea Project One UXO clearance campaign undertaken in late 2017, for the purposes of this assessment it is assumed that the same number of UXO will need to be cleared for Hornsea Three as for Hornsea Project One due to the similarities in location and typical UXO found in the region. UXO clearance works will include locating and exposing the UXO and will be undertaken from a vessel by UXO specialist contractors. While some noise and minor localised increases in SSC will result from these investigative works, it is not expected that any impacts will arise from these effects, particularly compared to the clearance of the UXO.

Potential impact	Maximum design scenario	Justification
Increased vessel traffic during construction may result in an increase in disturbance to or collision risk with marine mammals.	Up to 126 construction vessels in the vicinity of the Hornsea Three array area (making up to 10,774 return trips for the construction phase, based on the following total number of construction vessel return trips): • Up to four installation vessels (300 return trips), up to 24 support vessels (1,800 return trips) and up to 12 transport vessels (900 return trips) for wind turbine installation; • Up to three installation vessels (300 return trips), up to 13 support vessels (1,500 return trips), up to 12 dredging vessels (1,200 return trips) and up to four transport vessels (tugs) (1,200 return trips) for wind turbine gravity base foundation installation; • Up to two installation vessels (38 return trips), up to 12 support vessels (228 return trips) and up to four transport vessels (38 return trips) for offshore substation foundations installation; • Up to three main cable laying vessels (315 return trips), up to three main cable burial vessels (315 return trips), support vessels comprising up to four crew boats or SOVs, up to two service vessels, up to two diver vessels, up to two PLGR vessels, and up to two dredging vessels (1,890 return trips for support vessels) for array cable installation; • Up to four main cable laying vessels comprising up to one barge and three associated tugs (180 return trips), up to four main jointing vessels comprising up to one barge and three associated tugs (120 return trips), up to four main burial vessels support vessels comprising up to one barge and three associated tugs (180 return trips) and up to two crew boats or SOVs, up to one service vessels, up to one diver vessels, up to one PLGR vessels, and up to one dredging vessels (270 return trips for support vessels) for export cable installation; and • Up to eight vessels in a 5 km^2 area at any one time. 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.
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.	*Drilling operations for foundation installation: greatest sediment disturbance from a single foundation location* • Largest turbine monopile foundation (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 m^3 per foundation; • Largest offshore transformer substation with piled jacket foundation (up to 12 foundations), 24 piles per foundation, 4 m diameter, drilled to a penetration depth of 70 m, spoil volume of up to 21,112 m^3 per foundation and up to 100% of foundations may be drilled; • Largest offshore HVDC converter substation with piled jacket foundations (up to 4 foundations), 72 piles per foundation, 3.5 m diameter per pile, drilled to a penetration depth of 70 m, a spoil volume of up to 48,490 m^3 per foundation and up to 100% of foundations may be drilled; • Largest offshore accommodation platform with monopile foundations (up to three monopiles), associated diameter of 15 m, drilled to a penetration depth of 40 m, spoil volume of 7,069 m^3 per foundation and up to 100% of foundations may be drilled; • 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 eight years over two phases, with a gap of up to three years between an activity finishing in the first phase and starting in the second phase of construction. Foundation installation over up to 2.5 years within this time.	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 GBFs (which are separately assessed). The greatest volume of sediment disturbance by drilling, for both individual foundations and for the Hornsea Three array as a whole, is associated with the largest diameter monopile and piled jacket foundations for substations in the Hornsea Three 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 to 12 offshore transformer 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 Hornsea Three array area compared to the HVAC transmission system option.

Potential impact	Maximum design scenario	Justification
	Dredging for seabed preparation for foundation installation: greatest sediment disturbance from a single foundation location • Largest turbine gravity base foundation (up to 160 GBFs), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m, spoil volume per foundation 5,845 m^3; • Largest offshore transformer substation GBF (up to 12 GBFs), associated base dimensions 75 m, associated bed preparation area dimensions 175 m, average depth 2 m, spoil volume per foundation 61,250 m^3); • Largest offshore HVDC converter substation GBF (up to four GBFs), 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 m^3; • 7,535 m^3 total spoil volume per foundation for the largest offshore accommodation platform GBF (up to three GBFs), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m, spoil volume per foundation 5,845 m^3; Disposal of material on the seabed within Hornsea Three; Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 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 eight years over two phases, with a gap of up to three years between an activity finishing in the first phase and starting in the second phase of construction. Foundation installation over up to 2.5 years within this time.	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 GBF location is associated with the largest diameter or dimension GBF, which results in the greatest volume of spoil from a single foundation. Due to differences in both scale and number, GBFs for turbines, electrical substations and offshore accommodation platforms are separately considered. The HVDC transmission system option (up to 12 offshore transformer 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 Hornsea Three 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
	Cable installation Array cables • Installation method: mass flow excavator; • Total length 830 km; • 4,980,000 m^3 total spoil volume from installation of up to 830 km cables in a V-shape trench of width = 6 m and depth =2 m (830 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 4,980,000 m^3); and • 71,150 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). Interconnector cables • Installation method: mass flow excavator; • 15 interconnector 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 191 km in length (1,146 km in total); • Installation method: mass flow excavator; • 6,876,000 m^3 total spoil volume from installation of up to six 191 km cables in V-shape trenches of width = 6 m and depth =2 m (six x 191 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 6,876,000 m^3); and • 1,202,956 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 eight years over two phases. A gap of up to three years will occur between activity finishing in the first phase and starting in the second phase of construction. Individual elements of construction will be over shorter durations as follows: • Array cable installation over up to six months to 2.5 years; and • Export cable installation over up to four months to three years.	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 of 1 to 2 m height in the Hornsea Three array area 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.

Potential impact	Maximum design scenario	Justification
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 up to 126 construction vessels in the vicinity of the Hornsea Three array area (making up to 10,774 return trips for the construction phase, based on the following total number of construction vessel return trips): • Up to four installation vessels (300 return trips), up to 24 support vessels (1,800 return trips) and up to 12 transport vessels (900 return trips) for wind turbine installation; • Up to three installation vessels (300 return trips), up to 13 support vessels (1,500 return trips), up to 12 dredging vessels (1,200 return trips) and up to four transport vessels (tugs) (1,200 return trips) for wind turbine gravity base foundation installation; • Up to two installation vessels (38 return trips), up to 12 support vessels (228 return trips) and up to four transport vessels (38 return trips) for offshore substation foundations installation; • Up to three main cable laying vessels (315 return trips), up to three main cable burial vessels (315 return trips), support vessels comprising up to four crew boats or SOVs, up to two service vessels, up to two diver vessels, up to two PLGR vessels, and up to two dredging vessels (1,890 return trips for support vessels) for array cable installation; • Up to four main cable laying vessels comprising up to one barge and three associated tugs (180 return trips), up to four main jointing vessels comprising up to one barge and three associated tugs (120 return trips), up to four main burial vessels support vessels comprising up to one barge and three associated tugs (180 return trips) and up to two crew boats or SOVs, up to one service vessels, up to one diver vessels, up to one PLGR vessels, and up to one dredging vessels (270 return trips for support vessels) for export cable installation. 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. Potential contamination of nearshore/intertidal habitats from drilling mud (bentonite) used to facilitate the installation of export cables in the intertidal via HDD.	These parameters are considered to represent the likely maximum design scenario with regards to vessel movements during construction and the offshore storage of fuel.
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/disturbance of 68,645,736 m^2 due to construction activities, including 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 eight years over two phases with a gap of up to three years between phases; • Increased suspended sediment concentrations and sediment deposition arising from installation of 319 foundations, dredging for seabed preparation and cable installation over the eight year construction window; and • Accidental pollution events during the construction of 319 structures and from vessels and used during the construction phase.	This represents the maximum design scenarios for fish and shellfish receptors as described in volume 2, chapter 3: Fish and Shellfish Ecology, and therefore the maximum design scenario for effects on marine mammal prey species.

Potential impact	Maximum design scenario	Justification
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 300 turbines over a project lifetime of 35 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.	Operation and maintenance vessels in the vicinity of the Hornsea Three array area making up to 2,885 return trips per year, comprised of: • jack-up vessels (140 return trips); • crew transfer vessels (2,433 return trips); and • supply vessels (312 return trips). Up to 3,785 return helicopter trips/year to wind turbines.	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 2,201 km of cables: • Up to 830 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 1,146 km (six x 191 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.
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 300 turbines, up to 12 offshore transformer 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 2,822 round trips to port by operational and maintenance vessels (including supply/crew vessels and jack-up vessels) and up to 4,671 round trips by helicopter per year over the 35 year design life). A typical turbine is likely to contain approximately 25,000 l of lubricants (hydraulic oil, gear oil and grease), 80,000 l of liquid nitrogen and 7,000 kg of transformer silicon/ester oil, 2,000 l of diesel, 13,000 l of coolant and 6 kg of SF6 A typical offshore transformer substation is likely to contain up to 50,000 l of diesel, up to 200,000 l of transformer oil and up to 1,500 kg of SF6; A typical offshore HVDC substation is likely to contain up to 200,000 l of diesel; 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 (35 years) of the project due to: • Long term loss of 4,208,028 m^2 of benthic habitat (from 319 foundations, scour protection and cable protection); • Underwater noise from operation of up to 300 turbines and maintenance vessel traffic; • Introduction of 5,470,308 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 • Temporary habitat loss/disturbance of 9,770,400 m^2 over the lifetime of the project from maintenance operations (e.g. jack-up operations and cable remedial burial/repair; 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 volume 2, chapter 3: Fish and Shellfish Ecology, and therefore the maximum design scenario for effects on marine mammal prey species.

Potential impact	Maximum design scenario	Justification
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 319 foundations: 300 turbines, three offshore accommodation platforms, 12 offshore transformer substations and four offshore HVDC substations/offshore HVAC booster stations; • Removal of 2,201 km of cables (1,146 km of export cable (i.e. 6 x 191 km cables), 830 km of array cable, and 225 km interconnector cable); and • Up to 10,774 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 319 foundations (i.e. up to 300 turbines, up to 12 offshore transformer substations, up to four offshore HVDC substations and up to three accommodation platforms) and up to 2,201 km of cables (1,146 km of export cable (i.e. six 191 km cables), 830 km of array cable, and 225 km interconnector cable). Estimated to be up to 10,774 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 319 foundations (i.e. up to 300 turbines, up to 12 offshore transformer substations, up to four offshore HVDC substations/offshore HVAC booster stations and up to three accommodation platforms) and up to 2,201 km of cables (1,146 km of export cable (i.e. six x 191 km cables), 830 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.
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 319 foundations (i.e. up to 300 WTGs, up to 12 offshore transformer substations, up to four offshore HVDC substations and up to three accommodation platforms) and up to 2,201 km of cables (1,146 km of export cable (i.e. six x 191 km cables), 830 km of array cable, and 225 km interconnector cable). Accidental pollution may arise from vessel activity from up to 10,774 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 57,639,112 m^2; • Temporary increases in SSC and sediment deposition from removal of up to 319 foundations and 2,201 km of cables (1,146 km of export cable, 830 km of array cable, and 225 km interconnector cable); • Subsea noise from decommissioning of up to 319 foundations and 2,201 km of cables; • Loss of hard substrates and structural complexity (1,488,782 m^2 based on 319 gravity base foundations); • Permanent habitat loss/alteration (due to presence of scour and cable protection left *in situ*) totalling 3,616,852 m^2; and • Accidental release of pollutants from decommissioning of up to 319 foundations and from vessels used during the decommissioning phase (up 10,774 round trips).	Maximum design scenario as per decommissioning phase in volume 2, chapter 3: Fish and Shellfish Ecology.

4.9 Impact assessment methodology

4.9.1 Overview

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 the UK and Ireland. Terrestrial, Freshwater and Coastal, Second Edition (Chartered Institute of Ecology and Environmental Management (CIEEM) 2016);
- 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).

4.9.2 Impact assessment criteria

4.9.2.1 The criteria for determining the significance of effects is a two stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The terms used to define sensitivity and magnitude are based on those used in the DMRB methodology, which is described in further detail in volume 1, chapter 5: Environmental Impact Assessment Methodology.

4.9.2.2 The sensitivity of marine mammals 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.

4.9.2.3 Information on these aspects of sensitivity of the marine mammals 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.

4.9.2.4 The criteria for defining sensitivity in this chapter are outlined in Table 4.16 below. The sensitivity criteria were discussed and agreed at the EWG meeting in November 2017 and full meeting minutes are presented within the Evidence Plan (Consultation Report Annex 1 Evidence Plan).

Table 4.16: Definition of terms relating to the sensitivity of the receptor.

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

4.9.2.5 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 which would determine the number of individuals potentially affected; 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). These latter three factors in combination were used to inform an assessment of the likely severity of the effects resulting from the impact.

4.9.2.6 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 4.17 below. The magnitude criteria were discussed and agreed at the EWG meeting in November 2017 and full meeting minutes are presented within the Evidence Plan (Consultation Report Annex 1 Evidence Plan).

Table 4.17: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition used in this chapter
High	The impact would affect the behaviour and distribution of sufficient numbers of individuals, with sufficient severity, to affect the favourable conservation status and/or the long-term viability of the population at a generational scale (Adverse).
	Long term, large scale increase in the population trajectory at a generational scale (Beneficial).
Medium	Temporary changes in behaviour and/or distribution of individuals at a scale that would result in potential reductions to lifetime reproductive success to some individuals although not enough to affect the population trajectory over a generational scale. Permanent effects on individuals that may influence individual survival but not at a level that would alter population trajectory over a generational scale (Adverse).
	Benefit to the habitat influencing foraging efficiency resulting in increased reproductive potential and increased population health and size (Beneficial).
Low	Short-term and/or intermittent and temporary behavioural effects in a small proportion of the population. Reproductive rates of individuals may be impacted in the short term (over a limited number of breeding cycles). Survival and reproductive rates very unlikely to be impacted to the extent that the population trajectory would be altered (Adverse).
	Short term (over a limited number of breeding cycles) benefit to the habitat influencing foraging efficiency resulting in increased reproductive potential (Beneficial)
Negligible	Very short term, recoverable effect on the behaviour and/or distribution in a very small proportion of the population. No potential for the any changes in the individual reproductive success or survival therefore no changes to the population size or trajectory (Adverse).
	Very minor benefit to the habitat influencing foraging efficiency of a limited number of individuals (Beneficial).
No change	No predicted effect.

4.9.2.7 The significance of the effect upon marine mammals 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. The criteria were discussed and agreed at the EWG meeting in November 2017 and full meeting minutes are presented within the Evidence Plan (Consultation Report Annex 1 Evidence Plan).

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

		Magnitude of impact				
Sensitivity of receptor		*No change*	*Negligible*	*Low*	*Medium*	*High*
	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

4.9.3 Designated sites

4.9.3.1 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2)).

4.9.3.2 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2)), 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.

4.9.3.3 The Report to Inform Appropriate Assessment (document reference A5.2) 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 PEMMP (construction and operation phases) and Decommissioning Plan (decommissioning phase) will be produced and followed (Table 4.2). The 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 4.15) 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 15% of the maximum hammer energy (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.
A UXO specific MMMP, approved by the MMO in consultation with Natural England will be implemented during UXO clearance. The UXO MMMP will use ADDs, marine mammal observers and scare charges as the primary mitigation measures alongside other measures as may be agreed with Natural England and the MMO.	The use of an approved MMMP will mitigate for the risk of physical or permanent auditory injury and disturbance to marine mammals within a ‘mitigation zone’.

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 4.15 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 4.11.1.199 *et seq.*).

4.11.1.4 Assessment was based on the definition of Maximum design scenario piling parameters for each turbine foundation type (i.e. 5,000 kJ hammer energy for the monopiles and 2,500 kJ for the pin piles). The maximum design scenario parameters were intended to cover the absolute maximum piling parameters that would ever be required to install a foundation (in terms of maximal hammer energies and longest piling durations) – at this stage there is a large amount of uncertainty in ground parameters given the stage of the site investigations and therefore the maximum design scenario piling parameters are considered very precautionary and are intended to retain flexibility in project design whilst ensuring a precautionary assessment.

4.11.1.5 However, recent industry operational experience when installing offshore wind farms has shown that the hammer energies used have been much lower than those typically defined during the assessments. In recognition of this, both a 'most likely' ramp up scenario and an overall 'average' hammer energy were defined to be more representative of the actual piling activity. The 'most likely' scenario is the ramp up and maximum hammer energy likely to be used during the majority of piling events, based on engineering predictions (i.e. 3,500 kJ hammer energy for monopiles and 1,750 kJ for pin piles). The 'average' hammer energy was defined as an average, typical hammer energy that is representative of the hammer energies that will be used across the project, across all piling activity (i.e. 2,000 kJ for monopiles and 1,500 kJ for pin piles).

Marine mammals and noise

4.11.1.6 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.

4.11.1.7 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). In order to factor in the sensitivity of species based on their frequency range, different species can be classified into functional 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 phocid seals in water group (PW).

4.11.1.8 Various authors define thresholds for the prediction of specific impacts relating to underwater noise. These are based on the assumption that animals receiving a noise level at and above this threshold will be impacted, while animals receiving a lower noise level will not be impacted. These noise thresholds allow the modelling of noise impact footprints (also referred to as impact area) which define an area within which the noise is above the certain threshold. This allows the calculation of the number of animals likely to be present within the footprint and therefore the number of animals potentially impacted under a given scenario. Thresholds proposed by different authors, or even from the same authors, may be based on different sound metrics. In the following we describe the noise modelling that has been carried out to inform the assessment and detail the noise thresholds for the auditory injury and behavioural disturbance that will be adopted in this assessment.

Noise modelling

4.11.1.9 Predictive underwater noise modelling to estimate the noise levels likely to occur as a result of the construction of Hornsea Three has been carried out by Subacoustech Environmental Ltd using the INSPIRE model. The INSPIRE model represents a change from the approach presented in the PEIR, which used the dBSea model. On subsequent review it was determined that the dBSea model lacked empirical support and required further development before it can be confidently used in impact assessment. A detailed description of the modelling approach using the INSPIRE model is presented in volume 4, annex 3.1: Subsea Noise Technical Report.

4.11.1.10 The modelling considers a wide range of input parameters, including bathymetry, frequency content and speed of sound in water when calculating noise levels.

4.11.1.11 Modelling has been undertaken at five representative locations covering the Hornsea Three site and the accompanying offshore HVAC booster station search area, chosen to include proximity to nature conservation designations and varying water depths. The chosen locations are shown in Figure 5.1 and summarised in Table 5.1 of volume 4, annex 3.1: Subsea Noise Technical Report

4.11.1.12 The Northwest (hereafter referred to as NW) and Northeast (hereafter referred to as NE) locations give a wide spatial coverage of the Hornsea Three array area along the deep-water channel to the north. The South (hereafter referred to as S) location has been chosen to give spatial coverage to the south, showing the greatest potential noise propagation from this region. The two HVAC locations, HVAC North (hereafter referred to as HVAC N) and HVAC South (hereafter referred to as HVAC S), give coverage of the offshore HVAC booster station search area in shallower water closer to the coast.

4.11.1.13 The noise modelling results demonstrated that the highest impact ranges were found at the northwest modelling location within the Hornsea Three array (Hornsea Three NW) and at the south modelling location within the HVAC search area (HVAC S). Therefore, the modelling and associated ranges from these two locations are used for the basis of this assessment for cetaceans. For seals, whose areas of highest density were closer to the coast, the northwest modelling location represented the location of greatest predicted impact, as such, the modelling and associated ranges from this location was incorporated into the assessment for seals.

Auditory Injury

4.11.1.14 Exposure to loud sounds can lead to a reduction in hearing sensitivity, which can be (and in general is) restricted to particular frequencies, dependent on the frequency spectrum of the noise causing it. This reduction (threshold shift) results from physical injury to the auditory system and may be temporary (TTS) or permanent (PTS). In July 2016, the US National Oceanic and Atmospheric Administration (NOAA) released updated guidance on noise assessment metrics for auditory injury (National Marine Fisheries Service, 2016) with revised thresholds for PTS and TTS (henceforth referred to as NOAA thresholds). The NOAA thresholds supersede the thresholds for PTS and TTS onset presented in Southall *et al*. (2007) and in Lucke *et al.* (2009). This report presents PTS and TTS impact ranges for piling events, using the NOAA thresholds for all species.

4.11.1.15 The thresholds are based on a dual criteria approach whereby both should be evaluated and that predicting the largest range of impact, should be considered for the impact assessment. The first metric is pressure based, taken as zero-to-peak sound pressure level (SPL_{zp}) or as peak-to-peak sound pressure level (SPL_{pp}). Any single exposure at or above this pressure based metric is considered to have the potential to cause PTS or TTS, regardless of the exposure duration (cf. Southall *et al*., 2007). The second metric is energy based, and is a measure for the accumulated sound energy an animal is exposed to over an exposure period, referred to as sound exposure level (SEL) when considering single pulses, or cumulative sound exposure levels (SEL_{cum}) when considering exposure periods with multiple pulses. The sound exposure level metric is based on the 'equal-energy assumption', having its origin in human research, and stating that "*sounds of equivalent energy will have generally similar effects on the auditory systems of exposed human subjects, even if they differ in SPL, duration, and/or temporal exposure pattern"* (Southall *et al*., 2007). While the sound pressure levels are analysed unweighted, the National Marine Fisheries Service (2016) describe species (and author) specific frequency filters to be applied before the sound exposure level is calculated. The threshold values for PTS and TTS are given in Table 4.20 and details on the thresholds are provided in the following section.

4.11.1.16 Only PTS is considered as auditory injury in this assessment. This follows JNCC guidance on the prevention of injury and disturbance to EPS (JNCC, 2010). It is considered that assessment of auditory injury using PTS thresholds is sufficiently precautionary and allows a focus on where the larger risks of hearing damage are and to ensure that these risks are mitigated. In addition, the ranges of TTS overlap with disturbance ranges and many animals will actively avoid hearing damage by moving away or spending more time at or near the surface and that the consequences of any behavioural change are captured in the assessment of disturbance.

4.11.1.17 TTS ranges have been modelled and are presented for information but no assessment of magnitude of effect or overall effect significance has been undertaken. This because basing any impact assessment on the impact ranges for TTS using current TTS-onset thresholds would overestimate the potential for any ecologically significant effect. This is because the species specific TTS-thresholds developed by National Marine Fisheries Service (2016), and those presented by Southall *et al.* (2007) prior to that, describe those thresholds at which the onset of TTS is observed, which is, per their definition, a 6 dB shift in the hearing threshold, usually measured four minutes after sound exposure, which is considered as "*the minimum threshold shift clearly larger than any day-to-day or session-to-session variation in a subject's normal hearing ability"*, and which "*is typically the minimum amount of threshold shift that can be differentiated in most experimental conditions*." It is necessary to define TTS-onset thresholds, not to indicate any degree of signficant loss of hearing sensitivity, but in order to be able to predict where PTS might occur. Because expermients inducing PTS in animals is considered unethical, our ability to predict where PTS might occur relies on available data from humans and other terrestrial mammals that indicate that a shift in the hearing threshold of 40 dB may lead to the onset of PTS.

4.11.1.18 TTS is by definition, temporary, and the duration of effect at the threshold for TTS onset is likely to be low, expected to be less than an hour, and therefore unlikely to cause any major consequences for an animal. A large shift in the hearing threshold near to values that may cause PTS may however may require multiple days to recover (Finneran, 2015). An impact range which encompasses such a large variation in the predicted effect on individuals is extremely difficult to interpret in terms of the potential consequences for individuals, and therefore assessing the magnitude and significant of effect based on these TTS ranges is impossible to do reliably. It is important to bear in mind that the quantification of the spatial extent over which any impact is predicted to occur in the environmental assessment process, is done so in order to inform an assessment of the potential magnitude and significance of an impact. Because the TTS thresholds are not intended to indicate a level of impact of concern *per se*, but are used to enable the prediction of where PTS might occur, they should not be used for the basis of any assessment of impact significance.

Table 4.20: Thresholds for PTS and TTS adopted for the impact assessment.

Parameter (unit)	Harbour porpoise (HF cetacean)	Minke whale (LF cetacean)	White-beaked dolphin (MF cetacean)	Phocid seal (PW)
PTS				
SPL_{zp} dB re 1 µPa no weighting	202	219	230	218
SEL_{cum} dB re 1 µPa²s NOAA weighted, species	155	183	185	185
TTS				
SPL_{zp} dB re 1 µPa no weighting	196	213	224	212
SEL_{cum} dB re 1 µPa²s NOAA weighted, species	140	168	170	170

NOAA thresholds

4.11.1.19 National Marine Fisheries Service (2016) provides different threshold values for a set of 'functional hearing groups' adapted from Southall *et al.* (2007). For impulsive sounds such as those generated during pile driving, as in Southall *et al*. (2007), dual metric acoustic thresholds are provided for each hearing group: one unweighted SPL_{zp} value for instantaneously induced PTS or TTS, and one weighted SEL_{cum} value for PTS or TTS induced by cumulative sound exposure.

4.11.1.20 National Marine Fisheries Service (2016) proposes that SPL_{zp} should be either unweighted or flat weighted across the entire frequency band of a hearing group. Hearing ranges are defined and generalised for the entire group as a composite as follows:

- Pinnipeds in Water (PW): 50 Hz to 86 kHz;
- Low Frequency (LF): 7 Hz to 35 kHz;
- Medium Frequency (MF): 150 Hz to 160 kHz; and
- High Frequency (HF): 275 Hz to 160 kHz.

4.11.1.21 For determining the SEL_{cum} piling noise is weighted based on weighting curves given in Figure 4.10, in this report referred to as NOAA weighting. Compared to the M weighting from Southall *et al*. (2007), the filter defined in the NOAA weighting is much narrower and weights the sound levels according to a generalised hearing threshold for each species group. This means that the NOAA weighting is much more specific to the hearing abilities of the receiver than Southall's M weighting.

4.11.1.22 The SEL-thresholds for PTS and TTS take into account the received level and the duration of exposure, accounting for the accumulated exposure over the duration of an activity within a 24-hour period. National Marine Fisheries Service (2016) recommends the application of SEL_{cum} for the individual activity (e.g. one piling event with multiple strikes) rather than for multiple activities occurring within the same area or over the same time (e.g. concurrent piling). National Marine Fisheries Service (2016) threshold values are given in Table 4.20.

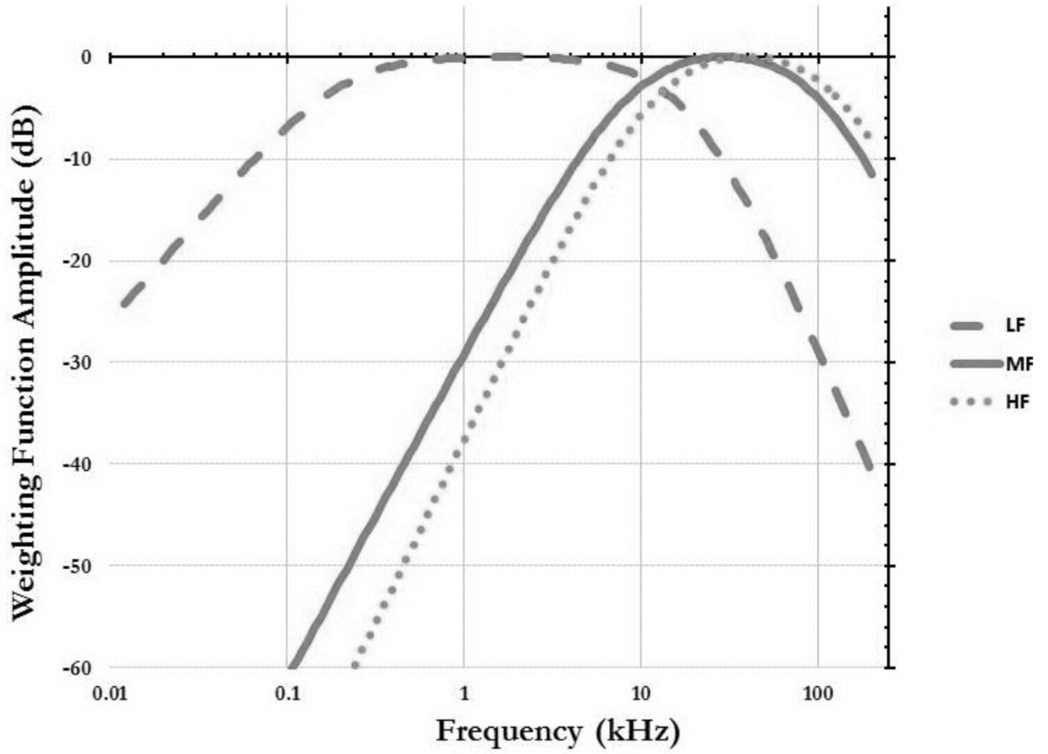

Figure 4.10: Auditory weighting functions for low-frequency (LF), mid-frequency (MF) and high-frequency (HF) cetaceans as described in National Marine Fisheries Service (2016).

4.11.1.23 To determine the number of animals experiencing energy-induced PTS or TTS, one has to calculate the accumulated energy during the course of the series of pile strikes while the animals move in their three-dimensional environment. Here assumptions have to be made on the swimming speed and direction of the movement, inducing uncertainties in the estimated number of animals experiencing PTS or TTS.

Disturbance

4.11.1.24 Unlike for thresholds of auditory injury, there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on the appropriate thresholds for behavioural response to pile driving noise. Behavioural responses to noise are highly variable and are dependent on a variety of animal dependent and environmental factors. Animal dependent factors include past experience, individual hearing sensitivity, activity patterns, motivational and behavioural state at the time of exposure. Demographic factors such as age, sex and presence of dependent offspring can also have an influence. Environmental factors include the habitat characteristics, presence of food, predators, proximity to shoreline or other features. Influenced by these factors, responses can be highly variable, from small changes in behaviour such as longer intervals between surfacing (Richardson, 1995a) or a cessation in vocalisation (Watkins, 1986) to more dramatic escape responses (Götz and Janik, 2016). This variability makes it extremely difficult to predict the likelihood of responses to underwater noise from piling. Even where empirical data exist on responses of animals in one particular environment, the context related variability makes it difficult to extrapolate from one study to a new situation. It is important to note that all any impact assessment can do, is predict the potential for behavioural responses, as definitive predictions of likelihood or magnitude are particularly difficult.

4.11.1.25 Two approaches have generally been used in UK EIA for underwater noise, the traditional approach being the use of a fixed threshold value for determining an impact area, similar to the approach for auditory injury as detailed above. The use of a fixed threshold assumes that all animals within the predicted impact area will display a behavioural reaction, while none of the animals outside this area will react. A second approach, is the adoption of a dose-response function, assuming that the proportion of animals displaying a behavioural reaction will depend on the received sound level. The characteristics of the received sound changes (e.g. received level decreases but other features of the sound may also change) with increasing distance to the sound source, and with it the proportion of animals reacting to the sound. The second of these approaches has been adopted in this assessment to provide an indication of the number of animals at risk of behavioural disturbance.

4.11.1.26 The idea behind the dose-response method is that not all animals react in the same way to sound levels, and that the probability of response varies as a function of received level. This is supported by several studies investigating the displacement of animals by piling sound (e.g. Brandt *et al*., 2011, Dähne *et al*., 2013, Russell *et al*., 2016). Using a dose-response function that allows for the calculation of the portion of animals reacting to a certain sound level therefore represents a more realistic approach compared to using a fixed threshold.

4.11.1.27 For the dose-response assessment, a series of isopleths were used, i.e. contours of equal sound levels around the sound source, with a stepwise decreasing unweighted single strike SEL (SELss) of 180 to 120 dB re 1 µPa²s, with a step size of 5 dB.

4.11.1.28 In order to calculate the number of individuals that might be predicted to respond to the piling noise using the dose-response approach, the estimated density for the area in-between adjacent contours was multiplied by the total area within each of these contour 'rings' and then multiplied by a value that represents the proportion of animals expected to respond within that contour, based on multiplication factors derived from a dose-response relationship described for each target species in the sections below.

4.11.1.29 The estimated densities were taken from a variety of sources, as shown in Table 4.21 depending on the species, the data available and the spatial coverage of surveys. Each of these data sources is described in detail in Volume 5, Annex 4.1: Marine Mammal Technical Report and summarised in Sections 4.6 and 4.7.

Table 4.21: The sources of density estimates used in the quantitative assessment of disturbance for each marine mammal species.

Species	Site specific density estimate	Wider area (beyond surveyed area)
Harbour porpoise	Density surface modelled using acoustic survey data collected over Hornsea Zone plus 10 km buffer *and* Corrected density from Aerial Digital surveys of the Hornsea Three study area	SCANS III density estimates for the appropriate blocks
Minke whale	Density surface modelled using visual survey data collected over Hornsea Zone plus 10 km buffer	SCANS III density estimates for the appropriate blocks
White-beaked dolphins	Density surface modelled using visual survey data collected over Hornsea Zone plus 10 km buffer	SCANS III density estimates for the appropriate blocks
Seals (both species)	Seal usage maps (Russell *et al.,* 2017)	

Harbour porpoise

4.11.1.30 The dose-response curve adopted in this assessment was developed by Graham *et al*. (2017a) and was generated from data collected during the first six weeks of piling for Phase 1 of the Beatrice Offshore Wind Farm monitoring program. It reflects the proportional decrease in occurrence of harbour porpoises with decreasing range from the piling site, as measured using CPODs. The dose-response curve detailed in Graham *et al*. (2017a) reveals the relationship between the proportion of animals responding and the corresponding received SEL_{ss} level (Figure 4.11). From the dose-response curve we used the proportion of animals responding to a certain SEL value as a multiplier to calculate the number of animals responding within each contour ring.

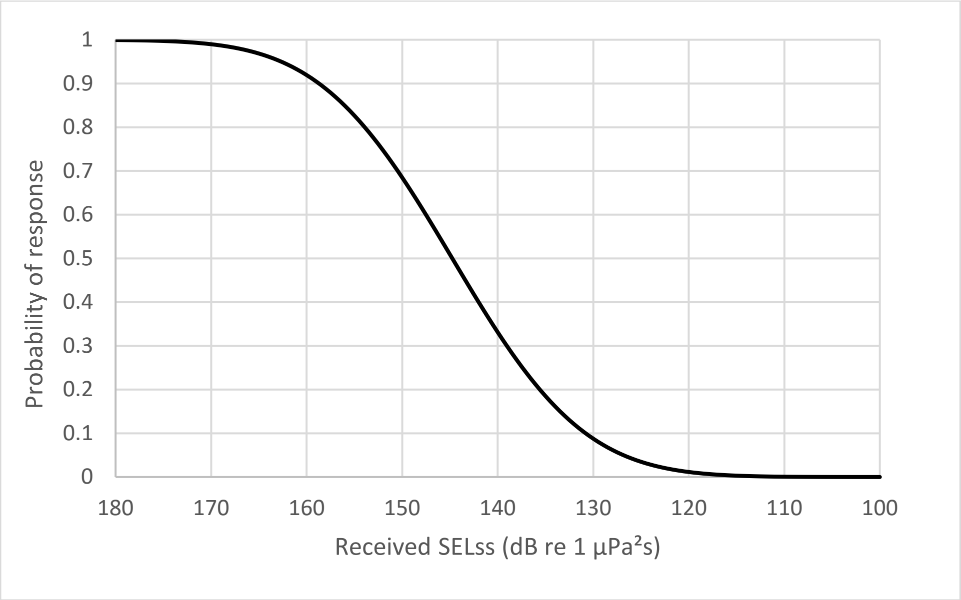

Figure 4.11: Relationship between the proportion of animals responding and the received single strike SEL (SELss), based on passive acoustic monitoring results obtained during Phase 1 of the Beatrice Offshore Wind Farm monitoring program (Graham *et al.*, 2017).

Minke whale and white-beaked dolphin

4.11.1.31 There are currently no data available on the behavioural responses of either minke whales or white-beaked dolphins, and therefore, no species specific dose-response curves are available for these two species. In the absence of a species specific dose-response curve, the dose-response curve for harbour porpoise was implemented for both minke whales and white-beaked dolphins. This was agreed with the EWG at a meeting on the 20th November, 2017.

Seals

4.11.1.32 A recent study by Russell *et al*. (2016) on the behaviour of 24 tagged harbour seals during pile driving at an offshore wind farm in the Wash, southeast England, provides the opportunity to incorporate recent, empirical data on behavioural responses in seals into piling noise assessments. The authors divided the study area in 5 x 5 km² grid cells and predicted the seal density and a corresponding change in density for each cell between periods of piling and periods of non-piling. SEL_{ss} values were modelled and averaged across the installation of all piles to generate a mean received SEL in the part of the water column with the lowest (and highest, respectively) predicted level for each of the grid cells. This allowed SEL values to be assigned to the predicted change in seal density. This analysis demonstrated that predicted seal abundance was reduced overall during piling activity across an area with a radius of 25 km from the piling activity, relative to seal abundance when no piling was taking place. It is important to note that during this study displacement was limited to piling activity only and within 2 hours of piling ending, seals were distributed as per during non-piling. Based on the data obtained by Russell *et al.* (2016), a dose-response curve was derived for depth-averaged received levels (mean SELss) (Figure 4.12) to match those predicted by the noise modelling. The Marine Mammal Technical Report (volume 5, annex 4.1) provides full detail of how this curve was derived.

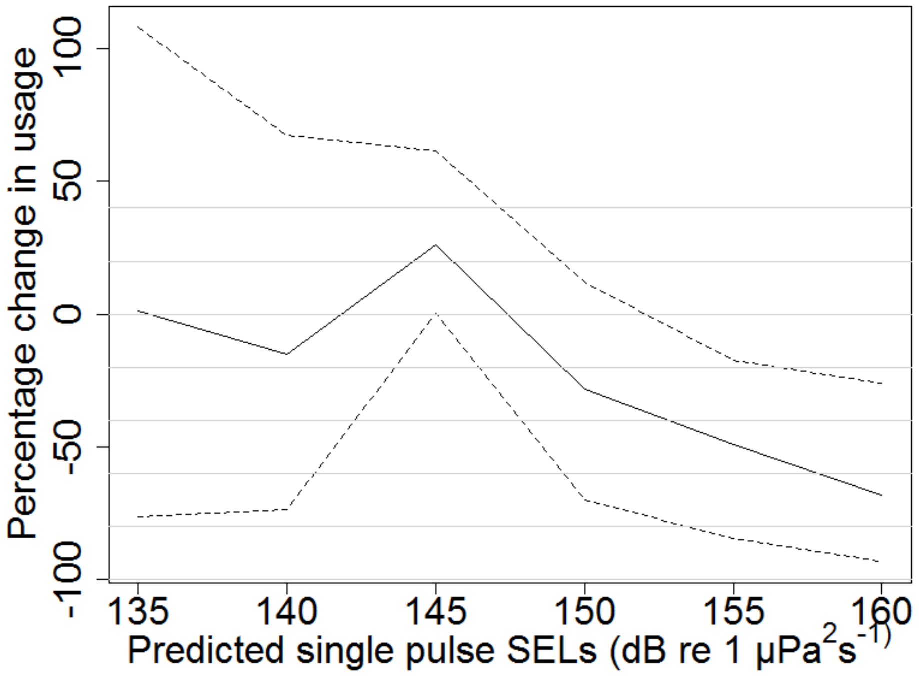

Figure 4.12: The predicted percentage change in seal usage given SELss at 5 dB increments. Please note each increment represents the next 5 dB. E.g. the predicted percentage change in usage value at 135 dB represents the mean for cells with estimated SELs of 135 **dB ≤** 140 dB.

Maximum design scenarios

4.11.1.33 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. 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).

4.11.1.34 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 three years between phases. It is assumed that the biggest impact 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 4.15 and described below.

4.11.1.35 Spatially, the maximum design scenario for the Hornsea Three array area is likely to arise for the installation of monopiles, where the maximum design scenario hammer energy is specified as 5,000 kJ, and the most likely scenario maximum hammer energy is 3,500 kJ, and where two vessels pile concurrently within the Hornsea Three array area. For this scenario a total of 189 days of piling could occur and could be spread over a two and a half year period, divided into two phases and a gap of up to three 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 382.8 days within the Hornsea Three array area plus offshore HVAC booster station search area.

4.11.1.36 Temporally, the maximum design scenario is represented by a single vessel installing pin piles (using a maximum design scenario hammer energy of 2,500 kJ, and a most likely scenario maximum hammer energy of 1,750 kJ) for jacket foundations, as the duration of piling would be longer compared to monopile foundations. For this scenario a total of 554.4 days piling could occur over a two and a half year piling period, again, split into two phases with a gap of up to three 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 277.2 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.

Auditory injury: PTS and TTS

4.11.1.37 Statutory Nature Conservation Body guidance (JNCC *et al*., 2010) defines injury as PTS, and TTS is not considered injury under EPS licencing as it is temporary and fully recoverable. Understanding and predicting the consequences of PTS for individuals is challenging and for TTS even more so. After small reductions of hearing sensitivity (< 15 dB) recovery is expected to be relatively quick, often within 60 minutes (Kastelein *et al*., 2013). To put this into context, the level of hearing shift at the TTS onset threshold is 6 dB. Therefore, for the majority of the animals within the TTS onset ranges presented here, the duration of the temporary reduction in sensitivity is expected to be short and not likely to be ecologically significant. TTS is only likely to be of concern when it reaches levels where effects could become permanent – and this is covered by the specific assessment of PTS-onset thresholds. Therefore, the assessment of auditory injury is based on the PTS results only, and TTS ranges are presented for information.

PTS: Harbour porpoise

Magnitude

4.11.1.38 Using the peak (SPL_{zp}) threshold, the maximum predicted range of PTS was 395 m for the maximum design scenario of 5,000 kJ for monopiles and 273 m for the maximum design scenario of 2,500 kJ for pin piles at the northwest location (Table 4.22). The corresponding values at Location HVAC S were lower.

4.11.1.39 Using the SEL_{cum} threshold the maximum predicted range of PTS was 1,200 m for the maximum design scenario for pin piles (2,500 kJ) at Location Hornsea Three NW (Table 4.22). However, as discussed in section 4.11.1.5, this represents the absolute maximum and will not be representative of the majority of the piling activity. Based on a pin pile hammer energy of 1,750 kJ ('most likely' scenario) the predicted PTS impact range at Location Hornsea Three NW using the SEL_{cum} threshold reduces to 200 m (Table 4.22). Given these impact ranges, alongside the adoption of standard mitigation (e.g. by adopting the JNCC piling mitigation protocol including a soft start, alongside the use of an acoustic deterrent device), the risk of PTS to any harbour porpoise as a result of exposure to piling noise is negligible, therefore the magnitude of the potential impact is considered negligible.

Table 4.22: Harbour porpoise PTS impact area (km^2) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
202 SPL_{zp} dB re 1 µPa	0.49	395	394	395	0.23	273	272	273
$NMFS_{HF}$ 155 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	2.74	1,200	600	911
HVAC S								
202 SPL_{zp} dB re 1 µPa	0.16	229	228	229	0.07	153	152	153
$NMFS_{HF}$ 155 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
202 SPL_{zp} dB re 1 µPa	0.34	328	327	328	0.15	218	217	217
$NMFS_{HF}$ 155 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.12	200	100	193
HVAC S								
202 SPL_{zp} dB re 1 µPa	0.11	188	187	188	0.05	121	120	121
$NMFS_{HF}$ 155 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100

Sensitivity

4.11.1.40 Studies of auditory injury in relation to the frequencies of the noise exposure have suggested that hearing impairment as a result of exposure to piling noise is likely to occur in and around the frequency of the fatiguing signal (Kastelein *et al.*, 2013), therefore auditory injury from piling is likely to be in lower frequency bands which would be unlikely to affect the ability of harbour porpoises to communicate or echolocate. However, given the fact that effects are irreversible and in light of the importance of sound for echolocation, foraging and communication in small toothed cetaceans, harbour porpoises are deemed to have a high sensitivity to PTS.

Significance of effect

4.11.1.41 Overall, the sensitivity of harbour porpoise to PTS is considered to be high and the magnitude of the effect is deemed to be negligible. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

PTS: Minke whale

Magnitude

4.11.1.42 Using the peak (SPL_{zp}) threshold, the maximum predicted range of PTS was 36 m for the monopile maximum design scenario of 5,000 kJ and 25 m for the pin pile scenario maximum hammer energy of 2,500 kJ at Location Hornsea Three NW (Table 4.23). The corresponding values at Location HVAC S were lower at 22 m and 15 m respectively.

4.11.1.43 Using the SEL_{cum} threshold the maximum predicted range of PTS was 1,500 m for the maximum design monopile scenario of 5,000 kJ at Location Hornsea Three NW (Table 4.23). However, as discussed in section 4.11.1.5, this represents the absolute maximum and will not be representative of the majority of the actual piling activity. Based on a monopile maximum hammer energy of 3,500 kJ ('most likely' scenario) the predicted PTS impact range at Location Hornsea Three NW using the SEL_{cum} threshold reduces to 500 m (Table 4.23). A study commissioned by ORJIP recently demonstrated that the Lofitech acoustic deterrent device was effective at deterring minke whales at similar ranges to the maximum ranges presented here (McGarry *et al.,* 2017). Therefore, the magnitude of the potential impact, in the presence of a standard JNCC mitigation protocol, including the use of an ADD and a piling soft start, is considered to be negligible.

Sensitivity

4.11.1.44 Although very little is known about minke whale hearing, it is likely that they rely on low frequency hearing. They do not echolocate but likely use sound for communication. Due to this uncertainty, and the fact that any effects will be irreversible, minke whales are deemed to have a high sensitivity to PTS.

Significance of effect

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

Table 4.23: Minke whale PTS impact area (km[2]) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
219 SPL_{zp} dB re 1 µPa	0	36	35	36	0	25	24	25
$NMFS_{LF}$ 183 SEL_{cum} dB re 1 µPa²s	3.08	1,500	400	912	0.15	300	100	204
HVAC S								
219 SPL_{zp} dB re 1 µPa	0	22	21	22	0	15	14	15
$NMFS_{LF}$ 183 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
219 SPL_{zp} dB re 1 µPa	0	30	29	30	0	20	19	20
$NMFS_{LF}$ 183 SEL_{cum} dB re 1 µPa²s	0.44	500	300	370	0.03	100	100	100
HVAC S								
219 SPL_{zp} dB re 1 µPa	0	18	17	18	0	12	11	12
$NMFS_{LF}$ 183 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100

PTS: White-beaked dolphin

Magnitude

4.11.1.46 Using the peak (SPL_{zp}) threshold, the maximum predicted range of PTS was 9 m for the monopile maximum design scenario hammer energy of 5,000 kJ and 6 m for the maximum design pin pile hammer energy of 2,500 kJ at Location Hornsea Three NW (Table 4.24). The corresponding ranges modelled at the HVAC South location were smaller than this.

4.11.1.47 Using the SEL_{cum} threshold, the maximum predicted range of PTS was 100 m for the maximum design scenario for both monopiles (5,000 kJ) and pin piles (2,500 kJ) (Table 4.24). Overall, the sensitivity is considered to be high and the magnitude is deemed to be negligible. Therefore, the overall effect will be of **negligible** adverse significance, which is not significant in EIA terms.

4.11.1.48 The magnitude of the potential impact, alongside the adoption of the standard JNCC mitigation protocol, is considered negligible.

Sensitivity

4.11.1.49 Most piling noise is relatively low frequency, and therefore the ecological effect of PTS at low frequencies, on a mid-frequency specialist species, such as white-beaked dolphins may be minimal. However, given how important sound is for echolocation, foraging and communication in small toothed cetaceans, white-beaked dolphins have been assessed as having a high sensitivity to PTS.

Significance of effect

4.11.1.50 Overall, the sensitivity is considered to be high and the magnitude is deemed to be negligible. Therefore, the overall effect will be of **negligible** adverse significance, which is not significant in EIA terms.

Table 4.24: White-beaked dolphin PTS impact area (km2) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
230 SPL_{zp} dB re 1 µPa	0	9	8	9	0	6	5	6
$NMFS_{MF}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
HVAC S								
230 SPL_{zp} dB re 1 µPa	0	6	5	6	0	4	3	4
$NMFS_{MF}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
230 SPL_{zp} dB re 1 µPa	0	7	6	7	0	5	4	5
$NMFS_{MF}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
HVAC S								
230 SPL_{zp} dB re 1 µPa	0	5	4	5	0	4	3	4
$NMFS_{MF}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100

PTS: Seal species

Magnitude

4.11.1.51 Using the peak (SPL_{zp}) threshold, the maximum predicted range of PTS was 41 m for the maximum design scenario of 5,000 kJ for monopiles and 29 m for the maximum design scenario of 2,500 kJ at Location Hornsea Three NW (Table 4.25). The corresponding values at Location HVAC S were lower.

4.11.1.52 Using the SEL_{cum} threshold, the maximum predicted range of PTS was 100 m for both the maximum design monopile (5,000 kJ) and pin pile (2,500 kJ) scenarios at both Location Hornsea Three NW and HVAC S (Table 4.25).

4.11.1.53 Based on the impact ranges presented above, alongside the adoption of standard mitigation (e.g. JNCC protocol including the use of an ADD prior to a soft start), the risk of PTS to any seals as a result of exposure to piling noise, and therefore the magnitude of the impact, is assessed as negligible.

Sensitivity

4.11.1.54 Seals are less dependent on hearing for foraging than cetacean species, but may rely on sound for communication and predator avoidance (e.g. Deecke *et al*., 2002). Hastie *et al.* (2015) reported that, based on calculations of SEL of tagged seals during the Lincs OWF construction, at least half of the tagged seals would have received a dose of sound greater than published thresholds for PTS. Based on the extent of the OWF construction in the Wash over the last ten years and the degree of overlap with the foraging ranges of harbour seals in the region (e.g. see Russell *et al*., 2016), it may be possible that a large number of individuals of the Wash population may have experienced levels of sound with the potential to cause some degree of hearing loss. The Wash harbour seal population has been increasing rapidly over this period and although there are clearly many other ecological factors that will influence the population health, this indicates that *predicted* levels of PTS are not affecting sufficient numbers of individuals, by a sufficient amount to cause a decrease in the population trajectory. However, despite the uncertainty in the ecological effects of PTS on seals, seals rely on hearing much less than cetaceans and therefore the sensitivity of seals to PTS has been assessed as medium.

Significance of effect

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

Table 4.25: Seal species PTS impact area (km²) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
218 SPL_{zp} dB re 1 µPa	0.01	41	40	41	0	29	28	29
$NMFS_{PW}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
HVAC S								
218 SPL_{zp} dB re 1 µPa	0	25	24	25	0	17	16	17
$NMFS_{PW}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
218 SPL_{zp} dB re 1 µPa	0	34	33	34	0	23	22	23
$NMFS_{PW}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
HVAC S								
218 SPL_{zp} dB re 1 µPa	0	20	19	20	0	14	13	14
$NMFS_{PW}$ 185 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100

PTS uncertainties

4.11.1.56 There are a number of factors that should be considered when interpreting the ranges presented here. A large degree of precaution is built into these predictions to account for uncertainty at various stages of the prediction process. These uncertainties apply across all species under consideration.

4.11.1.57 One such uncertainty is the assumption of the equal-energy-hypothesis used in the prediction of injury ranges as a result of cumulative exposure over multiple pulses. As discussed in National Marine Fisheries Service (2016), and also in Southall *et al*. (2007), this hypothesis may not hold for all situations due to the complexity of predicting PTS. It is well known that the equal energy rule over-estimates the effect of intermittent noise since the quiet periods between exposures will allow some recovery compared to noise that is continuously present with the same total SEL (Ward, 1997). A number of studies have demonstrated that the resulting auditory impairment in marine mammals from pulsed sound is less than that from continuous exposure with the same total SEL (Mooney *et al.,* 2009, Finneran *et al.,* 2010, Kastelein *et al*., 2014). However, National Marine Fisheries Service (2016), adopt the equal-energy-hypothesis for multiple pulse sound types, as there is currently no supported alternative method to accumulate exposure.

4.11.1.58 Another uncertainty is the rate at which animals are predicted to swim away from the piling noise. Relatively low swim speeds have been used in the modelling of cumulative exposure. This may be precautionary as several marine mammal species have been observed to increase their swimming speeds in relation to exposure to underwater noise (e.g. Dyndo *et al*., 2015, McGarry *et al*., 2017). This would have the effect of moving animals away faster from the most intense noise, thus reducing their overall exposure and therefore reducing the modelled impact ranges presented here.

4.11.1.59 The modelled piling duration of four hours for the maximum design scenario parameters and three hours for the most likely parameters are considered to be highly precautionary. Typically, installation is expected to last between one and two hours and only a small percentage (likely 5% or less) of piling operations will take longer.

<u>TTS: Harbour porpoise</u>

4.11.1.60 Using the peak (SPL_{zp}) threshold, the maximum predicted range of TTS was 920 m for the maximum monopile scenario (5,000 kJ) and 638 m for the maximum pin pile scenario (2,500 kJ) at Location Hornsea Three NW (Table 4.26). The corresponding ranges at Location HVAC S were lower (530 m and 356 m respectively).

4.11.1.61 Using the SEL_{cum} threshold the maximum predicted range of TTS was 12,200 m for the maximum monopile scenario (5,000 kJ) and 25,300 m for the maximum pin pile scenario (2,500 kJ) at Location Hornsea Three NW (Table 4.26). However, as discussed in paragraph 4.11.1.5, this represents the absolute maximum and will not be representative of the majority of the actual piling activity. Under the most likely scenario the predicted TTS impact range at Hornsea Three NW reduces to 5,500 m for monopiles (3,500 kJ) and 17,200 m for pin piles (1,750 kJ) (Table 4.26).

Table 4.26: Harbour porpoise TTS impact area (km^2) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
196 SPL_{zp} dB re 1 µPa	2.63	920	917	918	1.27	638	637	638
$NMFS_{HF}$ 140 SEL_{cum} dB re 1 µPa²s	306.79	12,200	7,300	9,775	1,103	25,300	13,600	18,523
HVAC S								
196 SPL_{zp} dB re 1 µPa	0.87	530	528	529	0.39	356	355	356
$NMFS_{HF}$ 140 SEL_{cum} dB re 1 µPa²s	35.7	4,000	2,700	3,356	213.16	9,800	6,400	8,203
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
196 SPL_{zp} dB re 1 µPa	1.83	766	765	766	0.81	509	508	509
$NMFS_{HF}$ 140 SEL_{cum} dB re 1 µPa²s	152.21	8,200	5,500	6,917	634.09	17,200	10,900	14,101
HVAC S								
196 SPL_{zp} dB re 1 µPa	0.59	437	435	436	0.24	281	279	280
$NMFS_{HF}$ 140 SEL_{cum} dB re 1 µPa²s	14.35	2,500	1,800	2,132	114.63	7,000	4,800	6,024

<u>TTS: Minke whale</u>

4.11.1.62 Using the peak (SPL_{zp}) threshold, the maximum predicted range of TTS was 83 m for the maximum monopile scenario (5,000 kJ) and 58 m for the maximum pin pile scenario (2,500 kJ) at Location Hornsea Three NW (Table 4.27). The corresponding values at Location HVAC S were lower (49 m and 33 m respectively).

4.11.1.63 Using the SEL_{cum} threshold the maximum predicted range of TTS was 32,200 m for the maximum monopile scenario (5,000 kJ) and 28,200 m for the maximum pin pile scenario (2,500 kJ) at Location Hornsea Three NW (Table 4.27). However, as discussed in section 4.11.1.5, this represents the absolute maximum and will not be representative of the majority of the actual piling activity. Under the most likely scenario the predicted TTS impact range at Hornsea Three NW reduces to 26,100 m for monopiles (3,500 kJ) and 21,500 m for pin piles (1,750 kJ) (Table 4.27).

Table 4.27: Minke whale TTS impact area (km^2) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
213 SPL_{zp} dB re 1 µPa	0.02	83	82	83	0.01	58	57	58
$NMFS_{HF}$ 168 SEL_{cum} dB re 1 µPa²s	1,417	32,200	14,500	20,868	1,109	28,200	12,700	18,446
HVAC S								
213 SPL_{zp} dB re 1 µPa	0.01	49	48	49	0	33	32	33
$NMFS_{HF}$ 168 SEL_{cum} dB re 1 µPa²s	248.38	11,400	6,300	8,822	156.51	9,100	4,900	6,992
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
213 SPL_{zp} dB re 1 µPa	0.01	69	68	69	0.01	46	45	46
$NMFS_{HF}$ 168 SEL_{cum} dB re 1 µPa²s	1,072	26,100	12,900	18,200	759	21,500	10,700	15,295
HVAC S								
213 SPL_{zp} dB re 1 µPa	0	40	39	40	0	26	25	26
$NMFS_{HF}$ 168 SEL_{cum} dB re 1 µPa²s	172.1	9,400	5,200	7,337	89.06	6,700	3,700	5,268

Table 4.28: White-beaked dolphin TTS impact area (km^2) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
224 SPL_{zp} dB re 1 µPa	0	18	17	18	0	13	12	13
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
HVAC S								
224 SPL_{zp} dB re 1 µPa	0	11	10	11	0	8	7	8
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
224 SPL_{zp} dB re 1 µPa	0	15	14	15	0	11	10	11
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100
HVAC S								
224 SPL_{zp} dB re 1 µPa	0	10	9	10	0	7	6	7
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 µPa²s	0.03	100	100	100	0.03	100	100	100

TTS: White-beaked dolphin

4.11.1.64 Using the peak (SPL_{zp}) threshold, the maximum predicted range of TTS was 18 m for the maximum design scenario for monopiles (5,000 kJ) and 13 m for the maximum design scenario for pin piles (2,500 kJ) at Location Hornsea Three NW (Table 4.27 and Table 4.28). The corresponding values at Location HVAC S lower (11 m and 8 m respectively). Using the SEL_{cum} threshold the maximum predicted range of TTS was 100 m for both the monopile (5,000 kJ) and pin pile (2,500 kJ) at both Location Hornsea Three NW and HVAC S (Table 4.27 and Table 4.28).

TTS: Seal species

4.11.1.65 Using the peak (SPL_{zp}) threshold, the maximum predicted range of TTS was 96 m for monopile (5,000 kJ) and 66 m for pin piles (2,500 kJ) at Location Hornsea Three NW (Table 4.29). The corresponding values at Location HVAC S were lower (56 m and 38 m respectively).

4.11.1.66 Using the SEL_{cum} threshold the maximum predicted range of TTS was 8,400 m for monopiles (5,000 kJ) and 5,400 m for pin piles (2,500 kJ) at Location Hornsea Three NW (Table 4.29). The corresponding ranges for HVAC S were 2,200 m and 700 m respectively. However, as discussed in section 1.2.2, this represents the absolute maximum and will not be representative of the actual piling activity. With a hammer energy to 3,500 kJ for monopiles ('most likely' scenario) and 1,750 kJ for pin piles ('most likely' scenario) the TTS impact ranges reduce to 5,500 m and 2,800 m respectively at Hornsea Three NW and 1,100 m and 100 m respectively at HVAC S (Table 4.29).

4.11.1.67 As discussed in paragraph 4.11.1.16 *et seq*, these ranges do not represent an impact which is considered to be of biological significance across the whole area indicated by these ranges, but are intended to indicate the level of noise exposure which could induce *any* measurable threshold shift. TTS within these ranges could range from a small (~6 dB) reduction in hearing sensitivity that would recover in less than one hour, to more significant reductions in hearing sensitivity that may last for a number of days. Reductions in hearing sensitivity may affect an animal's ability to forage, avoid predation and communicate but the TTS onset ranges alone do not allow us to assess the magnitude or significance of the likely consequences for individuals, and ultimately populations, of the predicted extent over which any TTS might occur. Qualitatively, these ranges suggest that the risk of TTS is highest for minke whales and harbour porpoises. The very low impact ranges suggest very little risk of any significant TTS to white-beaked dolphins and an intermediate risk to seals. Mitigation in place to reduce the risk of PTS to marine mammals will also reduce the risk of TTS below the ranges presented here.

Table 4.29: Seal species TTS impact area (km^2) and impact ranges (m) for locations Hornsea Three NW and HVAC S for the maximum design and most likely piling scenarios for both monopiles and pin piles.

	Area	Max Range	Min Range	Mean Range	Area	Max Range	Min Range	Mean Range
Maximum Design	Monopile (5,000 kJ)				Pin pile (2,500 kJ)			
Hornsea Three NW								
212 SPL_{zp} dB re 1 μPa	0.03	96	95	96	0.01	66	65	66
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 μPa²s	153.63	8,400	52,00	6,917	61.43	5,400	3,300	4,372
HVAC S								
212 SPL_{zp} dB re 1 μPa	0.01	56	55	56	0	38	37	38
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 μPa²s	10.83	2,200	1,400	1,844	0.82	700	300	498
Most Likely	Monopile (3,500 kJ)				Pin pile (1,750 kJ)			
Hornsea Three NW								
212 SPL_{zp} dB re 1 μPa	0.02	80	79	80	0.01	53	52	53
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 μPa²s	66.95	5,500	3,700	4,589	17.47	2,800	1,900	2,343
HVAC S								
212 SPL_{zp} dB re 1 μPa	0.01	46	45	46	0	30	29	30
$NMFS_{HF}$ 170 SEL_{cum} dB re 1 μPa²s	2.81	1,100	700	939	0.03	100	100	100

Behavioural effects

4.11.1.68 The noise modelling results demonstrated that the highest impact ranges for single strike SEL (SEL_{ss}) were found at the northeast modelling location within the Hornsea Three array (Hornsea Three NE) and at the south modelling location within the HVAC search area (HVAC S). The ranges from these two locations are used for the basis of this assessment of disturbance. However, the Hornsea Three NW location overlapped with higher seal density areas and so this location was used for the seal behavioural assessment instead of Hornsea Three NE.

4.11.1.69 There are a number of factors that should be considered when interpreting the number of animals predicted to experience disturbance. A large degree of precaution is built into these predictions to account for uncertainty at various stages of the prediction.

4.11.1.70 One such uncertainty is the density estimate used for each species to calculate the number of animals disturbed. As described in section 4.7.2, a range of datasets were available, however no single dataset could provide the spatial and temporal coverage or a contemporary estimate over the whole of the potential impact range. Therefore, a range of density estimates were used to estimate the number of animals experiencing behavioural disturbance.

4.11.1.71 Behavioural responses to noise are highly variable and are dependent on a variety of internal and external factors. Internal factors include past experience, individual hearing sensitivity, activity patterns, motivational and behavioural state at the time of exposure. Demographic factors such as age, sex and presence of dependent offspring can also have an influence. Environmental factors include the habitat characteristics, presence of food, predators, proximity to shoreline or other features. Responses themselves can also be highly variable, from small changes in behaviour such as longer intervals between surfacing (Richardson 1995b) or a cessation in vocalisation (Watkins 1986) to more dramatic escape responses (Götz and Janik 2016). This variability makes it challenging to predict the likelihood of responses to underwater noise from piling. Even where empirical data exist on responses of animals in one particular environment, the context related variability described above makes it difficult to extrapolate from one study to a new situation. It is important to note that all any impact assessment can do, is predict the *potential* for behavioural responses, as definitive predictions of likelihood or magnitude are particularly difficult. Another uncertainty is encountered with the use of the dose-response curves.

4.11.1.72 The dose-response curves are based on limited data (a small number of harbour porpoise studies and only a single harbour seal study), therefore there is only limited empirical data on the relationship between piling noise and the probability of a disturbance response, and only for these two species. Due to a lack of data to generate a dose-response curve for either minke whales or white-beaked dolphins, the harbour porpoise dose-response curve was applied to these two species. Harbour porpoises have been shown to be generally more responsive to underwater noise than other species, therefore the application of the harbour porpoise curve to other cetacean species is considered precautionary and potentially may overestimate the predicted impact for white-beaked dolphins and minke whales. Similarly, there are no data available to generate a grey seal dose-response curve and so the harbour seal curve was applied; and although there is uncertainty associated with the extrapolation of the harbour seal curve for the prediction of impacts on grey seals, grey seals are generally thought to be more robust than harbour seals. Based on their larger body size and larger capacity for fasting, their ability to adapt their foraging strategies in relation to energetic needs, grey seals are capable of adjusting their metabolic rate and foraging tactics to compensate for periods of changing energy demand and supply (e.g. Beck *et al*., 2003, Sparling *et al*., 2006). Grey seals are also very wide ranging and are capable of moving very large distances between different haul out and foraging regions (e.g. Russell *et al*., 2013); this behaviour coupled with the large and increasing North Sea population means that the adoption of a curve from harbour seals is considered precautionary.

4.11.1.73 Temporally, piling could occur up to a maximum of 554 days over a 2.5 year, two phase piling period, with a gap of up to three 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 a reduction in reproductive success over up to a maximum of four breeding cycles depending on the exact timing and duration of each phase.

4.11.1.74 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.

<u>Disturbance - Harbour porpoise</u>

Single Vessel – monopile

Magnitude

4.11.1.75 Figure 4.13 and Figure 4.14 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the harbour porpoise density surface as a result of a single operation installing a monopile using 5,000 kJ hammer energy (maximum design scenario) at Locations Hornsea Three NE and HVAC S. Using the aerial survey data in combination with the SCANS III density data, the corresponding number of animals predicted to be affected under this scenario are 2,659 porpoises for location Hornsea Three NE and 964 porpoises for location HVAC S. These represent 0.77% and 0.28% of the harbour porpoise reference population (North Sea MU) respectively (Table 4.30).Table 4.30). Using the density surface from the former Hornsea Zone plus 10 km buffer in combination with the SCANS III density data, the corresponding number of animals predicted to be affected is 4,999 porpoises for location Hornsea Three NE. This represents 1.45% of the harbour porpoise reference population (North Sea MU) (Table 4.30). The number of animals disturbed under the maximum design scenario is highly precautionary as these hammer energies will not be representative of the majority of the actual piling activity.

4.11.1.76 A more representative estimate for the amount of disturbance likely to occur is obtained from the 'average' scenario which predicts that 1,880 harbour porpoise and 653 harbour porpoise will be disturbed as a result of the overall average hammer energy achieved during monopile installation at Hornsea Three NE and HVAC S respectively, using the aerial survey/SCANS III density data. These represent 0.54% and 0.19% of the harbour porpoise reference population (Table 4.30). By comparison, using the density surface from the former Hornsea Zone plus 10 km buffer and the SCANS III density data, the predicted number of porpoise disturbed under the 'average' scenario is 3,717 porpoise at Hornsea Three NE which represents 1.08% of the reference population (Table 4.31).

4.11.1.77 Note, the impact contours for the HVAC S location did not overlap with the former Hornsea Zone plus 10 km buffer density surface or the aerial survey area and so only the SCANS III estimate is available for quantifying impact at this location.

4.11.1.78 With a single vessel installing monopile foundations for WTGs and offshore substations, the piling operations are expected to last for a total of 2.5 years, although it is important to note that there will not be continual piling across this whole period and piling activity will be concentrated into intermittent periods separated by days and in some cases weeks. Based on the maximum design scenario parameters presented above there may be up to a maximum of 319 days on which piling will occur, which represents 35% of the total number of days. Although it is important to note that the actual active piling will only be a small proportion of this time. This intermittent pattern of pile driving and the low percentage of active piling means that complete displacement is not expected across the 2.5 years. Combined with the low proportion of the population affected, the magnitude of the potential impact from single vessel operation installation of monopiles is considered low.

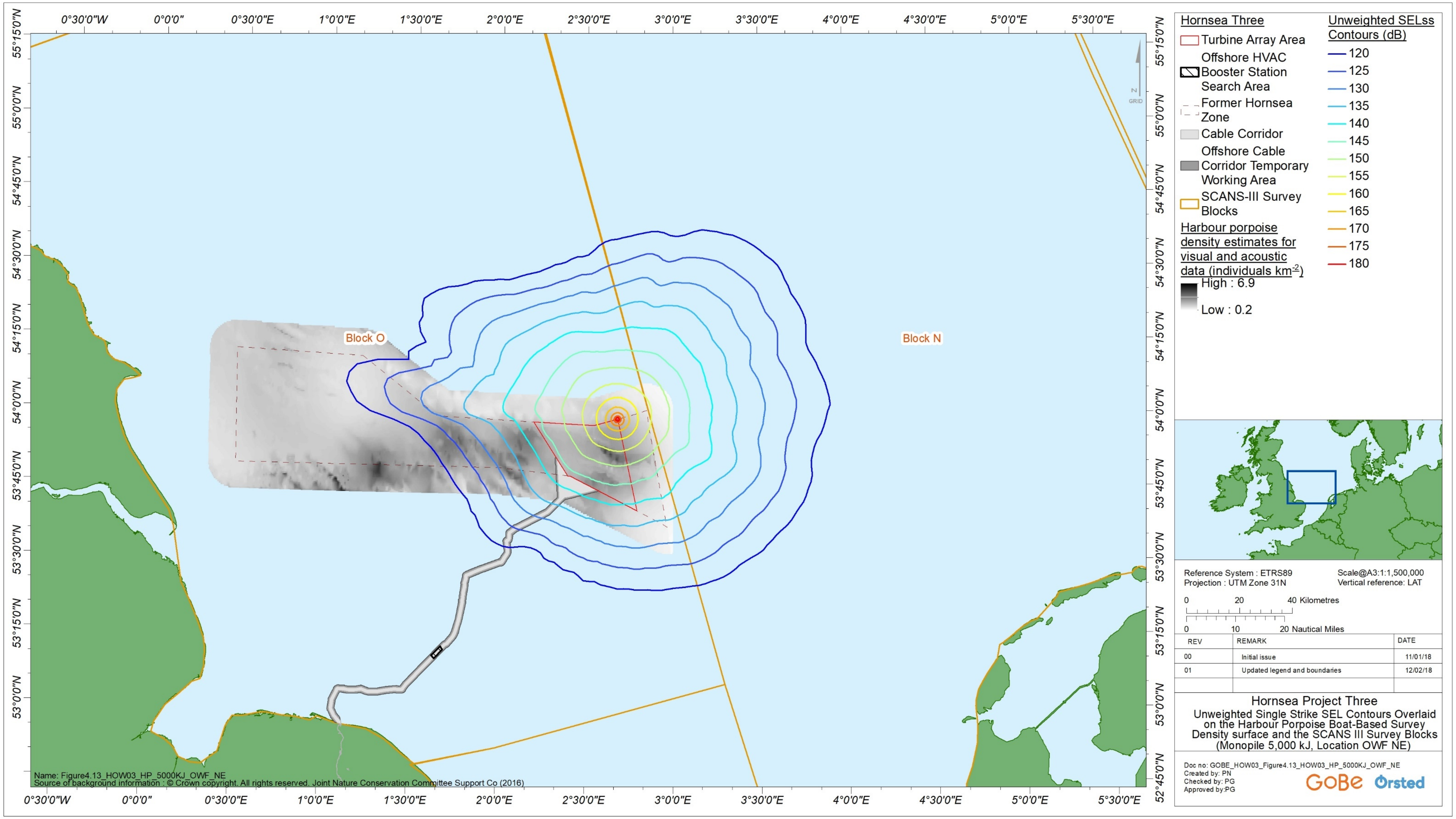

Figure 4.13: Unweighted single strike SEL contours overlaid on the harbour porpoise boat based survey density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location Hornsea Three NE).

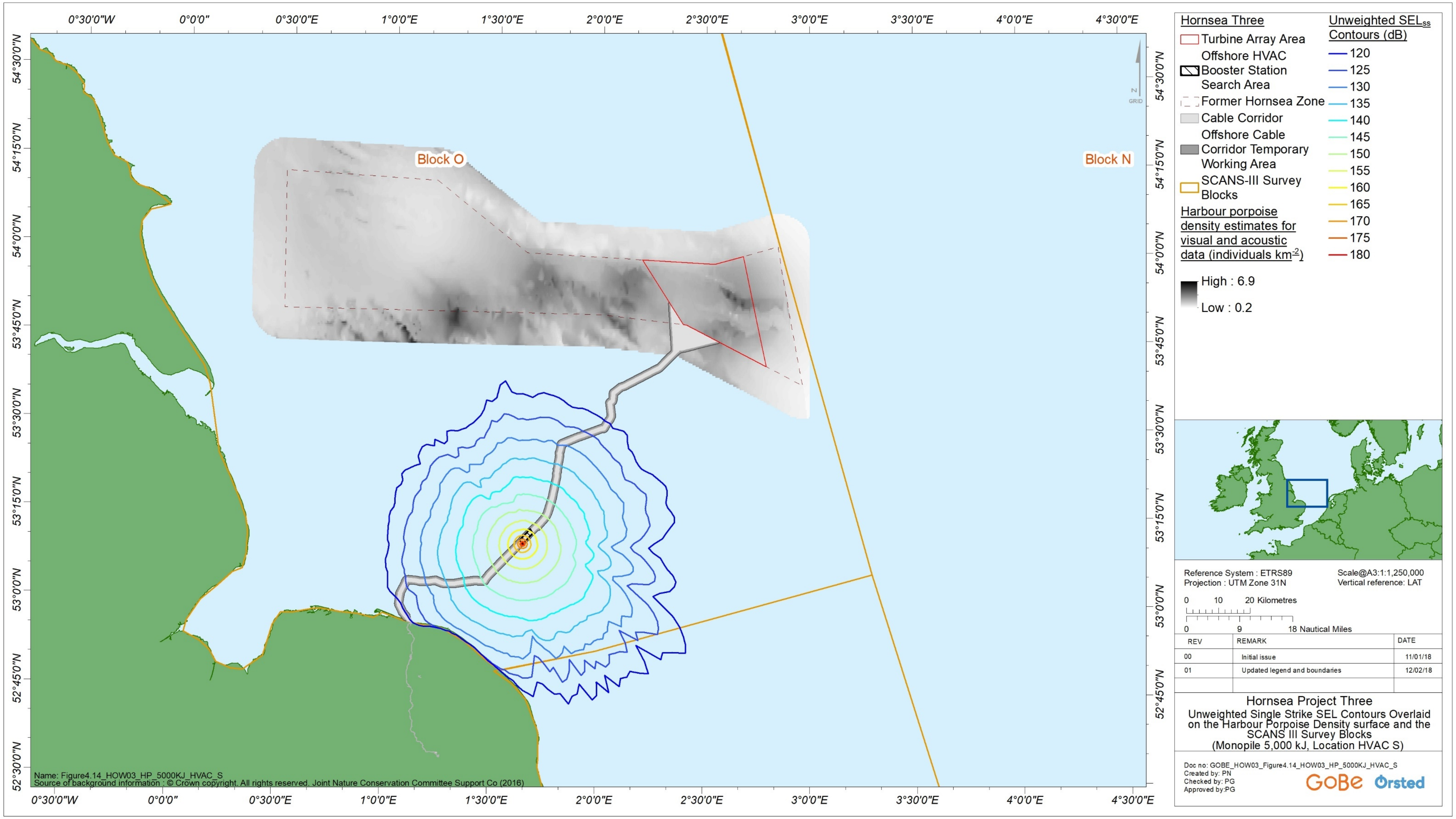

Figure 4.14: Unweighted single strike SEL contours overlaid on the harbour porpoise density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location HVAC S).

Table 4.30: Number of harbour porpoise experiencing behavioural disturbance during the installation of a monopile using aerial survey density and SCANS III density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Porpoise Impacted	% Population	# Porpoise Impacted	% Population
Hornsea Three NE (Aerial survey density & SCANS III)				
5,000 (maximum design scenario maximum hammer energy)	2,659	0.77%	2,507	0.73%
3,500 (most likely maximum hammer energy)	2,355	0.68%	2,210	0.64%
2,000 Average hammer energy	1,880	0.54%	1,748	0.51%
HVAC S (SCANS III)				
5,000 (worst case maximum hammer energy)	964 (673 – 1,475)	0.28% (0.19 – 0.43)	908 (635.4 – 1,387.4)	0.26% (0.18 – 0.40)
3,500 (most likely maximum hammer energy)	843 (588 – 1,289)	0.24% (0.17 – 0.37)	788 (552 – 1,205)	0.23% (0.16 – 0.34)
2,000 Average hammer energy	653 (457 – 999)	0.19% (0.13 – 0.29)	603 (422 – 922)	0.17% (0.12 – 0.27)

Table 4.31: Number of harbour porpoise experiencing behavioural disturbance during the installation of a monopile at location Hornsea Three NE using the modelled density surface within the former Hornsea Zone plus 10 km buffer and the SCANS III density (0.888 porpoise/km^2).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Porpoise Impacted	% Population	# Porpoise Impacted	% Population
5,000 (maximum design scenario hammer energy)	4,999	1.45%	4,819	1.40%
3,500 (most likely maximum hammer energy)	4,506	1.30%	4,332	1.25%
2,000 Average hammer energy	3,717	1.08%	3,554	1.03%

Sensitivity

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

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

4.11.1.81 The results from Wisniewska *et al.* (2016) could also suggest that porpoises have an ability to respond to short term reductions in food intake, implying a resilience to disturbance. As Hoekendjik *et al.* (2018) argue, this could help explain why porpoises are such an abundant and successful species. However, it is important to note that the studies providing evidence for the responsiveness of harbour porpoises to piling noise have not provided any evidence for subsequent individual consequences. In this way, responsiveness to disturbance is not the same as sensitivity to disturbance and porpoises may well be able to compensate by moving quickly to alternative areas to feed, while at the same time increasing their feeding rates. However due to observed responsiveness to piling noise harbour porpoises have been assessed here as having a medium sensitivity to disturbance and resulting displacement from foraging grounds.

Significance of effect

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

Single vessel – pin pile

Magnitude

4.11.1.83 Figure 4.15 and Figure 4.16 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the harbour porpoise density surface as a result of a single operation installing a pin pile using the maximum design scenario 2,500 kJ hammer energy at Locations Hornsea Three NE and HVAC S.

4.11.1.84 Using the aerial survey derived density plus the SCANS III density data beyond the limits of this, the corresponding number of animals predicted to be affected under the maximum design scenario are 2,076 porpoises for location Hornsea Three NE and 728 porpoises for location HVAC S. These represent 0.60% and 0.21% of the harbour porpoise reference population (North Sea MU) respectively (Table 4.32). Using the density surface derived from the surveys of the Hornsea Zone Study Area and the SCANS III density data beyond the limits of this, the corresponding number of animals predicted to be affected is 4,046 porpoises for location Hornsea Three NE. This represents 1.17% of the harbour porpoise reference population (North Sea MU) (Table 4.32).

4.11.1.85 The number of animals disturbed under the maximum scenario is highly precautionary as these hammer energies will not be representative of the majority of the actual piling activity. A more representative estimate of the total amount of disturbance potentially caused is obtained from the 'average' scenario which predicts that 1,480 porpoise and 504 porpoise will be disturbed overall as a result of pin pile installation at Hornsea Three NE and HVAC S respectively, using the aerial survey plus SCANS III density data. These represent 0.43% and 0.15% of the harbour porpoise reference population (Table 4.32). By comparison, using the former Hornsea Zone Study Area density surface and the SCANS III density data (Table 4.33) beyond that, the predicted number of porpoise disturbed under the 'average' scenario is 3,597 porpoise at Hornsea Three NE. While this estimate is considerably higher than that derived using the aerial survey plus SCANS III density data, it still represents only 1.17% of the reference population.

Table 4.32: Number of harbour porpoise experiencing behavioural disturbance during the installation of a pin pile using aerial survey and SCANS III density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Porpoise Impacted	% Population	# Porpoise Impacted	% Population
Hornsea Three NE (Aerial survey density & SCANS III)				
2,500 (maximum design scenario maximum hammer energy)	2,076	0.60%	1,939	0.56%
1,750 (most likely maximum hammer energy)	1,768	0.51%	1,640	0.47%
1,250 (average hammer energy)	1,480	0.43%	1,360	0.39%
HVAC S (SCANS III)				
2,500 (maximum design scenario maximum hammer energy)	728 (509 – 1,114)	0.21% (0.15 – 0.32)	676 (473 – 1,034)	0.20% (0.14 – 0.30)
1,750 (most likely maximum hammer energy)	610 (426 – 932)	0.18% (0.12 – 0.27)	560 (392 – 856)	0.16% (0.11 – 0.25)
1,250 (average hammer energy)	504 (352 – 770)	0.15% (0.10 – 0.22)	457 (320 – 699)	0.13% (0.09 – 0.20)

Table 4.33: Number of harbour porpoise experiencing behavioural disturbance during the installation of a pin pile at location Hornsea Three NE using the modelled density surface within the former Hornsea Zone plus 10 km buffer and the SCANS III density.

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Porpoise Impacted	% Population	# Porpoise Impacted	% Population
2,500 (maximum design scenario maximum hammer energy)	4,046	1.17%	3,879	1.12%
1,750 (most likely maximum hammer energy)	3,826	1.11%	3,656	1.06%
1,250 (average hammer energy)	3,597	1.04%	3,426	0.99%

4.11.1.86 Note, the impact contours for the HVAC S location did not overlap with the former Hornsea Zone plus 10 km buffer density surface or the aerial survey area and so only the above SCANS III estimate is available for this location.

4.11.1.87 With a single vessel installing pin pile foundations for WTGs and offshore substations, the piling operations are expected to last for a total of 2.5 years, although it is important to note that there will not be continual piling across this whole period and piling activity will be concentrated into intermittent periods separated by days and in some cases weeks. Based on the maximum design scenario parameters presented above there may be up to a maximum of 554 days of active piling which represents 61% of the total time. This intermittent pattern of pile driving and the low percentage of active piling means that complete displacement is not expected across the 2.5 years. Although the number of piling days is higher than for monopile installation, the overall level of predicted displacement is lower. Combined with the low proportion of the population affected, the magnitude of the potential impact from single vessel operation installation of a pin piles is considered low.

Sensitivity

4.11.1.88 As described in paragraphs 4.11.1.79 *et seq*, harbour porpoise are deemed to have a medium sensitivity to disturbance.

Significance of effect

4.11.1.89 Overall, the sensitivity of the receptor is considered to be medium and the magnitude is deemed to be low. The effect will, therefore the overall, be of minor adverse significance of this impact on, which is not significant in EIA terms.

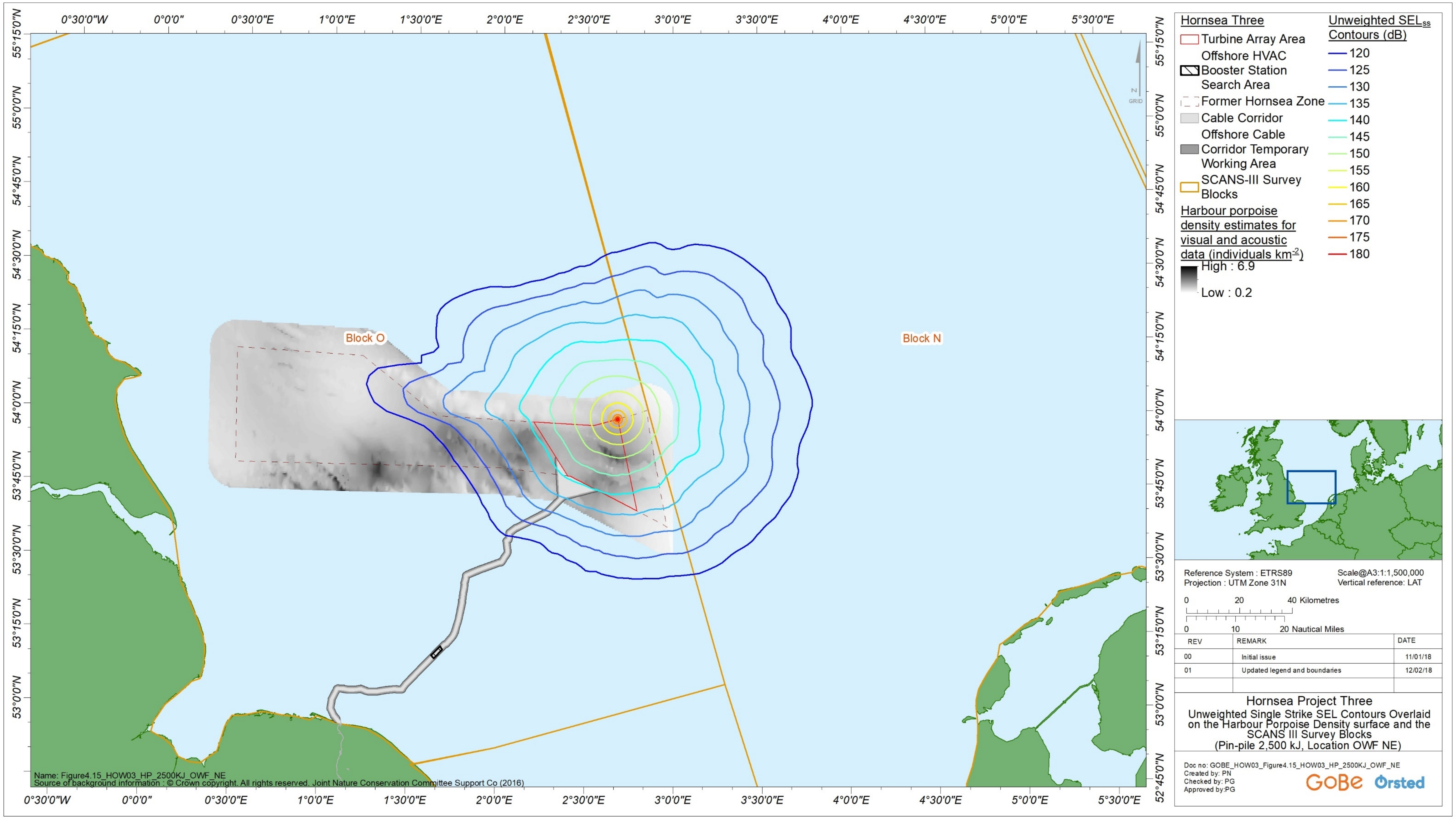

Figure 4.15: Unweighted single strike SEL contours overlaid on the harbour porpoise density surface and the SCANS III survey blocks (Pin pile 2,500 kJ, Location Hornsea Three NE).

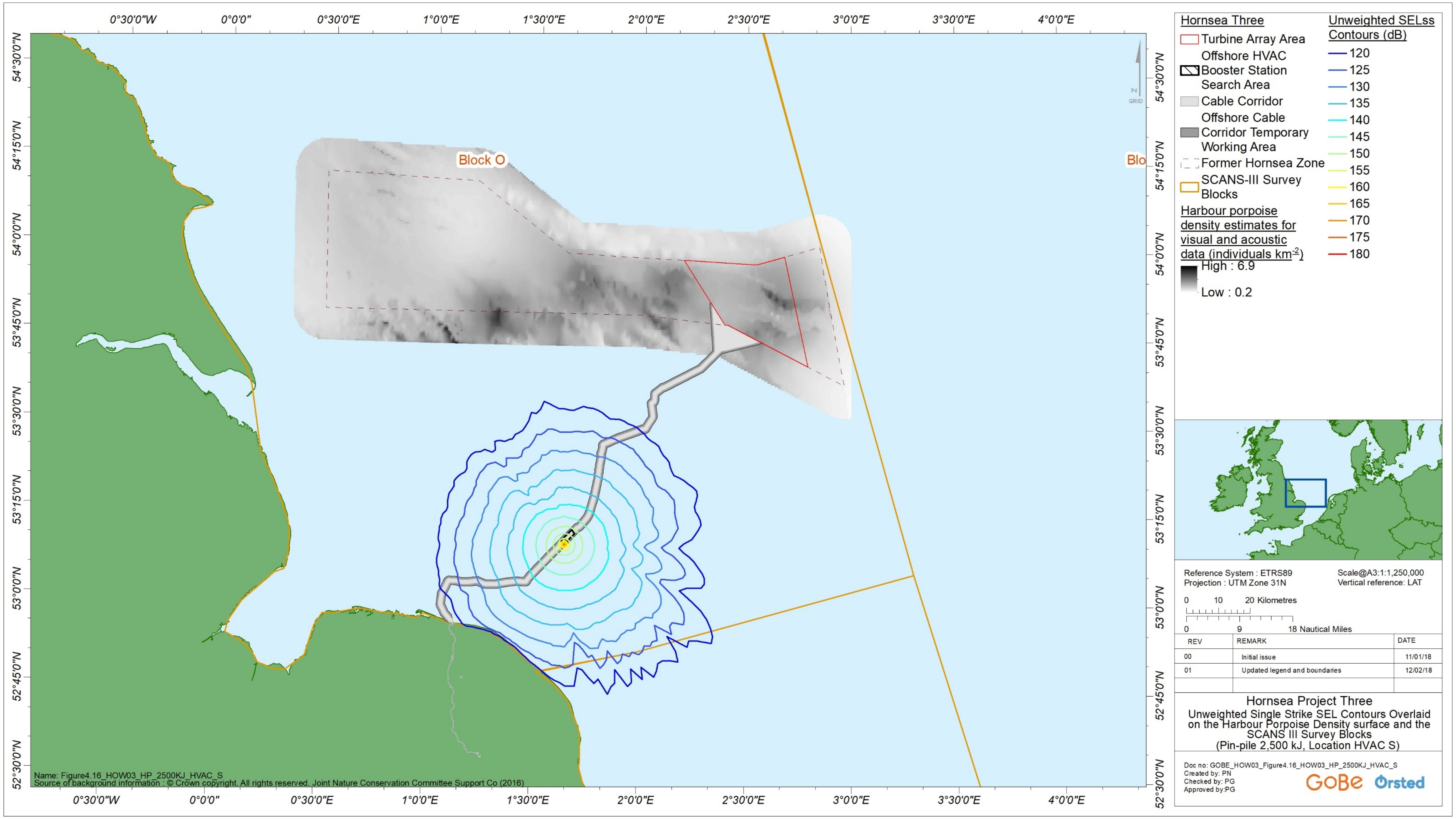

Figure 4.16: Unweighted single strike SEL contours overlaid on the harbour porpoise density surface and the SCANS III survey blocks (Pin pile 2,500 kJ, Location HVAC S).

Concurrent piling

Magnitude

4.11.1.90 Figure 4.17 displays unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the harbour porpoise density surface as a result of concurrent operations installing monopiles simultaneously at the maximum design scenario hammer maximum hammer energy of 5,000 kJ at locations Hornsea Three NE and Hornsea Three NW.

4.11.1.91 Using the aerial survey data in combination with the SCANS III density data, the number of animals predicted to be affected is 3,858 porpoises, which represents 1.12% of the harbour porpoise reference population (North Sea MU) (Table 4.34). Using the density surface of the former Hornsea Zone plus 10 km buffer and the SCANS III density data beyond that, the corresponding number of animals predicted to be affected is 7,330 porpoises which represents 2.12% of the harbour porpoise reference population (North Sea MU) (Table 4.34).

Table 4.34: Number of harbour porpoise experiencing behavioural disturbance during the concurrent installation of two monopiles (Hornsea Three NE and Hornsea Three NW).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Porpoise Impacted	% Population	# Porpoise Impacted	% Population
Aerial survey density data and SCANS III density				
5,000	3,858	1.12%	3,684	1.07%
3,500	3,463	1.00%	3,296	0.95%
2,000	2,830	0.82%	2,676	0.77%
Modelled density surface within the former Hornsea Zone + 10 km buffer and SCANS III density				
5,000	7,330	2.12%	7,111	2.06%
3,500	6,677	1.93%	6,467	1.87%
2,000	5,612	1.62%	5,418	1.57%

4.11.1.92 With two vessels installing monopile foundations for WTGs and offshore substations, the piling operations are expected to last for a total of 2.5 years, although it is important to note that there will not be continual piling across this whole period and piling activity will be concentrated into intermittent periods separated by days and in some cases weeks. Based on the maximum design scenario parameters presented above, with two vessels operating simultaneously there may be up to a maximum of 110 days on which piling occurs which represents 12% of the total time. Although it is important to note that actual active piling will occur much less than this as piling will not be continuous throughout the whole of these days. This intermittent pattern of pile driving and the reduced percentage of active piling means that although the overall footprint of impact (and subsequently number of animals affected) is greater for concurrent piling, the time over which this disturbance occurs is much shorter. Combined with the low proportion of the population affected, the magnitude of the potential impact from concurrent vessel operation installation of a pin piles is considered low.

Sensitivity

4.11.1.93 As described in paragraphs 4.11.1.79 *et seq*, harbour porpoise are assessed as having medium sensitivity to disturbance, therefore the overall significance of this impact on harbour porpoise is considered minor.

Significance of effect

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

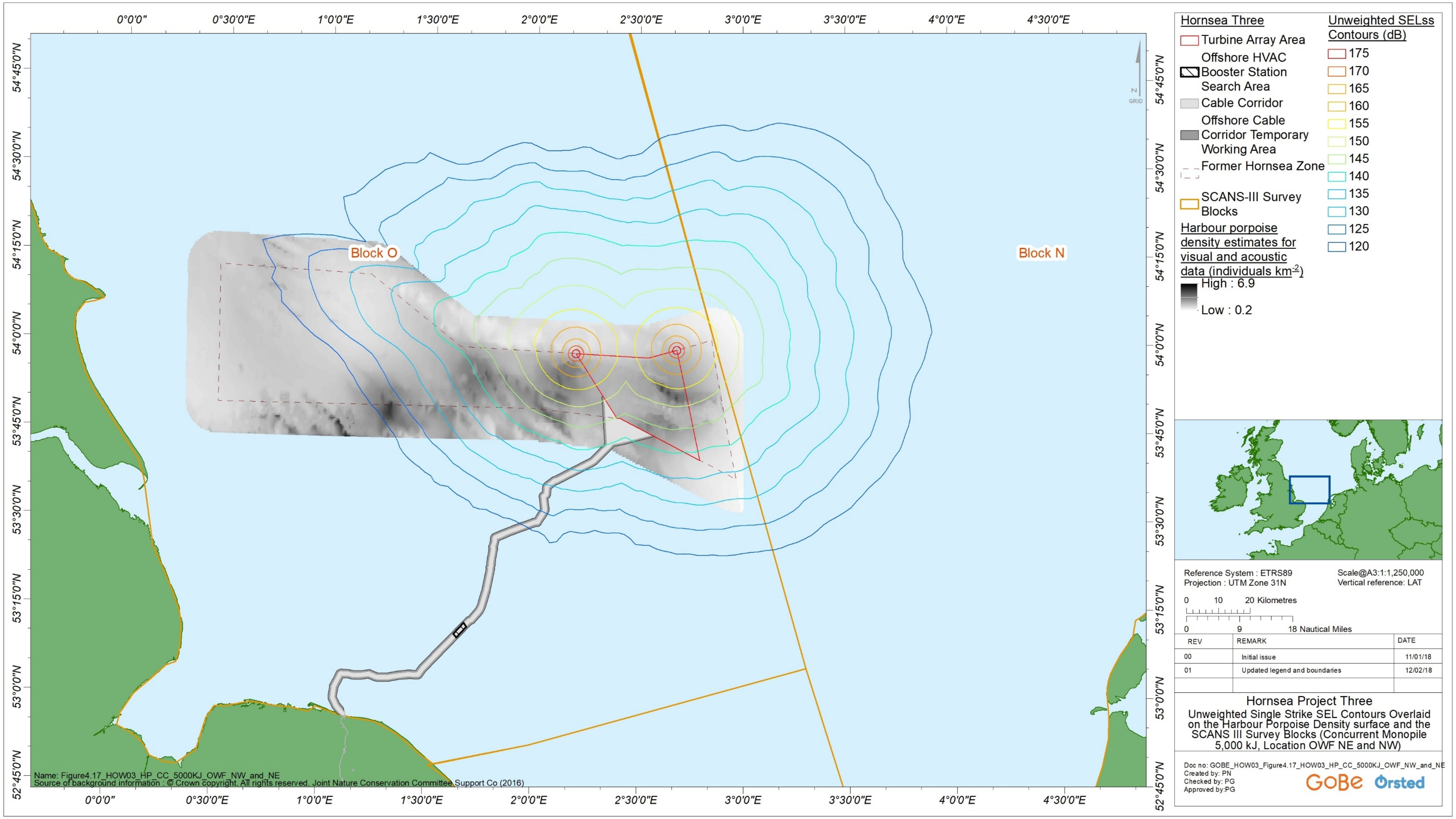

Figure 4.17: Unweighted single strike SEL contours overlaid on the harbour porpoise density surface and the SCANS III survey blocks (Concurrent monopile 5,000 kJ, Location Hornsea Three NE & Hornsea Three NW).

Disturbance – Minke whale

Single vessel – monopile

Magnitude

4.11.1.95 Figure 4.18 and Figure 4.19 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the minke whale density surface as a result of a single operation installing a monopile using 5,000 kJ hammer energy at Locations Hornsea Three NE and HVAC S.

4.11.1.96 Using the SCANS III density data, the corresponding average number of animals predicted to be affected under this scenario is 38 whales for location Hornsea Three NE and 10.8 whales for location HVAC S. These represent 0.16% and 0.05% of the minke whale reference population (Celtic and Greater North Seas MU) respectively (Table 4.35). Using the density surface from the former Hornsea Zone plus 10 km buffer and the SCANS III density data beyond that, the corresponding number of animals predicted to be affected is 26 whales for location Hornsea Three NE. This represents 0.11% of the minke whale reference population (Celtic and Greater North Seas MU) (Table 4.36).

4.11.1.97 Under the 'average' scenario (monopile 2,000 kJ) the number of impacted minke whales reduces to 26 and 7 for Hornsea Three NE and HVAC S respectively using the SCANS III density estimate. This represents 0.11% and 0.03% of the minke whale reference population.

4.11.1.98 Note, the impact contours for the HVAC S location did not overlap with the area covered by the surveys of the Hornsea Zone plus 10 km buffer (from which the predicted density surface was derived) so only the above SCANS III estimate is available for this location.

4.11.1.99 The magnitude of the potential impact from single vessel operation installation of monopiles is considered low.

Sensitivity

4.11.1.100 There is little information available on the behavioural responses of minke whales to underwater noise. Minke whales have been shown to change their diving patterns and behavioural state in response to disturbance from whale watching vessels; and it was suggested that a reduction in foraging activity at feeding grounds could result in reduced reproductive success in this species given its capital breeding pattern (i.e. that it relies on stored energy to provide resources for future breeding attempts) (Christiansen *et al*., 2013). McGarry *et al*. (2017) demonstrated that minke whales exhibited clear aversive responses to acoustic deterrent devices, resulting in an increased swim speed and increased directed movement away from the sound source. It is unknown if the Hornsea Three area and the wider surrounding area is a feeding ground for minke whales. Therefore, this assessment will assume that there is the potential for displacement from foraging areas which could, in turn, impact on the reproductive rates of affected individuals. Therefore, minke whales have been assessed as having a medium sensitivity to disturbance and resulting displacement.

Significance of effect

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

Table 4.35: Number of minke whales experiencing behavioural disturbance during the installation of a monopile using SCANS III density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Whales Impacted	% Population	# Whales Impacted	% Population
Hornsea Three NE				
5,000 (maximum design scenario maximum hammer energy)	38 (9.4 – 100.1)	0.16% (0.04 – 0.43)	35 (8.7 – 93.5)	0.15% (0.04 – 0.40)
3,500 (most likely maximum hammer energy)	33 (8.2 – 88.0)	0.14% (0.03 – 0.37)	31 (7.6 – 81.7)	0.13% (0.03 – 0.35)
2,000 Average hammer energy	26 (6.4 – 69.3)	0.11% (0.03 – 0.29)	24 (5.8 – 63.6)	0.10% (0.02 – 0.27)
HVAC S				
5,000 (maximum design scenario maximum hammer energy)	11 (2.0 – 29.9)	0.05% (0.01 – 0.13)	10 (1.9 – 28.4)	0.04% (0.01 – 0.12)
3,500 (most likely maximum hammer energy)	9 (1.7 – 26.2)	0.04% (0.01 – 0.11)	9 (1.6 – 24.6)	0.04% (0.01 – 0.10)
2,000 Average hammer energy	7 (1.3 – 20.4)	0.03% (0.01 – 0.09)	7 (1.2 – 18.8)	0.03% (0.01 – 0.08)

Table 4.36: Number of minke whales experiencing behavioural disturbance during the installation of a monopile using the modelled density surface within the former Hornsea Zone plus 10 km buffer and the SCANS III density beyond that.

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Whales Impacted	% Population	# Whales Impacted	% Population
5,000	26	0.11%	24	0.10%

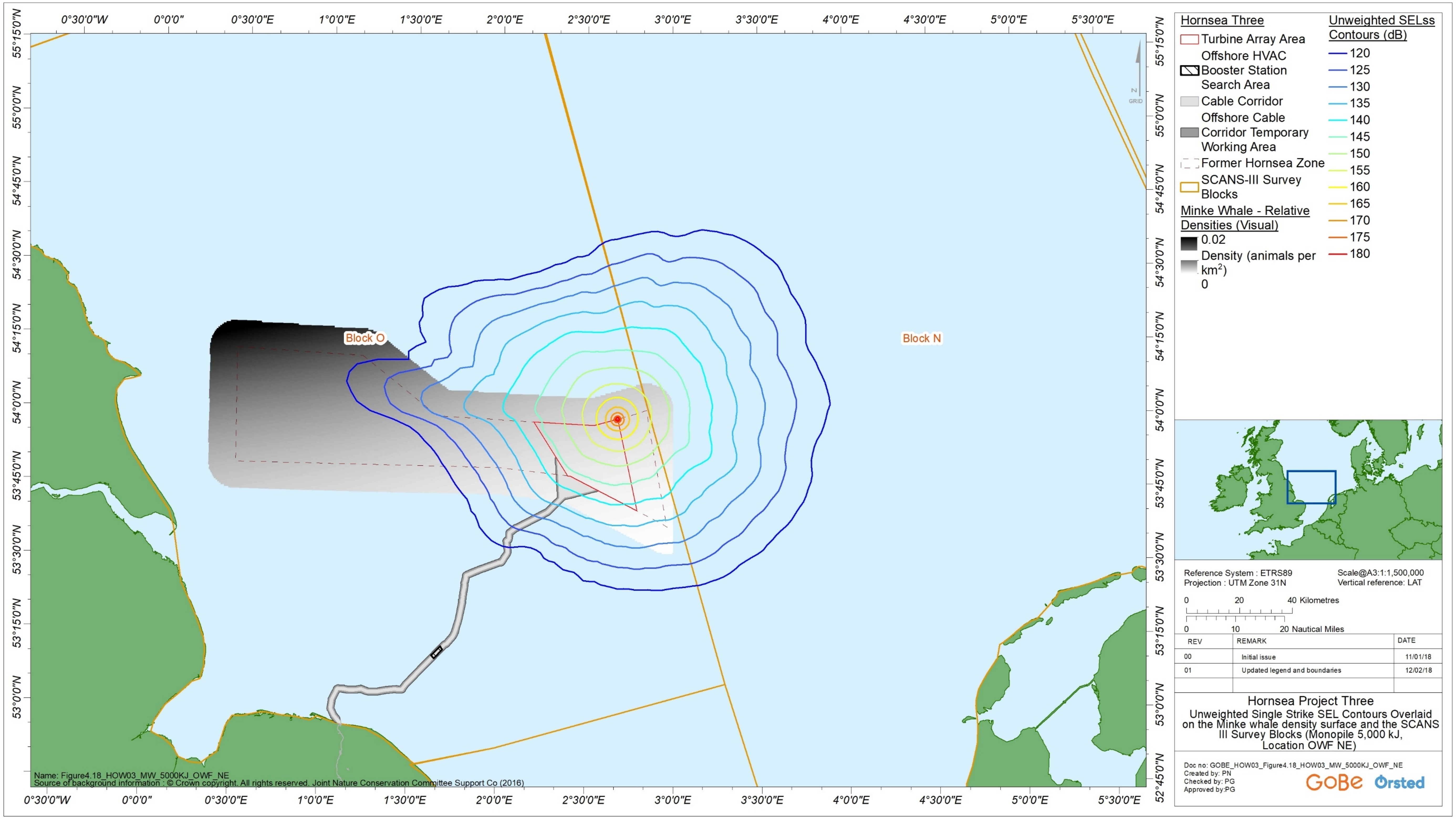

Figure 4.18: Unweighted single strike SEL contours overlaid on the minke whale density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location Hornsea Three NE).

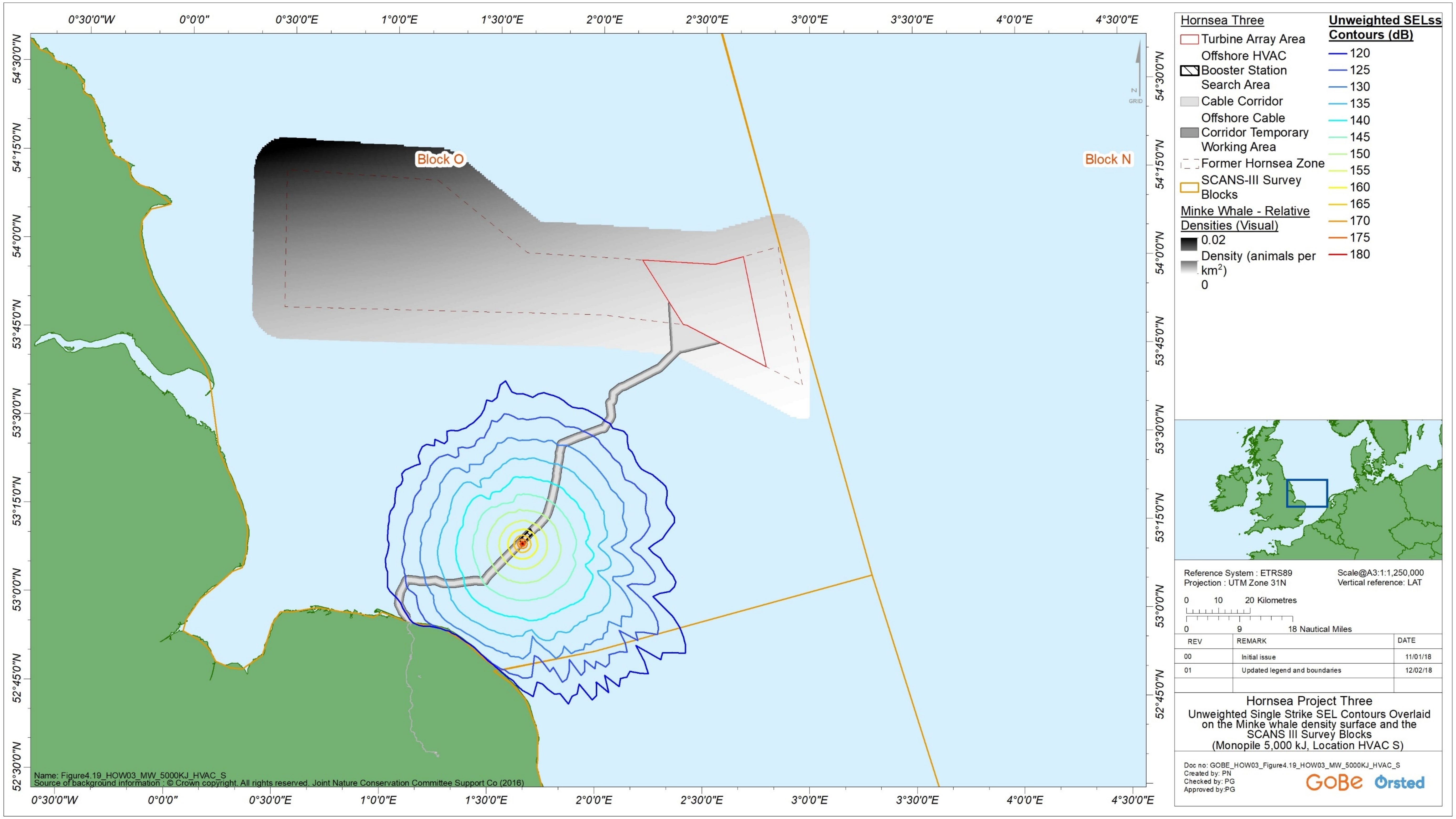

Figure 4.19: Unweighted single strike SEL contours overlaid on the minke whale density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location HVAC S).

Single vessel - pin pile

Magnitude

4.11.1.102 Figure 4.20 and Figure 4.21 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the minke whale density surface as a result of a single operation installing a pin pile using 2,500 kJ hammer energy at Locations Hornsea Three NE and HVAC S.

4.11.1.103 Since the single vessel monopile assessment demonstrated that the estimates of the number of individuals affected were highest using the SCANS III density, relative to those calculated using the Hornsea Zone Survey Area densities, only the results using the SCANS III density data, are presented here. The number of animals predicted to be affected are 29 whales for location Hornsea Three NE and 8 whales for location HVAC S. These represent 0.12% and 0.03% of the minke whale reference population (Celtic and Greater North Seas MU) respectively (Table 4.37).

4.11.1.104 Under the 'average' scenario (pin pile 1,250 kJ) the number of impacted minke whales reduces to 20 and 6 for Hornsea Three NE and HVAC S respectively. This represents 0.09% and 0.02% of the minke whale reference population.

4.11.1.105 The magnitude of the potential impact from single operation installation of a pin pile is considered low.

Sensitivity

4.11.1.106 As described in paragraph 4.11.1.100, minke whales are deemed to have a medium sensitivity to disturbance.

Significance of effect

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

Table 4.37: Number of minke whales experiencing behavioural disturbance during the installation of a pin pile using SCANS III density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Whales Impacted	% Population	# Whales Impacted	% Population
Hornsea Three NE				
2,500 (maximum design scenario maximum hammer energy)	29 (7.1 – 77.0)	0.12% (0.03 – 0.33)	27 (6.5 – 71.1)	0.11% (0.03 – 0.30)
1,750 (most likely maximum hammer energy)	25 (6.0 – 64.9)	0.10% (0.03 - 0.28)	22 (5.4 – 59.4)	0.10% (0.02 – 0.25)
1,250 (average hammer energy)	20 (4.9 – 53.8)	0.09% (0.02 – 0.23)	18 (4.3 – 48.6)	0.08% (0.02 – 0.21)
HVAC S				
2,500 (maximum design scenario maximum hammer energy)	8 (1.5 – 22.7)	0.03% (0.01 – 0.08)	8 (1.4 – 21.1)	0.03% (0.01 – 0.09)
1,750 (most likely maximum hammer energy)	7 (1.2 – 19.0)	0.03% (0.01 – 0.08)	6 (1.1 – 17.5)	0.03% (0.00 – 0.07)
1,250 (average hammer energy)	6 (1.0 – 15.7)	0.02% (0.00 – 0.07)	5 (0.9 – 14.3)	0.02% (0.00 – 0.06)

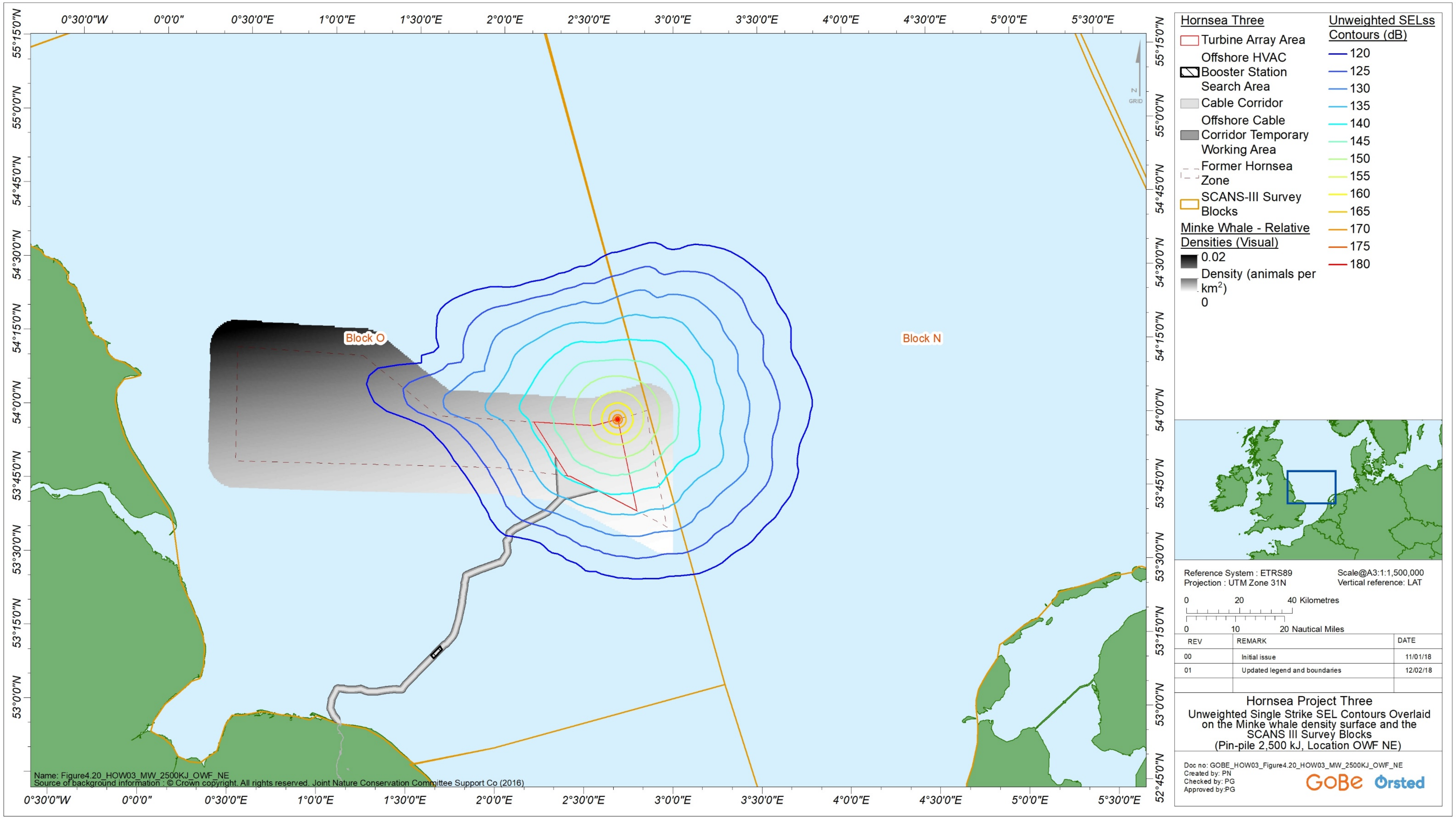

Figure 4.20: Unweighted single strike SEL contours overlaid on the minke whale density surface and the SCANS III survey blocks (Pin pile 2,500 kJ, Location Hornsea Three NE).

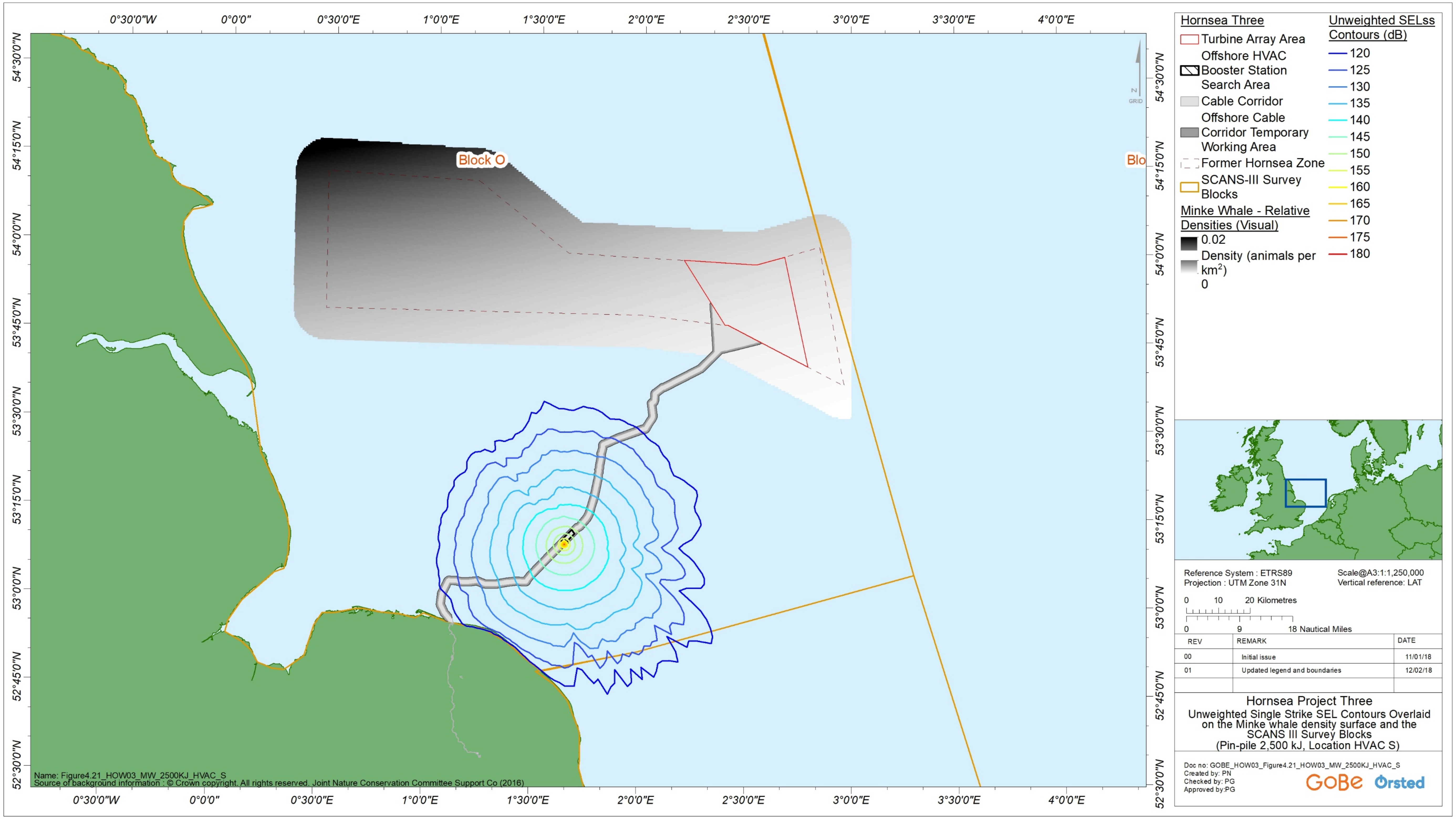

Figure 4.21: Unweighted single strike SEL contours overlaid on the minke whale density surface and the SCANS III survey blocks (Pin pile 2,500 kJ, Location HVAC S).

Concurrent piling

Magnitude

4.11.1.108 Figure 4.22 displays unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the minke whale density surface as a result of concurrent operations installing two monopiles at the maximum design scenario maximum hammer energy (5,000 kJ) simultaneously at locations Hornsea Three NE and Hornsea Three NW.

4.11.1.109 Using the SCANS III density data, the corresponding number of animals predicted to be affected is 51 whales, which represents 0.22% of the minke whale reference population (Celtic and Greater North Seas MU) (Table 4.38).

4.11.1.110 Using the density surface for the former Hornsea Zone plus 10 km buffer and the SCANS III density data beyond that, the corresponding number of animals predicted to be affected is 35 whales which represents 0.15% of the minke whale reference population (Celtic and Greater North Seas MU) (Table 4.38).

4.11.1.111 The magnitude of the potential impact from the concurrent installation of monopiles is considered low.

Sensitivity

4.11.1.112 As described in paragraph 4.11.1.100, minke whales are deemed to have a medium sensitivity to disturbance.

Significance of effect

4.11.1.113 Overall, the sensitivity of minke whales to disturbance from concurrent piling of monopiles is considered to be medium and the magnitude is deemed to be low. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

Table 4.38: Number of minke whales experiencing behavioural disturbance during the concurrent installation of 2 monopiles (Hornsea Three NE and Hornsea Three NW).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Whales Impacted	% Population	# Whales Impacted	% Population
SCANS III				
5,000	51	0.22%	49	0.21%
3,500	46	0.19%	43	0.18%
2,000	37	0.16%	34	0.15%
Modelled density surface within the former Hornsea Zone + 10 km buffer and the SCANS III density beyond that				
5,000	35	0.15%	33	0.14%

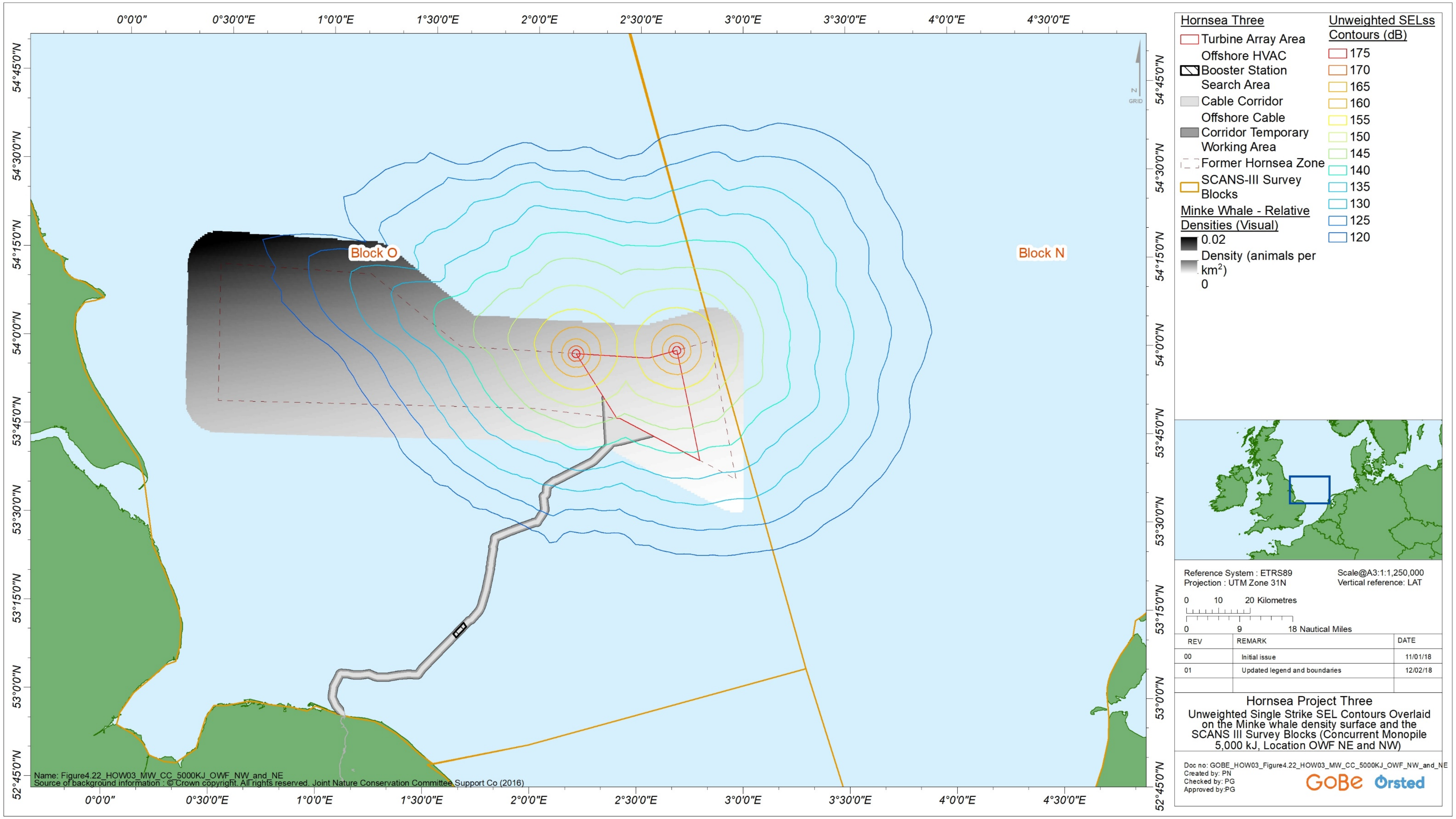

Figure 4.22: Unweighted single strike SEL contours overlaid on the minke whale density surface and the SCANS III survey blocks (Concurrent monopile 5,000 kJ, Location Hornsea Three NE & Hornsea Three NW).

Disturbance – White-beaked dolphin

Single vessel – monopile

Magnitude

4.11.1.114 Figure 4.23 and Figure 4.24 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the white-beaked dolphin density surface as a result of a single operation installing a monopile using 5,000 kJ hammer energy at Locations Hornsea Three NE and HVAC S.

4.11.1.115 Using the SCANS III density data, the corresponding number of animals predicted to be affected under this scenario are 4.0 dolphins for location Hornsea Three NE and 2.2 dolphins for location HVAC S. These represent 0.03% and 0.01% of the white-beaked dolphin reference population (Celtic and Greater North Seas MU) respectively (Table 4.39).

Table 4.39: Number of white-beaked dolphins experiencing behavioural disturbance during the installation of a monopile using SCANS III density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Dolphins Impacted	% Population	# Dolphins Impacted	% Population
Hornsea Three NE				
5,000 (maximum design scenario maximum hammer energy)	4.0 (0.0 – 16.3)	0.03% (0.00 – 0.10)	3.8 (0.0 – 15.6)	0.02% (0.00 – 0.10)
3,500 (most likely maximum hammer energy)	3.6 (0.0 – 14.6)	0.02% (0.00 – 0.09)	3.4 (0.0 – 13.9)	0.02% (0.00 – 0.09)
2,000 Average hammer energy	2.9 (0.0 – 11.9)	0.02% (0.00 – 0.07)	2.8 (0.0 – 11.3)	0.02% (0.00 – 0.07)
HVAC S				
5,000 (maximum design scenario maximum hammer energy)	2.2 (0.0 – 8.8)	0.01% (0.00 – 0.06)	2.0 (0.0 – 8.3)	0.01% (0.00 – 0.05)
3,500 (most likely maximum hammer energy)	1.9 (0.0 – 7.7)	0.01% (0.00 – 0.05)	1.8 (0.0 – 7.2)	0.01% (0.00 – 0.05)
2,000 Average hammer energy	1.5 (0.0 – 6.0)	0.01% (0.00 – 0.04)	1.4 (0.0 – 5.5)	0.01% (0.00 – 0.03)

4.11.1.116 Using the density surface for the former Hornsea Zone plus 10 km buffer and the SCANS III density data beyond that, the corresponding number of animals predicted to be affected is 5.4 dolphins for location Hornsea Three NE. This represents 0.03% of the white-beaked dolphin reference population (Celtic and Greater North Seas MU) (Table 4.40).

Table 4.40: Number of white-beaked dolphins experiencing behavioural disturbance during the installation of a monopile at Hornsea Three NE using the modelled density surface within the former Hornsea Zone plus 10 km buffer and the SCANS III density.

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Dolphins Impacted	% Population	# Dolphins Impacted	% Population
5,000	5.4	0.03%	5.0	0.03%
3,500	4.8	0.03%	4.5	0.03%
2,000	3.9	0.02%	3.6	0.02%

4.11.1.117 Based on the overall maximum average hammer energy, which for monopiles is 2,000 kJ, the number of white-beaked dolphins affected reduces to 2.9 and 1.5 for Hornsea Three NE and HVAC S respectively using the SCANS III density data. This represents 0.02% and 0.01% of the white-beaked dolphin reference population (Table 4.39).

4.11.1.118 Based on the overall maximum average hammer energy of 2,000 kJ, the number of white-beaked dolphins affected reduces to 3.9 for Hornsea Three NE using the former Hornsea Zone plus 10 km buffer density surface and the SCANS III density data beyond that. This represents 0.02% of the white-beaked dolphin reference population (Table 4.40).

4.11.1.119 Note, the impact contours for the HVAC S location did not overlap with the former Hornsea Zone plus 10 km buffer density surface and so only the above SCANS III estimate is available for this location.

4.11.1.120 The magnitude of the potential impact from single operation installation of a monopile is considered **negligible**.

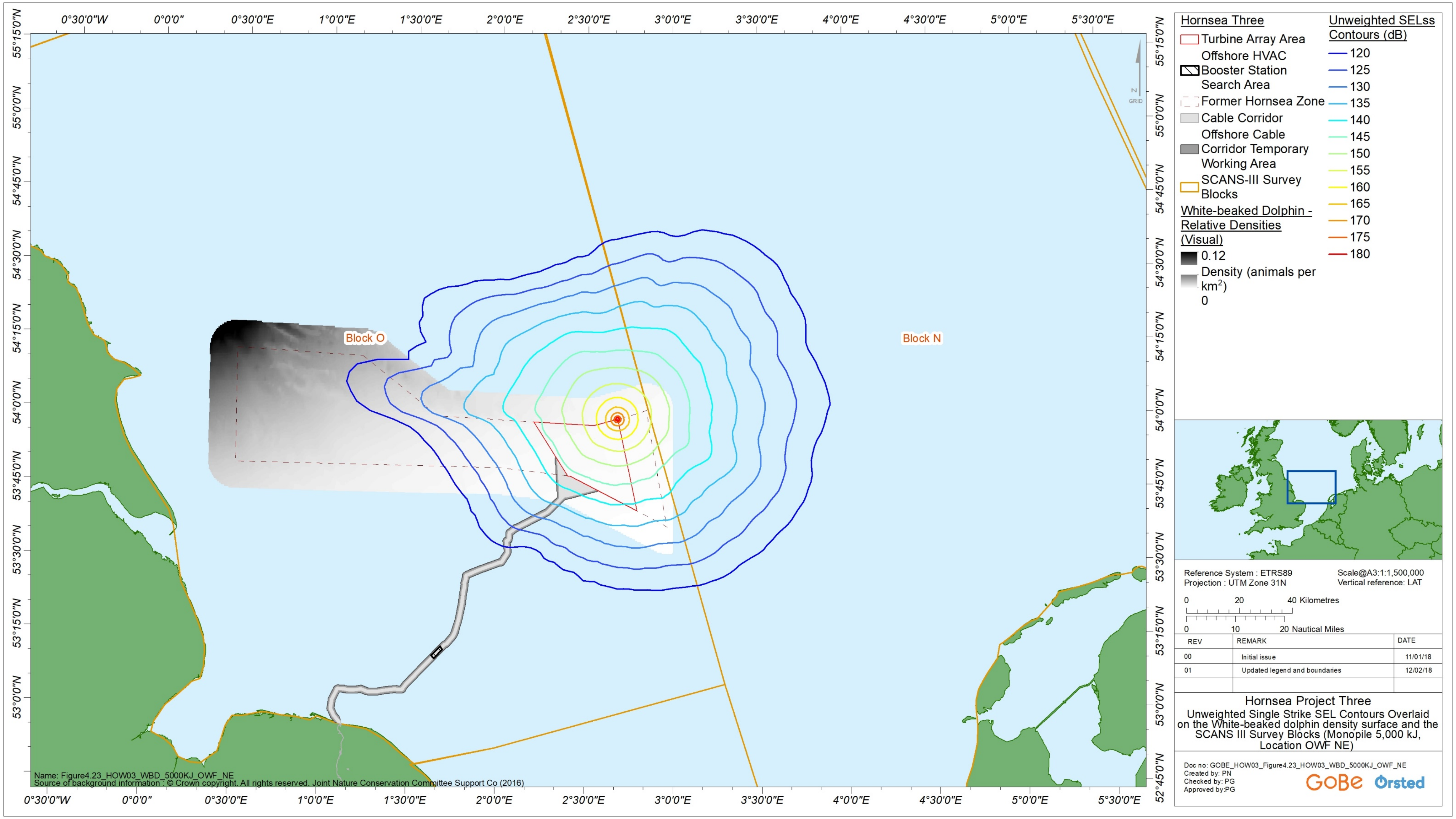

Figure 4.23: Unweighted single strike SEL contours overlaid on the white-beaked dolphin density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location Hornsea Three NE).

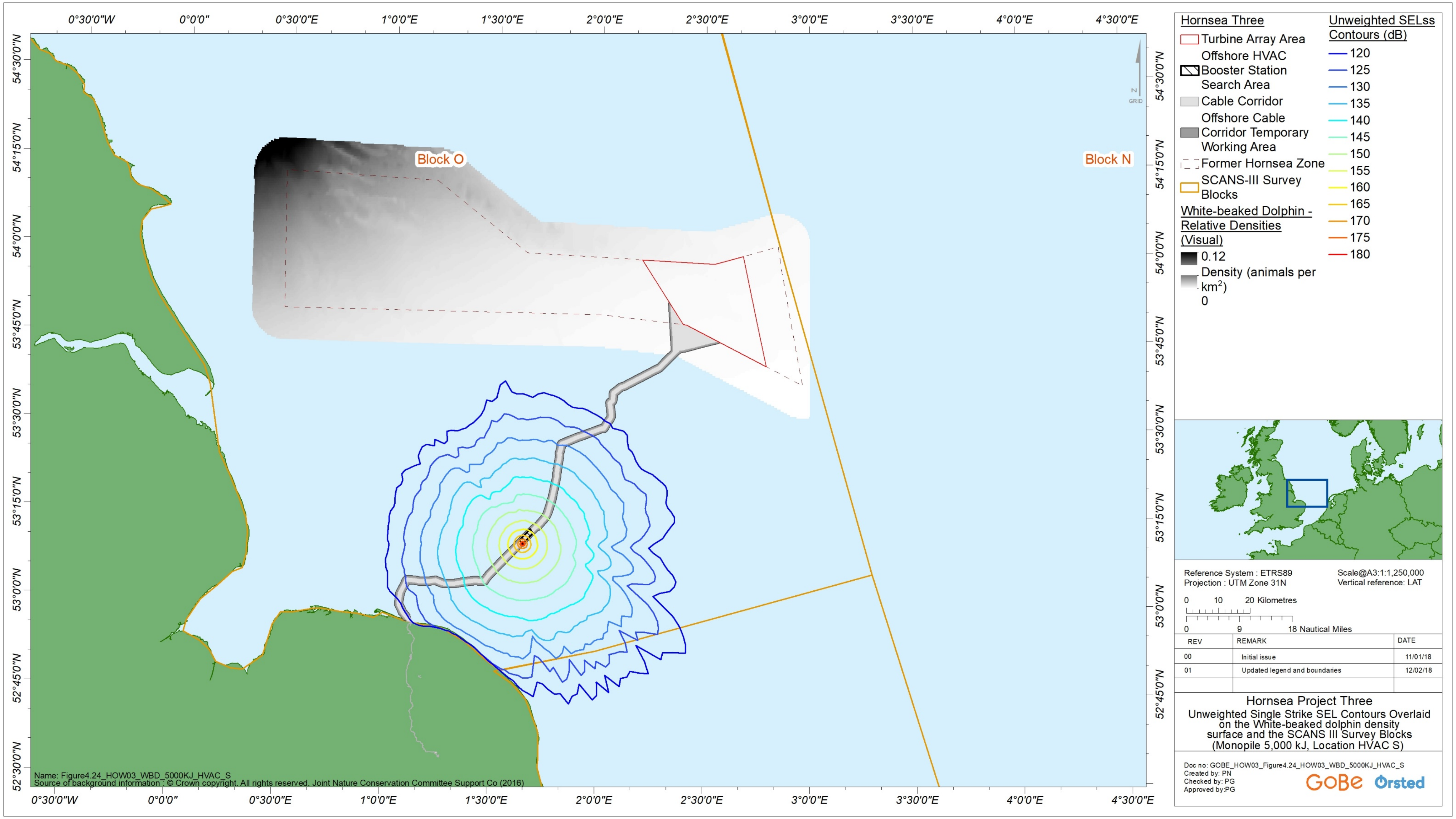

Figure 4.24: Unweighted single strike SEL contours overlaid on the white-beaked dolphin density surface and the SCANS III survey blocks (Monopile 5,000 kJ, Location HVAC S).

Sensitivity

4.11.1.121 There is limited information on the effects of disturbance on white-beaked dolphins specifically. However, there is evidence for bottlenose dolphins which can be used as a proxy since both species are categorised as mid-frequency cetaceans.

4.11.1.122 Bottlenose dolphins have been shown to be displaced from an area as a result of the noise produced by offshore construction activities. In a recent study in the Moray Firth, small effects of pile driving on dolphin presence have been observed however, dolphins were not excluded from the vicinity of the piling activities (Graham *et al*., 2017b). The pile driving resulted in a slight reduction of the presence, detection positive hours and the encounter duration for dolphins within the immediate area. Encounter rates decreased within the immediate area and increased outside of the immediate area on days of piling activity.

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

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

Significance of effect

4.11.1.125 Overall, the sensitivity of the receptor is considered to be medium and the magnitude of the potential impact from single operation installation of a monopiles is deemed to be negligible. Therefore, the overall effect will, be of **negligible** adverse significance, which is not significant in EIA terms.

Single vessel - pin pile

Magnitude

4.11.1.126 Figure 4.25 and Figure 4.26 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the white-beaked dolphin density surface as a result of a single operation installing a pin pile using the maximum design scenario maximum hammer energy of 2,500 kJ at Locations Hornsea Three NE and HVAC S.

4.11.1.127 Using the SCANS III density data, the corresponding number of animals predicted to be affected under this scenario are 3.2 dolphins for location Hornsea Three NE and 1.6 dolphins for location HVAC S. These represent 0.02% and 0.01% of the white-beaked dolphin reference population (Celtic and Greater North Seas MU) respectively (Table 4.41).

4.11.1.128 Under the overall maximum average hammer energy (which for pin piles is 1,250 kJ) the number of impacted white-beaked dolphins reduces to 2.4 and 1.1 for Hornsea Three NE and HVAC S respectively using the SCANS III density estimate. This represents 0.01% and 0.01% of the white-beaked dolphin reference population (Table 4.41).

4.11.1.129 Using the former Hornsea Zone plus 10 km buffer density surface combined with the SCANS III density data, the corresponding number of animals predicted to be affected under this scenario are 4.3 dolphins for location Hornsea Three NE. This represents 0.03 % and 0.01% of the white-beaked dolphin reference population (Celtic and Greater North Seas MU) respectively (Table 4.42).

Table 4.41: Number of white-beaked dolphins experiencing behavioural disturbance during the installation of a pin pile using SCANS III density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Dolphins Impacted	% Population	# Dolphins Impacted	% Population
Hornsea Three NE				
2,500 (maximum design scenario maximum hammer energy)	3.2 (0.0 – 13.0)	0.02% (0.00 – 0.08)	3.0 (0.0 – 12.4)	0.02% (0.00 – 0.08)
1,750 (most likely maximum hammer energy)	2.8 (0.0 – 11.3)	0.02% (0.00 – 0.07)	2.6 (0.0 – 10.6)	0.02% (0.00 – 0.07)
1,250 (average hammer energy)	2.4 (0.0 – 9.6)	0.01% (0.00 – 0.06)	2.2 (0.0 – 9.0)	0.01% (0.00 – 0.05)
HVAC S				
2,500 (maximum design scenario maximum hammer energy)	1.6 (0.0 – 6.7)	0.01% (0.00 – 0.04)	1.5 (0.0 – 6.2)	0.01% (0.00 – 0.04)
1,750 (most likely maximum hammer energy)	1.4 (0.0 – 5.6)	0.01% (0.00 – 0.04)	1.3 (0.0 – 5.1)	0.01% (0.00 – 0.03)
1,250 (average hammer energy)	1.1 (0.0 – 4.6)	0.01% (0.00 – 0.03)	1.0 (0.0 – 4.2)	0.01% (0.00 – 0.03)

Table 4.42: Number of white-beaked dolphins experiencing behavioural disturbance during the installation of a pin pile using modelled density surface within the former Hornsea Zone plus 10 km buffer and the SCANS III density data.

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Dolphins Impacted	% Population	# Dolphins Impacted	% Population
Hornsea Three NE				
2,500 (maximum design scenario maximum hammer energy)	4.3	0.03%	3.9	0.02%
1,750 (most likely maximum hammer energy)	3.6	0.02%	3.4	0.02%
1,250 (average hammer energy)	3.1	0.02%	2.8	0.02%

4.11.1.130 Under the overall maximum average hammer energy (which for pin piles is 1,250 kJ) the number of impacted white-beaked dolphins reduces to 2.4 and 1.1 for Hornsea Three NE and HVAC S respectively using the SCANS III density estimate, and 3.1 for Hornsea Three NE using the former Hornsea Zone plus 10 km buffer density surface. These represent 0.01%, 0.01% and 0.02% of the white-beaked dolphin reference population respectively (Table 4.41).

4.11.1.131 The magnitude of the potential impact from single vessel operation installation of a pin pile is considered negligible.

Sensitivity

4.11.1.132 As described in paragraph 4.11.1.121, white-beaked dolphins are deemed to have a medium sensitivity to disturbance.

Significance of effect

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

Concurrent piling

Magnitude

4.11.1.134 Figure 4.27 displays unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the white-beaked dolphin density surface as a result of concurrent operations installing monopiles (5,000 kJ) simultaneously at locations Hornsea Three NE and Hornsea Three NW.

4.11.1.135 Using the SCANS III density data, the corresponding number of animals predicted to be affected is 6.7 dolphins, which represents 0.04% of the white-beaked dolphin reference population (Celtic and Greater North Seas MU) (Table 4.43).

Table 4.43: Number of white-beaked dolphins experiencing behavioural disturbance during the concurrent installation of 2 monopiles (Hornsea Three NE and Hornsea Three NW).

Hammer Energy (kJ)	120 – 180 dB		130 – 180 dB	
	# Dolphins Impacted	% Population	# Dolphins Impacted	% Population
SCANS III				
5,000	6.7	0.04%	6.4	0.04%
Modelled density surface within the former Hornsea Zone + 10 km buffer and the SCANS III density				
5,000	12.4	0.08%	11.5	0.07%
3,500	11.1	0.07%	10.3	0.06%
2,000	9.0	0.06%	8.3	0.05%

4.11.1.136 Using the former Hornsea Zone plus 10 km buffer density surface and the SCANS III density data, the corresponding number of animals predicted to be affected is 12.4 dolphins which represents 0.08% of the white-beaked dolphin reference population (Celtic and Greater North Seas MU) (Table 4.43).

4.11.1.137 The magnitude of the potential impact from a two vessel operation installing monopiles is considered negligible.

Sensitivity

4.11.1.138 As described in paragraph 4.11.1.121, white-beaked dolphins are deemed to have a medium sensitivity to disturbance.

Significance of effect

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

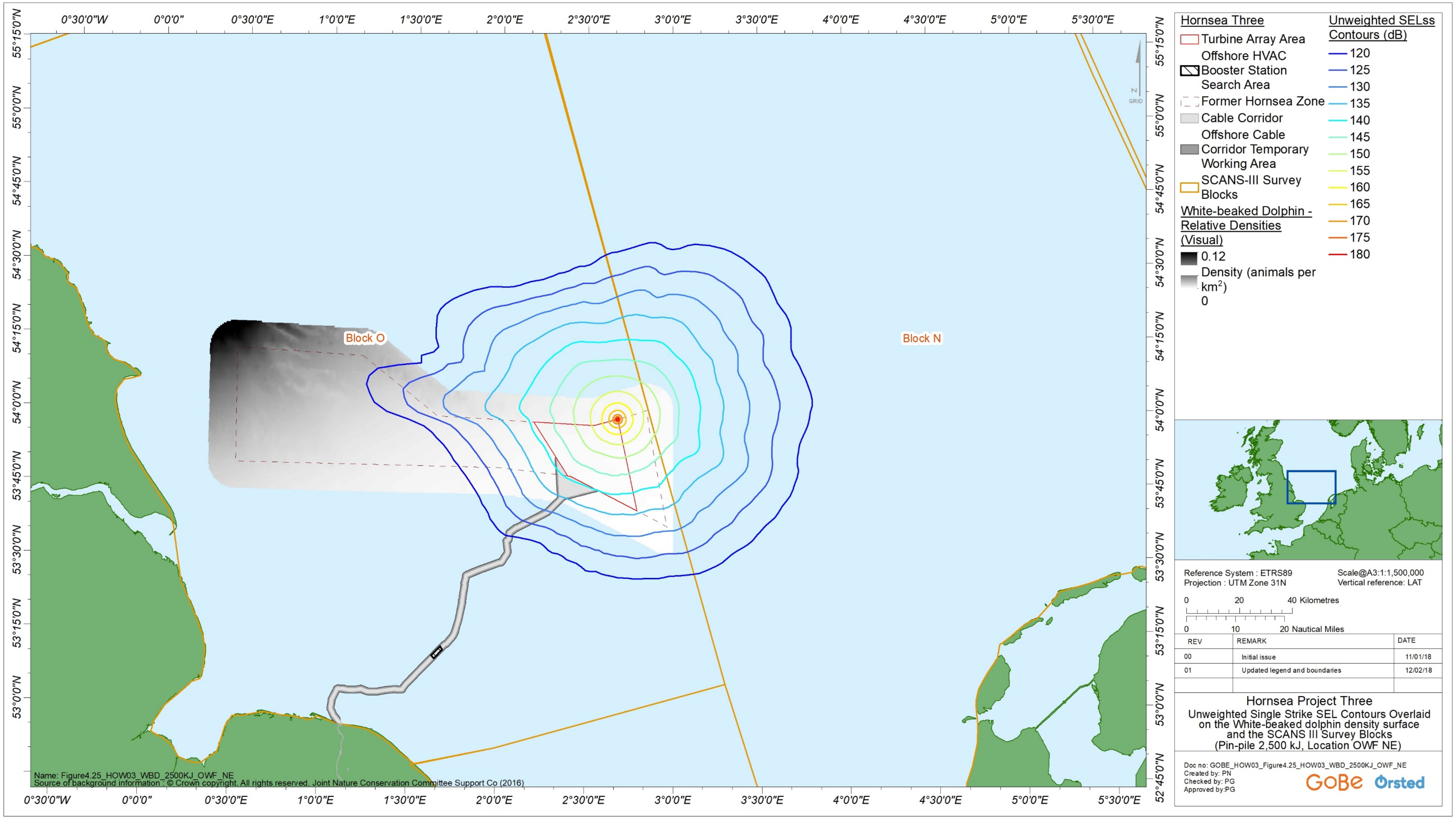

Figure 4.25: Unweighted single strike SEL contours overlaid on the white-beaked dolphin density surface and the SCANS III survey blocks (Pin pile 2,500 kJ, Location Hornsea Three NE).

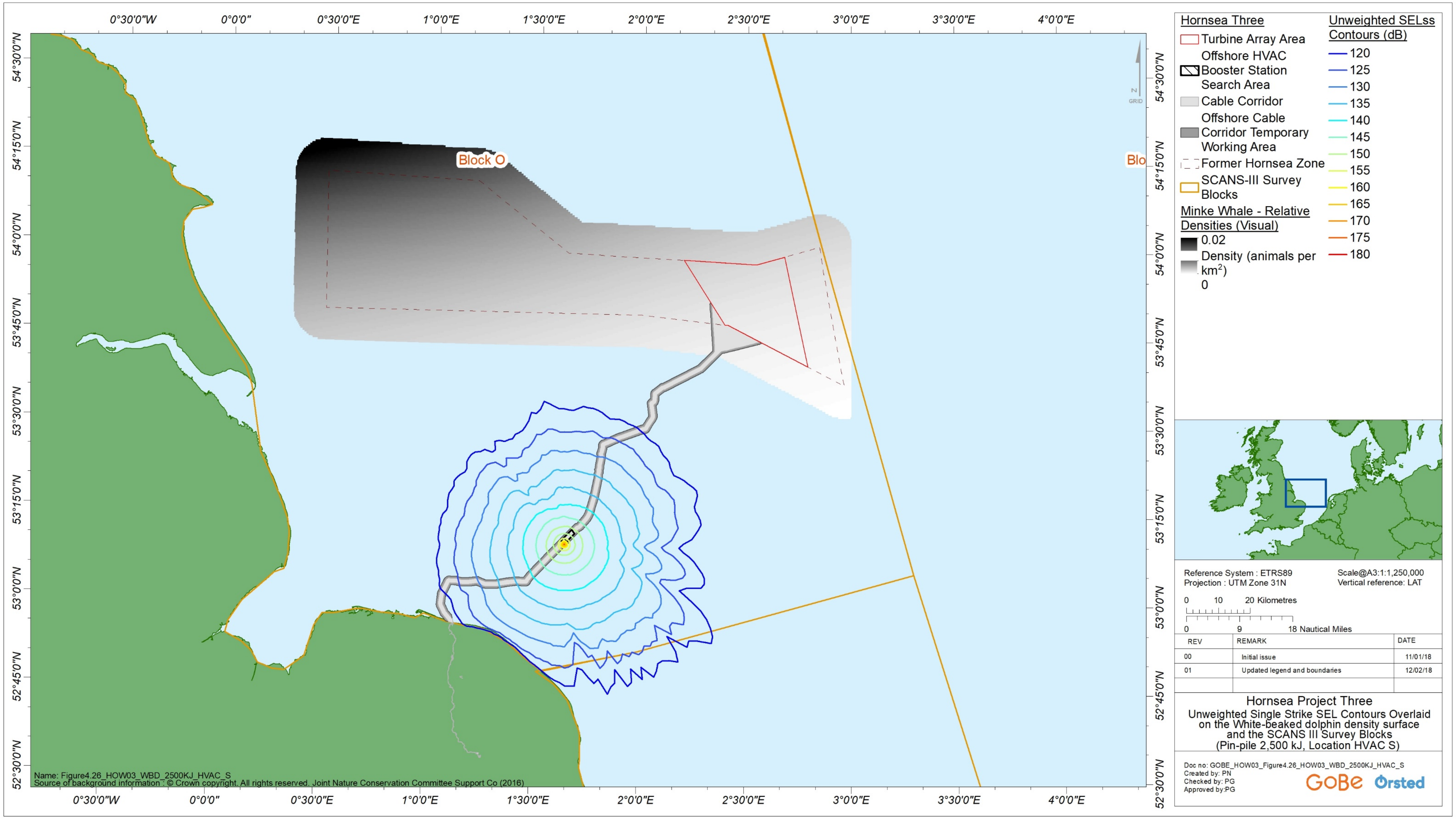

Figure 4.26: Unweighted single strike SEL contours overlaid on the white-beaked dolphin density surface and the SCANS III survey blocks (Pin pile 2,500 kJ, Location HVAC S).

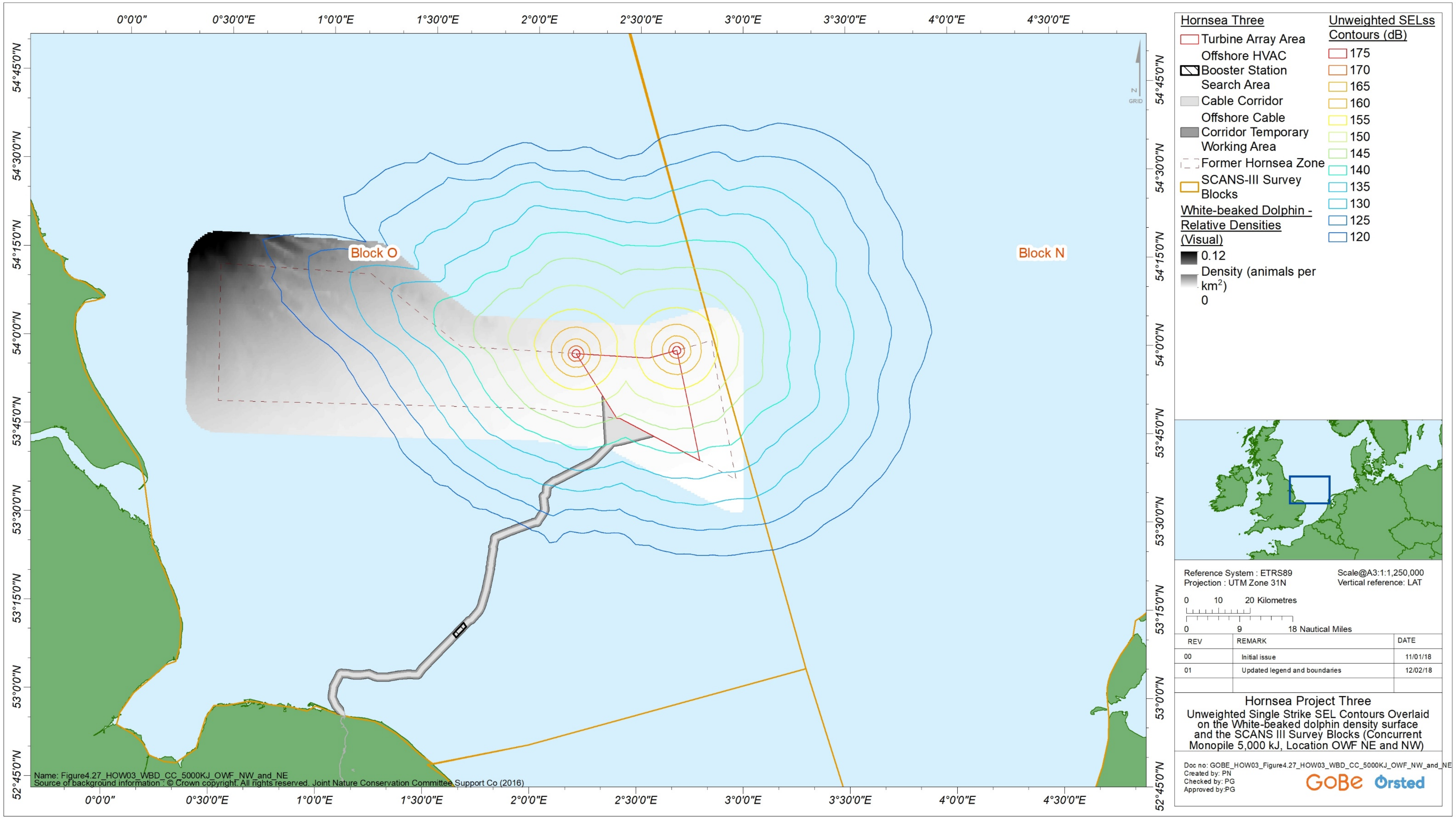

Figure 4.27: Unweighted single strike SEL contours overlaid on the white-beaked dolphin density surface and the SCANS III survey blocks (Concurrent monopile 5,000 kJ, Location Hornsea Three NE & Hornsea Three NW).

Disturbance: Harbour seal

4.11.1.140 A study of tagged harbour seals in the Wash has demonstrated they were displaced from the vicinity during pile-driving activities. Russell *et al*. (2016) showed that seal abundance was reduced during pile-driving compared to during breaks in piling. The derivation of a dose response curve from these data (see Russell and Hastie, 2018) suggests that significant displacement occurred above received single pulse SEL levels of approximately 150 dB re 1 μPa^2 s. The duration of the displacement was only short-term as seals returned to non-piling distributions within two hours after the end of a pile-driving event.

Single vessel – monopile

Magnitude

4.11.1.141 Figure 4.28 and Figure 4.29 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the harbour seal at-sea density surface as a result of a single operation installing a monopile using 5,000 kJ hammer energy at Locations Hornsea Three NW and HVAC S.

4.11.1.142 The corresponding number of animals predicted to be affected under this scenario are 4.5 seals for location Hornsea Three NW and 3.8 seals for location HVAC S. These represent up to a maximum of 0.07% of the harbour seal reference population (South-East England MU) (Table 4.44). Due to this very low level of predicted impact from the maximum design scenario, the assessment was not repeated for the most likely maximum or average hammer energies.

4.11.1.143 In general, there is little overlap between the impact footprint of the OWF pile driving locations and the main areas where harbour seals are found (Figure 4.28) meaning that the potential for impact is low for wind turbine foundation installation. This is reflected in the very low numbers presented above and in Table 4.44.

Table 4.44: Number of harbour seals experiencing behavioural disturbance during the installation of a monopile using at-sea usage density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB	
	# Seals Impacted	% Population
Hornsea Three NW		
5,000	4.5 (0.8 – 8.2)	0.07% (0.01 – 0.12)
HVAC S		
5,000	3.8 (1.2 – 6.3)	0.06% (0.02 – 0.09)

4.11.1.144 There is a greater degree of overlap with areas of seal usage of the impact footprints from pile driving at the HVAC location (Figure 4.29), although the numbers of animals expected to be disturbed is still very low. Noise levels in the coastal areas with higher seal density are below the levels expected to result in behavioural reactions based on the Russell *et al*. (2016) derived dose response curve and therefore no barrier effect on seals travelling to or from haul outs is expected.

4.11.1.145 The magnitude of the potential impact from single-vessel operation installation of monopiles is considered negligible.

Sensitivity

4.11.1.146 Unlike harbour porpoise, harbour seals store energy in a thick layer of blubber, which means that they are more tolerant of periods of fasting when hauled out and resting between foraging trips, and when hauled out during the breeding and moulting periods. Therefore, they are unlikely to be particularly sensitive to short-term displacement from foraging grounds during periods of active piling. Juvenile harbour seals may be more sensitive to displacement from foraging grounds due to a smaller body size and higher energetic needs. Therefore, harbour seals have been assessed as having medium sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

Significance of effect

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

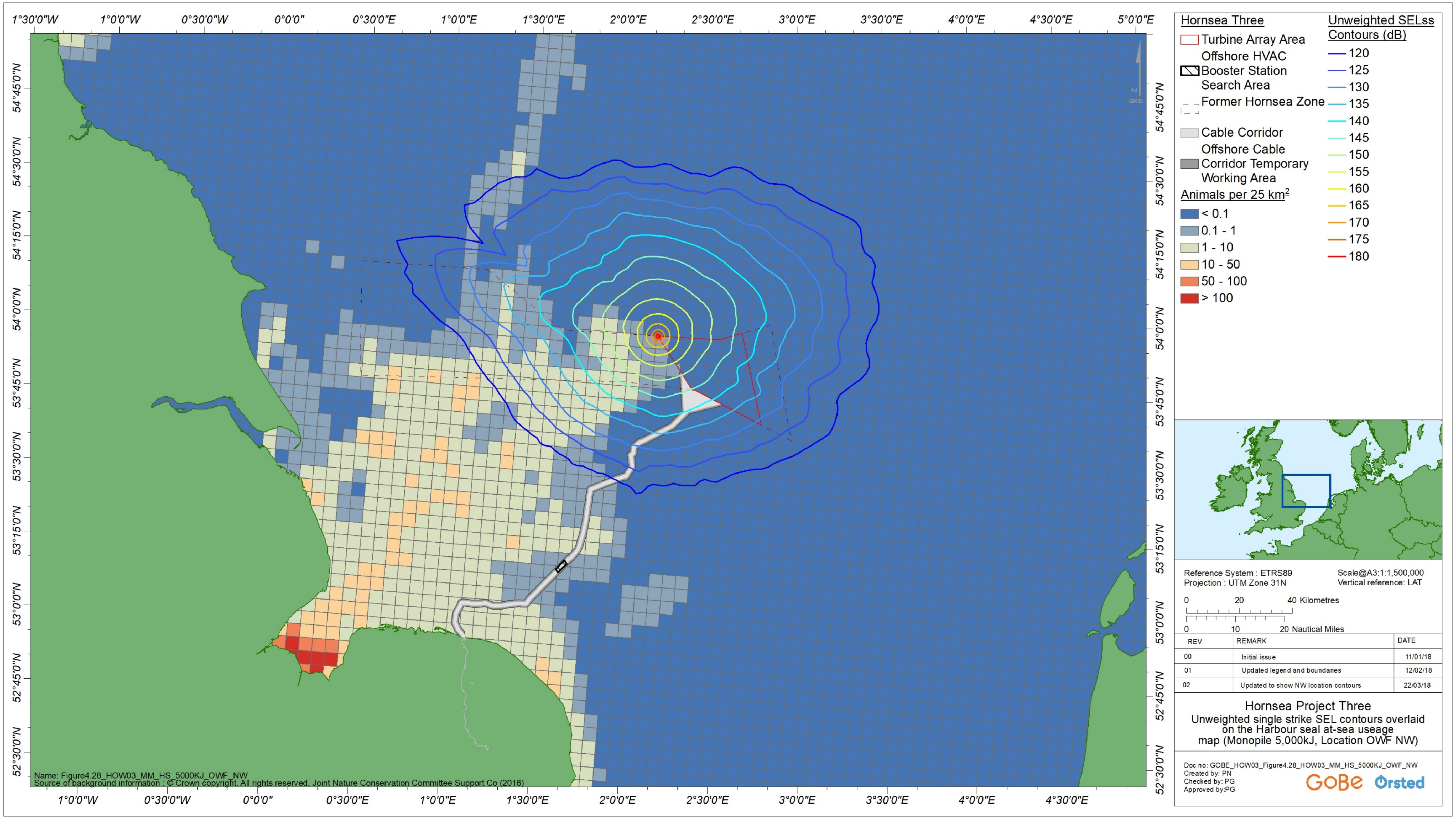

Figure 4.28: Unweighted single strike SEL contours overlaid on the harbour seal at-sea usage map (Monopile 5,000 kJ, Location Hornsea Three NW).

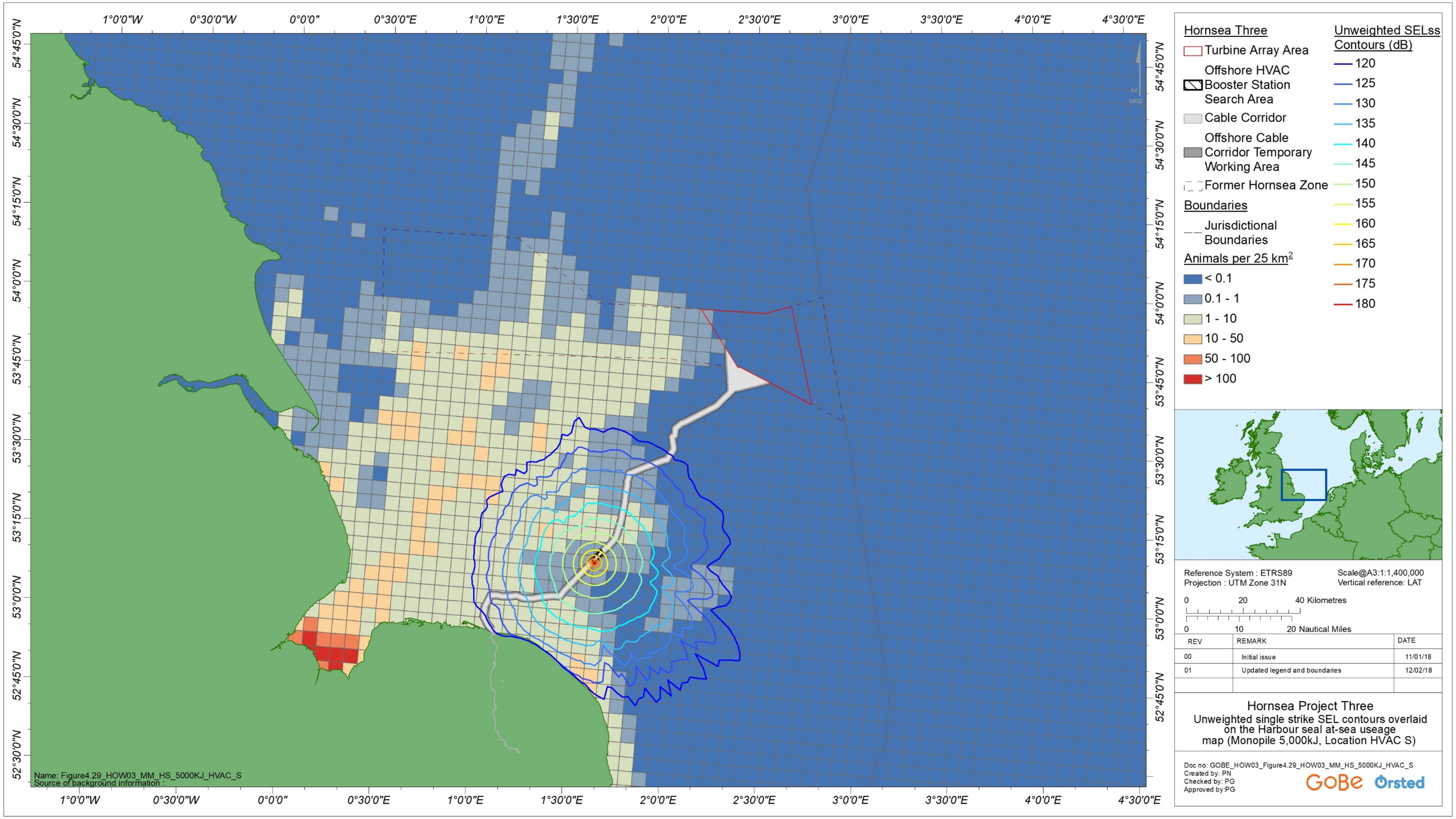

Figure 4.29: Unweighted single strike SEL contours overlaid on the harbour seal at-sea usage map (Monopile 5,000 kJ, Location HVAC S).

Single vessel - pin pile

Magnitude

4.11.1.148 Figure 4.30 and Figure 4.31 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the harbour seal at-sea density surface as a result of a single operation installing a pin pile using 2,500 kJ hammer energy at Locations Hornsea Three NW and HVAC S.

4.11.1.149 The corresponding number of animals predicted to be affected under each scenario are 2.2 seals for location Hornsea Three NW and 1.63 seal for location HVAC S. This represents a maximum of 0.03% of the harbour seal reference population (South-East England MU) (Table 4.45).

Table 4.45: Number of harbour seals experiencing behavioural disturbance during the installation of a pin pile using at-sea usage density data.

Hammer Energy (kJ)	120 – 180 dB	
	# Seals Impacted	% Population
Hornsea Three NW		
2,500	2.2 (0.42 – 3.90)	0.03% (0.01 – 0.06)
HVAC S		
2,500	1.6 (0.47 – 2.79)	0.02% (0.01 – 0.04)

4.11.1.150 As above for monopiles, there is very little overlap between the impact footprint of the OWF pile driving locations and the areas where harbour seals are found (Figure 4.30) meaning that the potential for impact is very low for pile driving from wind turbine foundation installation. This is reflected in the very low numbers presented above and in Table 4.44. Due to this very low level of predicted impact from the maximum design scenario, the assessment was not repeated for the most likely maximum or average hammer energies.

4.11.1.151 As above for monopiles, there is a greater degree of overlap with areas of seal usage of the impact footprints from pile driving at the HVAC location (Figure 4.31), although the numbers of animals expected to be disturbed is very low. Noise levels in the coastal areas with higher seal density are below the levels expected to result in behavioural reactions based on the Russell *et al*. (2016) derived dose response curve and therefore no barrier effect on seals travelling to or from haul outs is expected.

4.11.1.152 The magnitude of the potential disturbance impact from single operation installation of a pin pile is considered negligible.

Sensitivity

4.11.1.153 As described in paragraph 4.11.1.146, harbour seals are deemed to have a medium sensitivity to disturbance.

Significance of effect

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

Concurrent piling

Magnitude

4.11.1.155 Figure 4.32 displays unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the harbour seal at-sea density surface as a result of concurrent operations installing monopiles (5,000 kJ) simultaneously at locations Hornsea Three NW and HVAC S.

The corresponding number of animals predicted to be affected is 8.3 seals which represents 0.12% (Table 4.46) of the harbour seal reference population (South-East England MU). The magnitude of the impact is therefore considered to be low. Due to this very low level of predicted impact from the maximum design scenario, the assessment was not repeated for the most likely maximum or average hammer energies.

Sensitivity

4.11.1.156 As described in paragraph 4.11.1.146, harbour seal are deemed to have a medium sensitivity to disturbance.

Significance of effect

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

Table 4.46: Number of harbour seals experiencing behavioural disturbance during the concurrent installation of two monopiles (Hornsea Three NW and HVAC S) using at-sea usage density data.

Hammer Energy (kJ)	120 – 180 dB	
	# Seals Impacted	% Population
Hornsea Three NW + HVAC S concurrent		
5,000	8.3	0.12%

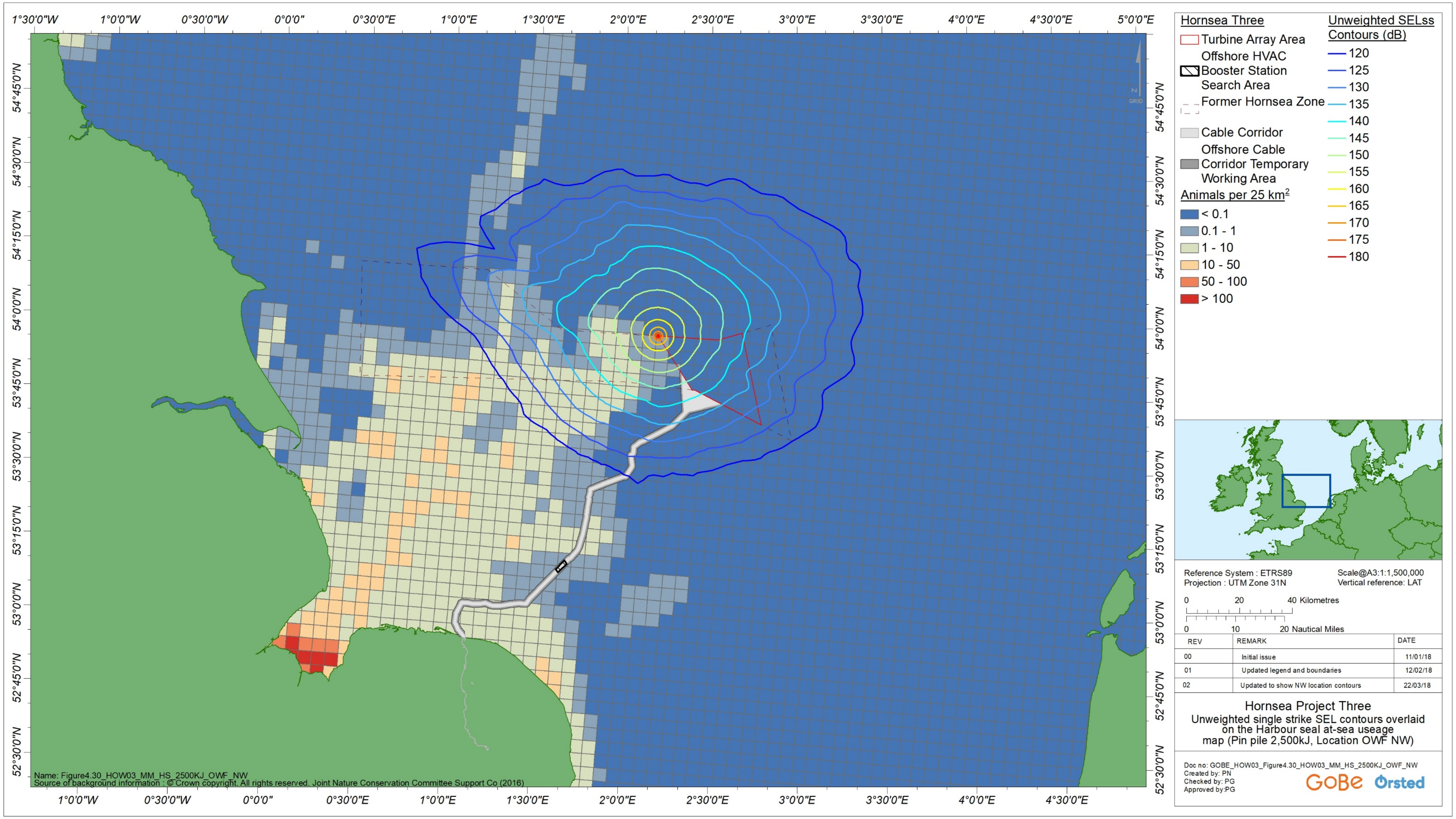

Figure 4.30: Unweighted single strike SEL contours overlaid on the harbour seal at-sea usage map (Pin pile 2,500 kJ, Location Hornsea Three NW).

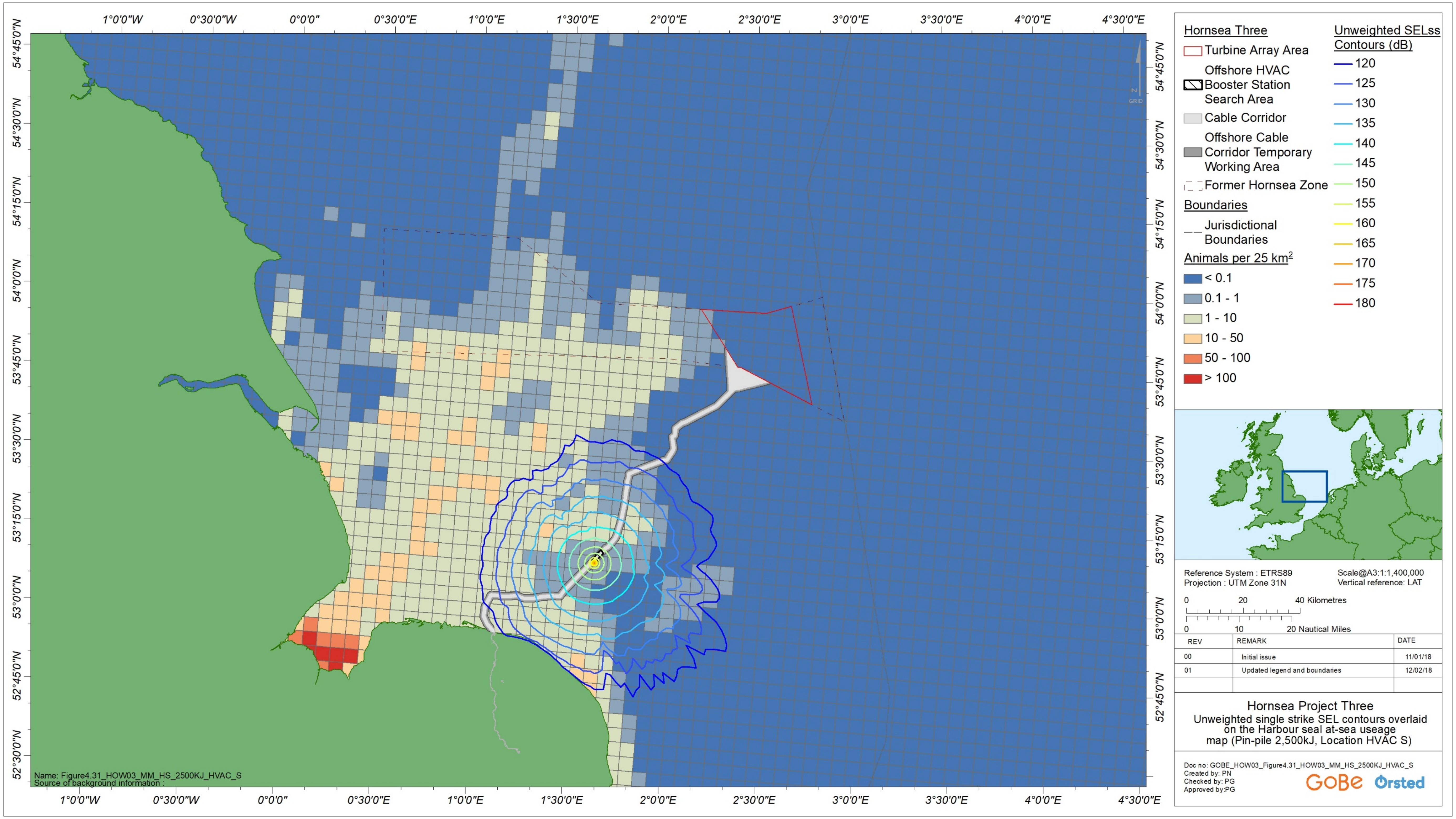

Figure 4.31: Unweighted single strike SEL contours overlaid on the harbour seal at-sea usage map (Pin pile 2,500 kJ, Location HVAC S).

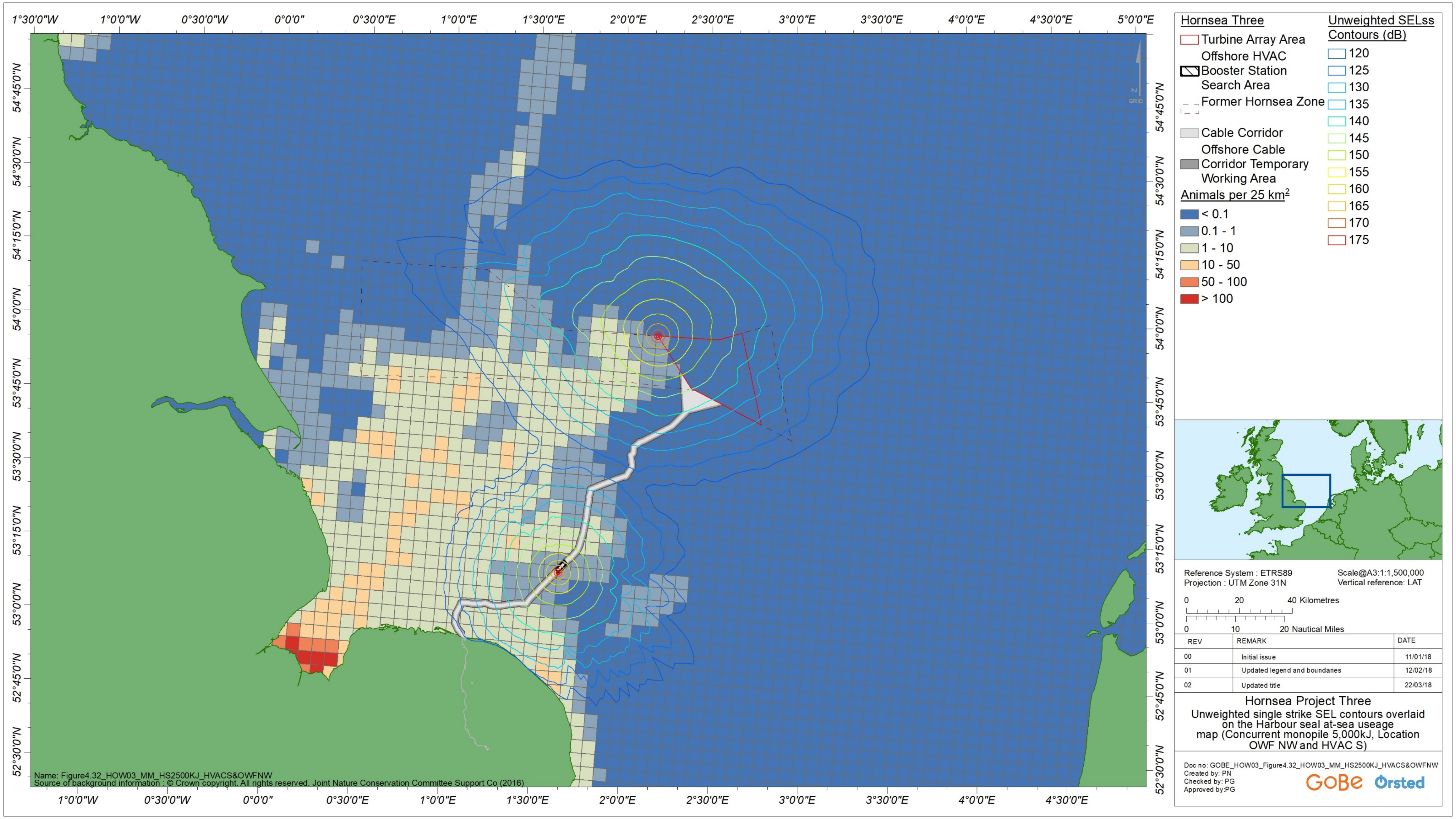

Figure 4.32: Unweighted single strike SEL contours overlaid on the harbour seal at-sea usage map (Concurrent monopile 5,000 kJ, Location Hornsea Three NW & HVAC S).

Disturbance: Grey seal

4.11.1.158 There are no data on the response of grey seals to piling noise. However, grey seals are generally considered to be more robust than harbour seals (based on their larger body size and larger capacity for fasting, their wide ranging and highly mobile nature and the large and increasing North Sea population) and therefore the application of the harbour seal dose response curve is considered precautionary. Therefore, it is expected that grey seals will not experience significant displacement at received single pulse SEL levels lower than 150 dB re 1 µPa^2 s. The duration of any displacement is also expected to be short-term in light of the finding that harbour seal distribution returned to normal within two hours after pile-driving (Russell *et al.,* 2016).

Single vessel – monopile

Magnitude

4.11.1.159 Figure 4.33 and Figure 4.34 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the grey seal at-sea density surface as a result of a single operation installing a monopile using 5,000 kJ hammer energy at Locations Hornsea Three NW and HVAC S.

4.11.1.160 The corresponding number of animals predicted to be affected under each scenario are 48.2 seals for location Hornsea Three NW and 4.7 seals for location HVAC S. These represent a maximum of 0.12% of the grey seal reference population (combined South-East England and North-East England MU) (Table 4.47).

Table 4.47: Number of grey seals experiencing behavioural disturbance during the installation of a monopile using at-sea usage density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB	
	# Seals Impacted	% Population
Hornsea Three NW		
5,000	48.2 (7.7 – 89.5)	0.12% (0.02 – 0.22)
HVAC S		
5,000	4.7 (0.5 – 9.0)	0.01% (0.00 – 0.02)

4.11.1.161 As above for harbour seals, there is very little overlap between the impact footprint of the OWF pile driving locations and the areas that grey seals use (Figure 4.33) meaning that the potential for impact is very low for pile driving from wind turbine foundation installation. This is reflected in the very low numbers presented above and in Table 4.44. Due to this very low level of predicted impact from the maximum design scenario, the assessment was not repeated for the most likely maximum or average hammer energies.

4.11.1.162 As above for harbour seals, there is a greater degree of overlap with areas of seal usage of the impact footprints from pile driving at the HVAC location (Figure 4.34), although the numbers of animals expected to be disturbed is very low. Noise levels in the coastal areas with higher seal density are below the levels expected to result in behavioural reactions based on the Russell *et al*. (2016) derived dose response curve and therefore no barrier effect on seals travelling to or from haul outs or breeding sites is expected.

4.11.1.163 The magnitude of the potential impact from single operation installation of a monopiles is considered low.

Sensitivity

4.11.1.164 Grey seals are capital breeders and store energy in a thick layer of blubber, which means that they are tolerant of periods of fasting when hauled out and resting between foraging trips, and when hauled out during the breeding and moulting periods. Grey seals are also highly adaptable to a changing environment and are capable of adjusting their metabolic rate and foraging tactics, to compensate for periods of changing energy demand and supply (e.g. Beck *et al.,* 2003, Sparling *et al.,* 2006). Grey seals are also very wide ranging and are capable of moving very large distances between different haul out and foraging regions (e.g. Russell *et al*., 2013). Therefore, they are unlikely to be sensitive to short-term displacement from foraging grounds during periods of active piling. As such, grey seals seal have been assessed as having low sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

Significance of effect

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

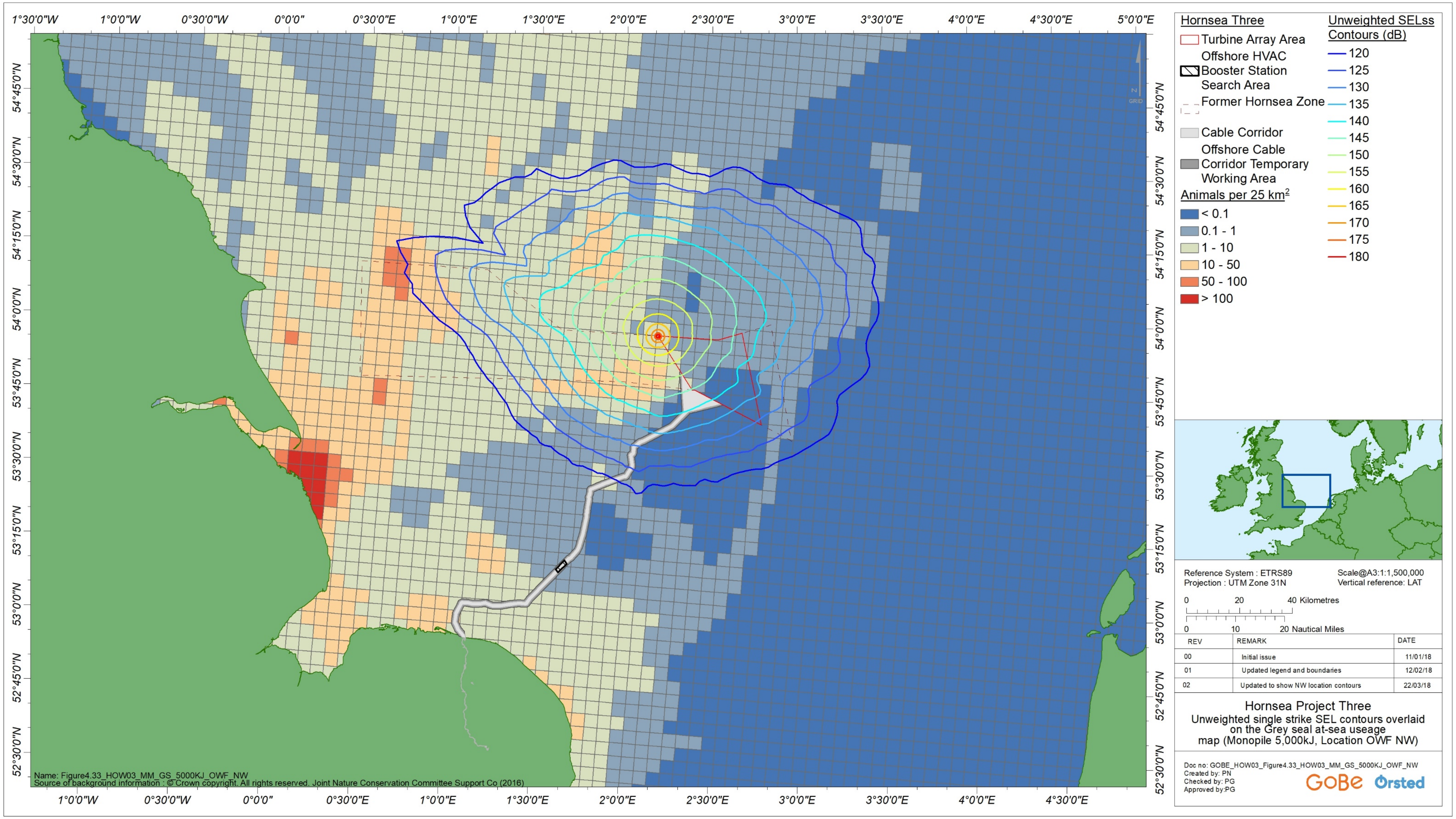

Figure 4.33: Unweighted single strike SEL contours overlaid on the grey seal at-sea usage map (Monopile 5,000 kJ, Location Hornsea Three NW).

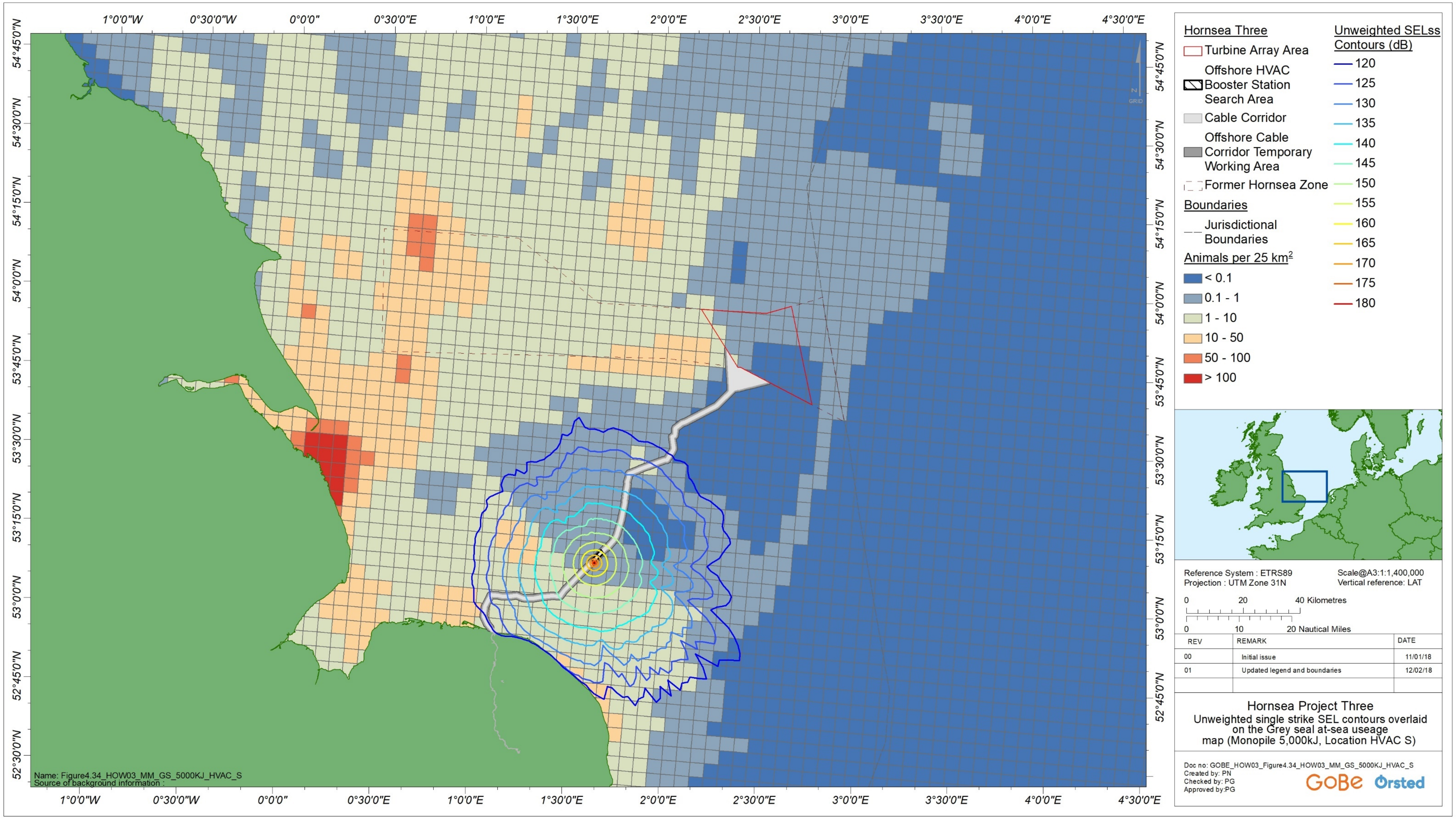

Figure 4.34: Unweighted single strike SEL contours overlaid on the grey seal at-sea usage map (Monopile 5,000 kJ, Location HVAC S).

Single vessel – Pin pile

Magnitude

4.11.1.166 Figure 4.35 and Figure 4.36 display unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the grey seal at-sea density surface as a result of a single operation installing a pin pile using 2,500 kJ hammer energy at Locations Hornsea Three NW and HVAC S.

4.11.1.167 The corresponding number of animals predicted to be affected under each scenario are 24.8 seals for location Hornsea Three NW and 2.7 seals for location HVAC S. These represent a maximum of 0.06% of the grey seal reference population (combined South-East England and North-East England MU) (Table 4.48). Due to this very low level of predicted impact from the maximum design scenario, the assessment was not repeated for the most likely maximum or average hammer energies.

4.11.1.168 The magnitude of the potential impact from single operation installation of a pin pile is considered negligible.

Table 4.48: Number of grey seals experiencing behavioural disturbance during the installation of a pin pile using at-sea usage density data (mean and lower and upper 95% CI).

Hammer Energy (kJ)	120 – 180 dB	
	# Seals Impacted	% Population
Hornsea Three NW		
2,500	24.8 (4.8 – 45.2)	0.06% (0.01 – 0.11)
HVAC S		
2,500	2.7 (0.3 – 5.1)	0.01% (0.00 – 0.01)

Sensitivity

4.11.1.169 As described in paragraph 4.11.1.164, grey seals are deemed to have a low sensitivity to disturbance.

Significance of effect

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

Concurrent piling

Magnitude

4.11.1.171 Figure 4.37 displays unweighted noise contours with SEL values decreasing in 5 dB steps from the source, overlain on the grey seal at-sea density surface as a result of concurrent operations installing monopiles (5,000 kJ) simultaneously at locations Hornsea Three NW and HVAC S.

4.11.1.172 The corresponding number of animals predicted to be affected is 53 seals, which represents 0.13% of the grey seal reference population (combined South-East England and North-East England MU) (Table 4.49). As such, the magnitude is deemed to be low. Due to this very low level of predicted impact from the maximum design scenario, the assessment was not repeated for the most likely maximum or average hammer energies.

Sensitivity

4.11.1.173 As described in paragraph 4.11.1.164, grey seals are deemed to have a low sensitivity to disturbance.

Significance of effect

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

Table 4.49: Number of grey seals experiencing behavioural disturbance during the concurrent installation of 2 monopiles (Hornsea Three NW and HVAC S) using at-sea usage density data.

Hammer Energy (kJ)	120 – 180 dB	
	# Seals Impacted	% Population
Hornsea Three NW + HVAC S concurrent		
5,000	53.0	0.13%

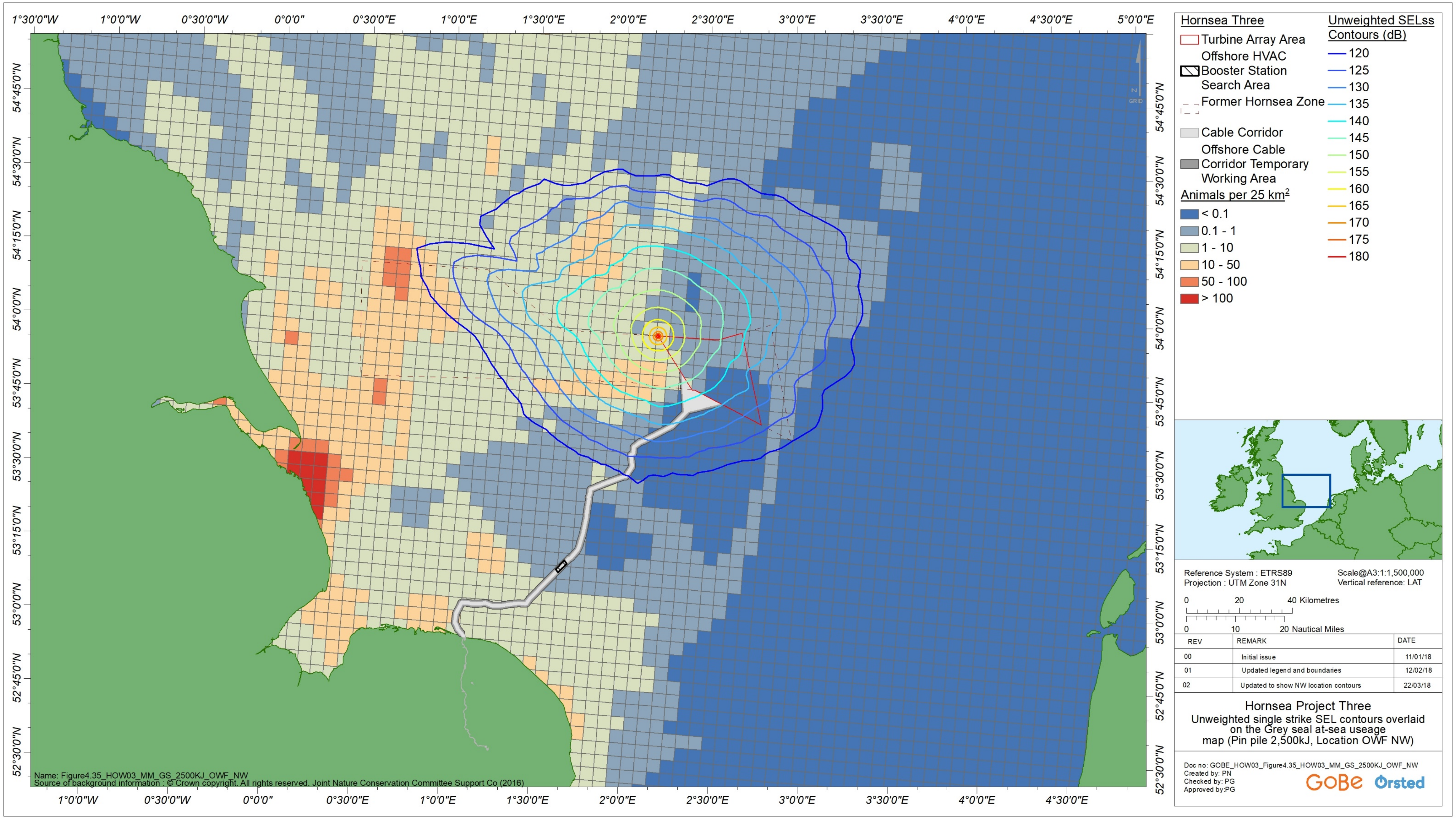

Figure 4.35: Unweighted single strike SEL contours overlaid on the grey seal at-sea usage map (Pin pile 2,500 kJ, Location Hornsea Three NW).

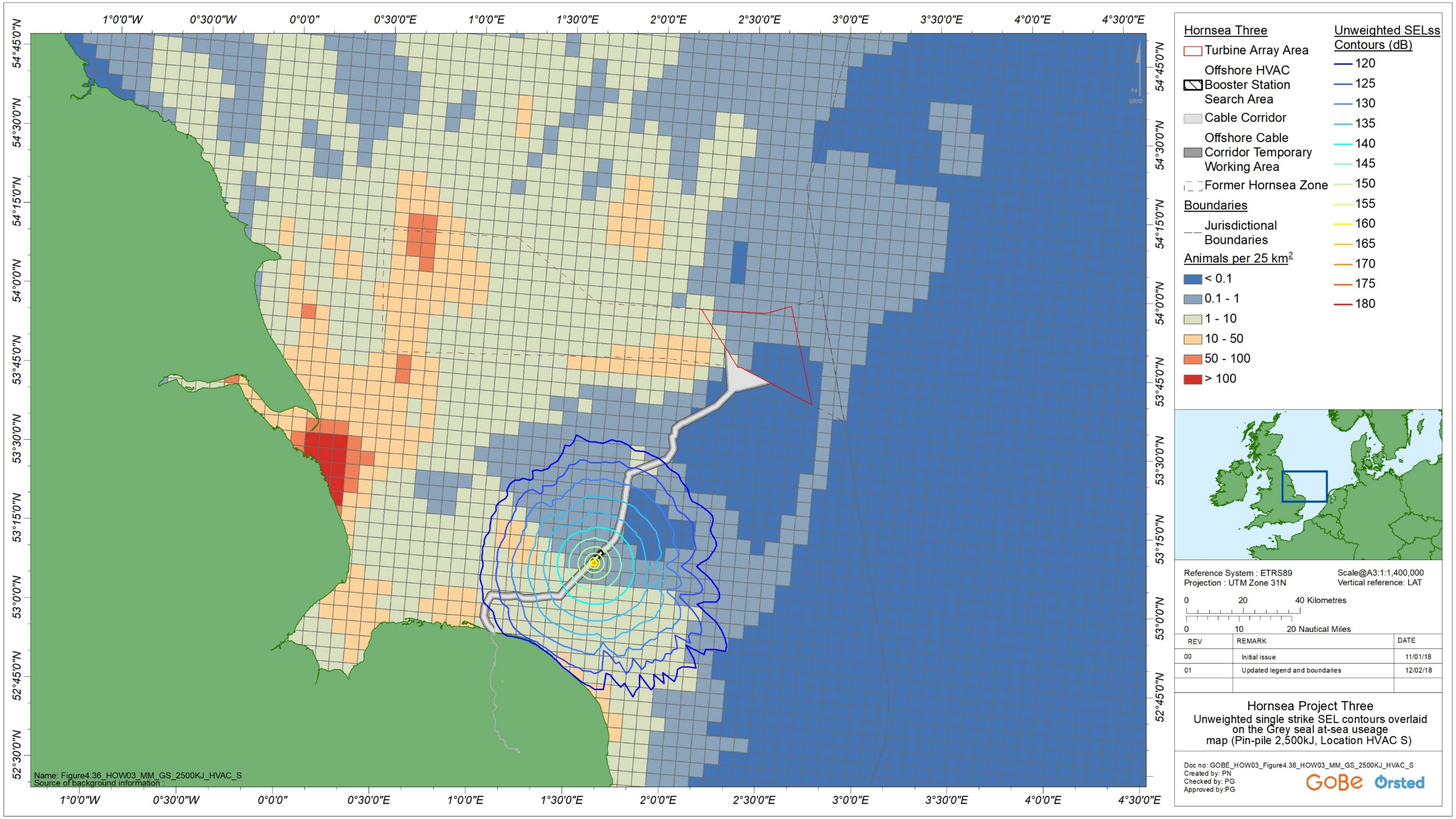

Figure 4.36: Unweighted single strike SEL contours overlaid on the grey seal at-sea usage map (Pin pile 2,500 kJ, Location HVAC S).

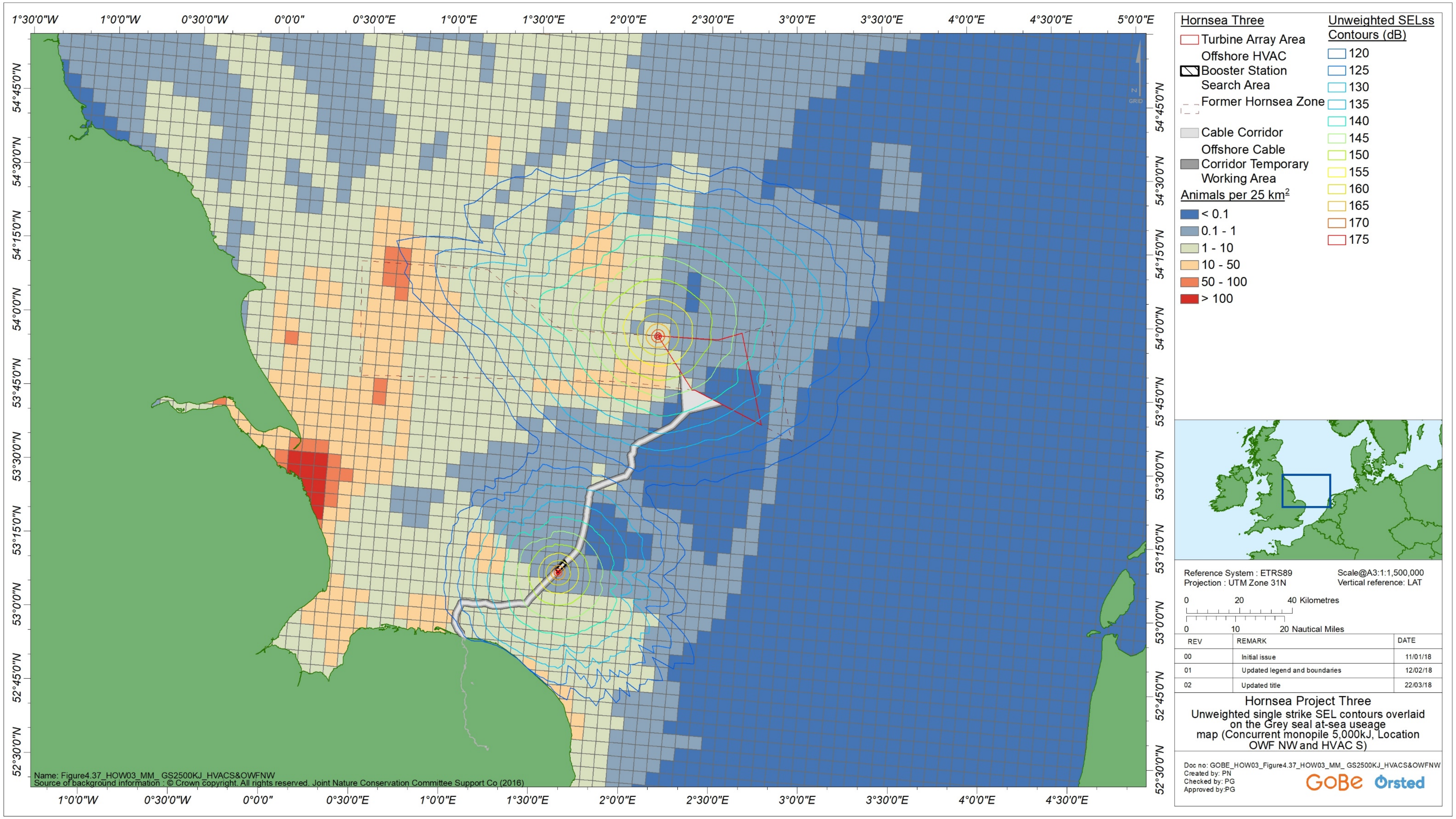

Figure 4.37: Unweighted single strike SEL contours overlaid on the grey seal at-sea usage map (Concurrent monopile 5,000 kJ, Location Hornsea Three NW & HVAC S).

Summary

Table 4.50: Piling noise impact assessment summary.

	Sensitivity	Magnitude	Impact Significance
Harbour porpoise			
PTS	High	Negligible with embedded mitigation	Minor
Disturbance: Single monopile	Medium	Low	Minor
Disturbance: Single pin pile	Medium	Low	Minor
Disturbance: Concurrent monopiles	Medium	Low	Minor
Minke whale			
PTS	High	Negligible with embedded mitigation	Minor
Disturbance: Single monopile	Medium	Low	Minor
Disturbance: Single pin pile	Medium	Low	Minor
Disturbance: Concurrent monopiles	Medium	Low	Minor
White-beaked dolphin			
PTS	High	Negligible with embedded mitigation	Minor
Disturbance: Single monopile	Medium	Negligible	Negligible
Disturbance: Single pin pile	Medium	Negligible	Negligible
Disturbance: Concurrent monopiles	Medium	Negligible	Negligible
Harbour seal			
PTS	Medium	Negligible with embedded mitigation	Negligible
Disturbance: Single monopile	Medium	Negligible	Negligible
Disturbance: Single pin pile	Medium	Negligible	Negligible
Disturbance: Concurrent monopiles	Medium	Low	Minor
Grey seal			
PTS	Medium	Negligible with embedded mitigation	Negligible
Disturbance: Single monopile	Low	Low	Minor
Disturbance: Single pin pile	Low	Negligible	Negligible
Disturbance: Concurrent monopiles	Low	Low	Minor

Underwater noise from UXO detonation has the potential to cause injury or disturbance to marine mammals

4.11.1.175 There is the potential requirement for underwater UXO clearance prior to construction. The preference would be to avoid UXO wherever possible or remove them from the seabed for disposal to a designated area. However, in some cases, this may be considered unsafe and therefore it is necessary to consider the requirement for underwater UXO detonation. The specific locations, numbers and sizes of UXO that will require detonation is only determined post-consent and therefore it is not possible to accurately characterise the nature of the UXO that may require detonation or define the appropriate mitigation measures at this stage. Consequently, Hornsea Three are not seeking to consent the detonation of UXO as part of this DCO application and it is the project's position that this should not be included in the assessment. A detailed assessment of UXO would be made as part of a future licence application once it is known whether UXO detonation is required, where, and what size UXO are that require detonation. However, Hornsea Three recognise that there is a possibility that UXO clearance may be required prior to commencement of construction of the project and that in-situ detonations of UXO are another source of noise in the marine environment and hence some consideration of the additional impact from this activity is appropriate. Therefore, high level acknowledgement of this activity will be given within the assessment but no detailed assessment or site specific modelling can be carried out until further, detailed information is available.

4.11.1.176 UXO clearance for the purposes of this assessment is considered to involve the detonation of the UXO *in situ* to make it safe to undertake construction works in the surrounding area. UXO detonations underwater are performed for those UXO that are considered unsafe for removal to be disposed of onshore.

4.11.1.177 A detailed UXO survey will be undertaken prior to construction and until that survey takes place the exact number and locations of UXO that may need to be detonated is not known. Therefore, as described in Table 4.15, the maximum design scenario for this assessment has been based on the number of UXO cleared for Hornsea Project One. This assessment has used the noise modelling carried out for Hornsea Project One and also the charge weights recorded for the UXO cleared. The largest charge weight recorded for Hornsea Project One was approximately 265 kg.

4.11.1.178 Explosive detonations, some of the loudest anthropogenic underwater noises, can result in source levels of 272-287 dB SPL_{peak} re 1µPa@1 m with a frequency spectrum of 2 – 1,000 Hz and the highest energies between 6 - 21 Hz over very rapid durations of 1 – 10 ms (Gotz *et al*., 2009, Richardson *et al*., 1995). The low frequency energy has the potential to travel considerable distances (Parvin *et al*., 2007) and this level of sound can cause injury or even cause death to marine mammals, with the injuries from both the high peak pressures and the initial shock wave that is generated (Genesis, 2011, von Benda-Beckman *et al*., 2017). The main potential effects from UXO detonations to individual animals are: physical injury (from the shock wave); auditory injury (from the acoustic wave) resulting in permanent threshold shift (PTS); and behaviour changes such as disturbance to feeding, mating, resting and breeding. As described in Section 4.10, the project will have a UXO specific marine mammal mitigation plan (MMMP), including mitigation measures such as the use of marine mammal observers (MMOs) and acoustic deterrent devices (ADDs).

4.11.1.179 Current advice from the statutory nature conservation bodies (SNCBs) is that the NOAA injury thresholds (NMFS, 2016) should be used for assessing the impacts from UXO detonation on marine mammals. However, the suitability of the NOAA criteria for UXO is currently under discussion at an industry level due to the lack of empirical evidence from UXO detonations using the NOAA metrics, in particular the range dependent characteristics of the peak sounds, and whether current propagation models can accurately predict the range at which these thresholds are reached. Current models have not been validated at ranges relevant to the predictions and there is a possibility that models significantly overestimate ranges for large charge masses (> 25 kg; von Benda-Beckman *et al.,* 2015). Therefore, the areas of the noise contours from the NOAA modelling for Hornsea Project One have been presented alongside the data from von Benda-Beckman *et al*. (2015) with the thresholds based on Southall *et al*. (2007) to provide a range for this assessment.

Magnitude of impact

4.11.1.180 The magnitude of the impact from UXO detonations is related to the source level of the noise generated, which may be affected by a range of factors including: design; composition; age; state of deterioration; orientation; whether it is covered by sediment; and the charge weight of the explosive (Von Benda-Beckman, 2015). Ultimately, only the charge weight of the explosive can be factored into noise modelling and has the greatest influence on the noise modelling source levels.

4.11.1.181 The NOAA modelling for Hornsea Project One did not consider the bathymetry at the site due to uncertainties at the time of modelling of the locations where UXO may be found. The von Benda-Beckman *et al*. (2015) modelling did include bathymetry, with most detonations occurring at approximately 25 – 30 m depth. The most common UXO found within Hornsea Project One had charge sizes of 240 kg, with the total weight of explosive including the detonation charge being 260 kg for which the NOAA PTS range for harbour porpoise is known. The remainder of the Hornsea Project One noise modelling predicted impact ranges for 227 kg and 700 kg charge weights. The von Benda-Beckman *et al*. (2015) modelling incorporated a charge weight of 263 kg which has also been presented here.

4.11.1.182 The respective thresholds used for the assessment are presented in Table 4.51. For the purposes of the PTS and disturbance assessments, it is assumed there is no mitigation. No thresholds for where blast injuries can occur to marine mammals have been assessed although any blast injury impacts would be within the PTS range.

UXO Clearance - PTS

Magnitude

4.11.1.183 von Benda-Beckman *et al*. (2015) modelled effect ranges for explosions of up to 1,000 kg charge size, using a model validated out to 2 km by empirical measurements. They found that PTS onset (using a SEL threshold of 179 dB re 1 µPa2s derived from Lucke *et al.* (2009)) ranged between hundreds of metres and just over 10 km for this range of charge masses. Near the surface (where porpoises spend a large proportion of their time (e.g. Teilmann *et al.,* 2007), PTS ranges were lower; just below 5 km for the largest charge masses.

4.11.1.184 von Benda-Beckman *et al*. (2015) reported that for a 263 kg charge weight at 28 m depth, based on values of overpressure levels that would lead to ear trauma from Ketten (2004), PTS for harbour porpoise could extend out to 1.8 km from the source, affecting an area of 10.18 km^2. In the absence of modelled results for other species using the same threshold, this has been assumed to apply across white-beaked dolphin, minke whales and seals.

4.11.1.185 Beatrice Offshore Wind Farm Limited (BOWL) in the Moray Firth also undertook noise modelling of UXO for a 50 kg explosive using the Southall *et al*. (2007) and NOAA thresholds. The BOWL modelling predicted PTS ranges of 225 m (0.16 km^2) for cetaceans and 764 m (1.83 km^2) for pinnipeds using Southall *et al*. (2007). Based on the NOAA thresholds, PTS ranges were 3.9 km (47.73 km^2) for HF cetaceans, 690 m (2.99 km^2) for LF cetaceans and the same as Southall for MF cetaceans and seals.

4.11.1.186 The noise modelling for Hornsea Project One of a 227 kg charge weight predicted PTS ranges (based on NOAA thresholds) of 8.2 km (211.24 km^2) for harbour porpoise, 550 m (0.95 km^2) for white-beaked dolphin, 1.66 km (8.66 km^2) for minke whale and 1.83 km (10.52 km^2) for pinnipeds. Modelling for a 260 kg UXO was also undertaken for harbour porpoise using the NOAA criteria which gave a range of 8.5 km (226.98 km^2).

4.11.1.187 The number of each species of marine mammal that could potentially be affected by PTS from UXO clearance for the range of charge sizes is presented in Table 4.51. This is quantified by calculating the numbers of animals likely to be within each of the stated impact ranges by multiplying the area of the impact range by the appropriate density estimate. Due to the lack of site specific information at the current stage of the assessment, the variation in the range of impact ranges under consideration, and that fact that this assessment will be updated using more detailed UXO survey data prior to construction, it was deemed appropriate to adopt average uniform densities at the broadest spatial scale in this assessment. The SCANS III densities were therefore used for cetaceans, and the seal usage maps used for seals.

Table 4.51: Estimate number of marine mammals potentially at risk of PTS during UXO clearance.

Impact	Receptor	Impact area (km^2)	Estimated number in impact area	% of reference population	Magnitude
263 kg charge weight von Benda-Beckman *et al.* (2015)	Harbour porpoise	10.18	9	0.003	Low
	White-beaked dolphin		<1	0.0001	Negligible
	Minke whale		<1	0.0004	Negligible
	Harbour seal		0	0	Negligible
	Grey seal		<1	<0.0001	Negligible
50 kg charge weight BOWL (2016) modelling of Southall *et al.* (2007)	Harbour porpoise	0.16	<1	<0.0001	Negligible
	White-beaked dolphin		<1	<0.0001	Negligible
	Minke whale		<1	<0.0001	Negligible
	Harbour seal	1.83	0	0	
	Grey seal		<1	<0.0001	
50 kg charge weight BOWL (2016) modelling of NOAA	Harbour porpoise	47.73	42	0.012	Low
	Minke whale	2.99	<1	<0.0001	Negligible
260 kg charge weight Hornsea Project One modelling using NOAA	Harbour porpoise	226.98	200	0.0578	Low
227 kg charge weight Hornsea Project One modelling of NOAA thresholds	White-beaked dolphin	0.95	<1	<0.0001	Negligible
	Minke whale	8.66	<1	<0.0001	Negligible
	Harbour seal	10.52	<1	<0.0001	Negligible
	Grey seal	10.52	<1	<0.0001	Negligible

4.11.1.188 The resulting impact is considered to be of negligible to low magnitude, without mitigation, for all species. Once more detailed information is available from site specific surveys and investigations, as stated in Table 4.19, a detailed assessment of the risk of injury and disturbance to marine mammals will be carried out and on the basis of this detailed assessment, a UXO specific MMMP will be developed for Hornsea Three and agreed with the MMO and statutory consultees. It is anticipated that in compliance with EPS guidance (JNCC, 2010), this MMMP will reduce the risk of injury to all marine mammal species to negligible.

Sensitivity

4.11.1.189 The sensitivity to PTS as a result of exposure to explosions from UXO clearance is considered high in all cetaceans and medium for seals.

Significance of the effect

4.11.1.190 Overall, with the adoption of a UXO specific MMMP tailored to reducing the risk of injury, the sensitivity of the receptor is considered to be high to medium and the magnitude is deemed to be negligible. The effect will, therefore, be of **minor** to **negligible** adverse significance, which is not significant in EIA terms.

UXO Clearance - Disturbance

4.11.1.191 Behavioural responses to noise are highly variable and are dependent on a variety of internal and external factors. Internal factors include past experience, individual hearing sensitivity, activity patterns, motivational and behavioural state at the time of exposure. Demographic factors such as age, sex and presence of dependent offspring can also have an influence. Environmental factors include the habitat characteristics, presence of food, predators, proximity to shoreline or other features. Responses themselves can also be highly variable, from small changes in behaviour such as longer intervals between surfacing (Richardson, 1995b) or a cessation in vocalisation (Watkins, 1986) to more dramatic escape responses (Götz and Janik, 2016).

4.11.1.192 This variability makes it challenging to predict the likelihood of responses to underwater noise from UXO detonations. Even where empirical data exist on responses of animals in one particular environment, the context related variability described above makes it difficult to extrapolate from one study to a new situation. It is important to note that all any impact assessment can do, is predict the *potential* for behavioural responses, as definitive predictions of likelihood or magnitude are particularly difficult.

Magnitude

4.11.1.193 Natural England and JNCC advise that a buffer of 26 km around the source location is used to determine the impact area from UXO clearance with respect to disturbance of harbour porpoise in the Southern North Sea cSAC. Hornsea Three array area is outside the cSAC, however the cable corridor, where UXO detonations may still be required, passes through the cSAC and therefore the use of the 26 km area has been used for this assessment. In the absence of agreed metrics for the use of other marine mammal species for disturbance, and given a lack of empirical data on the likelihood of response to explosives, this 26 km area has been applied for all species.

4.11.1.194 In addition to the use of the 26 km threshold, the TTS ranges modelled by the Beatrice Offshore Wind farm were also used to indicate the potential range of expected behavioural responses. This is based on the conclusion in Southall *et al.* (2007) in relation to exposures to single pulses: "*upon exposure to a single pulse, the onset of significant behavioural disturbance is proposed to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e., TTS-onset). We recognize that this is not a behavioural effect per se, but we use this auditory effect as a de facto behavioural threshold until better measures are identified*."

4.11.1.195 As stated in Table 4.19, a UXO specific MMMP will be employed for Hornsea Three UXO detonation, however the mitigation is highly unlikely on the basis of current understanding to mitigate the full area for disturbance. Therefore, the assessment and estimates of the number each species that may be affected as presented in Table 4.52 is based on a no mitigation scenario.

Table 4.52: Estimate number of marine mammals potentially at risk of disturbance during UXO clearance.

Impact/Metric of assessment	Receptor	Estimated number in impact area	% of reference population	Magnitude
Disturbance area of 2124 km^2	Harbour porpoise	1869	0.5	Low
	White-beaked dolphin	43	0.3	Low
	Minke whale	21	0.1	Low
	Grey seal	98	0.2	Low
	Harbour seal	3	0.04	Low
TTS-onset as proxy for behavioural response, from a 50 kg charge mass	Harbour porpoise	143	0.04	Negligible
	White-beaked dolphin	<1	<0.001	Negligible
	Minke whale	<1	<0.001	Negligible
	Grey seal	<1	<0.001	Negligible
	Harbour seal	<1	<0.001	Negligible

4.11.1.196 Each detonation will result in a single pulse of sound and based on data gathered on Hornsea Project One, only a small number of UXO, a total of 23, are anticipated to require detonation. Therefore, animals will experience very short lived periods of disturbance on an estimated 23 occasions. Due to this, and the low percentages of the reference populations predicted to be affected, the magnitude of disturbance from UXO clearance is considered low for all species.

Sensitivity

4.11.1.197 Due to the very short term and temporary nature of the impact, the sensitivity to disturbance from noise from UXO clearance is considered medium for harbour porpoise, minke whale, white-beaked dolphin and harbour seals, and low for grey seals.

Significance of the effect

4.11.1.198 Overall, the sensitivity is considered to be medium to low and the magnitude is deemed to be low for all species. Therefore, the effect will be of minor to negligible adverse significance for all species of marine mammal, which is not significant in EIA terms.

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

4.11.1.199 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.

Magnitude of impact

4.11.1.200 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.

4.11.1.201 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 4.11.1.205), and therefore background noise levels are likely to be high.

4.11.1.202 Though impacts of increased vessel movement have the potential to occur at times during the eight 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 eight year construction period, with a three year gap between the same construction activity in different phases (Table 4.15). 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 dolphins, are known to approach vessels 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 a few hundred metres from the noise source for all species.

4.11.1.203 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. Vessel movements from large vessels and medium 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. During piling, marine mammals could potentially be displaced from a large area around the piling location (as quantified in paragraph 4.11.1.75 *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, marine mammals are likely to respond first and foremost to the greater noise levels produced by piling. Marine mammals therefore have a greater potential to be impacted by increased vessel movements during periods when piling is not taking place.

4.11.1.204 Table 4.15 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 eight year offshore construction period, this would equate to a potential increase in vessel movements of approximately 5,237 per construction phase, or 2,095 per year/145 per month/5.7 per day during each 2.5 year construction phase within the eight year offshore construction period, with up to 8 vessels in a 5 km^2 area at any one time. These numbers are based upon an assumption that the same (maximum) number of vessel 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.

4.11.1.205 The current level of vessel activity passing through the Hornsea Three array area, plus a 10 NM buffer (Hornsea Three Array Area Shipping and Navigation Study Area; section 1.8.2 of volume 2, Chapter 7: Shipping and Navigation) is on average 19.6 vessels per day (volume 2, chapter 7: Shipping and Navigation). The future baseline (within 20 years of current baseline and not vessel traffic associated with Hornsea Three) is expected to show an increase in vessel activity within the same study area of 10% (section 1.1.6 of volume 2, chapter 7: Shipping and Navigation). 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.

4.11.1.206 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 4.11.1.213). Therefore, the magnitude of the impact has been assessed as low.

<u>Sensitivity of the receptor</u>

4.11.1.207 The main source of noise from vessels comes from propeller cavitation and vessel noise is known to increase with speed and loading for all vessel sizes (Senior *et al*., 2008). Reactions of marine mammals to vessel noise are often linked to changes in the engine and propeller speed (Richardson *et al.*, 1995).

4.11.1.208 Studies have shown that unless the received vocalisation and masking noise come from the same direction, masking is unlikely to be 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.

4.11.1.209 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), undertook a modelling study which predicted that increased vessel movements associated with offshore wind development in the Moray Firth did not have a negative effect on the local population of bottlenose dolphin, although it did note that foraging may be disrupted by the disturbance from vessels.

4.11.1.210 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).

4.11.1.211 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.

4.11.1.212 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; Heinanen and Skov (2015) identified that the occurrence of harbour porpoise declines significantly when the number of vessels in a 5 km^2 area exceeds 80 in one day. With an average of 19.6 vessels per day as a baseline, with a maximum increase of 6 vessels per day, in an area considerably larger than 5 km^2, vessel density will remain well below this threshold level for harbour porpoises. As a maximum design scenario, with commissioning of a turbine occurring within the same 5km^2 as piling, up to 8 vessels may be in a 5 km^2 area during construction. Other species such as white-beaked dolphin are regularly sighted near vessels and may also approach vessels (e.g. bow-riding). However, dolphins are also known to show aversion behaviours to vessel presence, including increased swimming speed, avoidance, increased group cohesion and longer dive duration (Miller *et al.,* 2008). Sensitivity to vessel noise is most likely related to the marine mammal activity at the time of disturbance (ICW, 2006, Senior *et al*., 2008). For example, resting dolphins are likely to avoid vessels, foraging dolphins will ignore them and socialising dolphins may approach vessels (Richardson *et al*., 1995).

4.11.1.213 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). Therefore, collisions between vessels and marine mammals are not necessarily lethal on all occasions.

4.11.1.214 As marine mammals depend on hearing for location of prey, migration and communication they are sensitive to potential masking by 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.

4.11.1.215 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). While the recovery from vessel disturbance is dependent on the number of vessels present during the operational phase, operational phase vessels are likely to be smaller and consequently disturbance and collision risk are considered to be reduced. Between the construction phases, vessel presence will reduce, with less operational vessels required than the maximum assessed (fewer structures will require proportionally fewer operational visits) and during the second phase of construction, it is likely that vessels may undertake joint construction and operational activities while on site, reducing the combined vessel movements required. Therefore, the sensitivity of all the marine mammal species assessed here is considered to be medium.

<u>Significance of the effect</u>

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

4.11.1.217 Due to the medium sensitivity of receptors and the **low** 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.1.218 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.

<u>Magnitude of impact</u>

4.11.1.219 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).

4.11.1.220 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 4.15). 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).

4.11.1.221 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 (i.e. one tidal excursion in length). 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 (volume 2, chapter 1: Marine Processes).

4.11.1.222 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 (volume 2, 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.

4.11.1.223 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). No significant adverse effects on fish and shellfish were predicted from increases to SSC and it likely that the noise and vessel presence associated with the activities causing the increase in SSC will displace marine mammals away from the affected zone. Therefore, the magnitude of this impact on marine mammals is deemed to be negligible.

<u>Sensitivity of the receptor</u>

4.11.1.224 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.

4.11.1.225 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.

4.11.1.226 In general, since light is limited in the marine environment, most marine mammals use their hearing, and other sensory modalities, including touch, instead of sight, to gain information about their environment. The sensitivity of marine mammals to increased SSC is therefore considered to be low.

<u>Significance of the effect</u>

4.11.1.227 Overall, 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.

4.11.1.228 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.1.229 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

4.11.1.230 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 4.15). 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.

4.11.1.231 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 4.15). An impact upon marine mammal receptors would only be realised if an incident occurs where the fuel is accidentally released.

4.11.1.232 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. It likely that the noise and vessel presence associated with the activities will result in displacement of marine mammals from the area where a pollution release could occur. Therefore, the magnitude is considered to be negligible.

Sensitivity of the receptor

4.11.1.233 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).

4.11.1.234 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.

4.11.1.235 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). However, marine mammals are likely to avoid any minor events and therefore the sensitivity is considered to be low.

Significance of the effect

4.11.1.236 Overall, 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.

4.11.1.237 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.1.238 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).

4.11.1.239 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

4.11.1.240 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 (volume 2, 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 67.30 km^2, equating to 0.03% of the total seabed area within the southern North Sea fish and shellfish area and 6.75% 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.

4.11.1.241 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 (volume 2, 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, of volume 2, 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.

4.11.1.242 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 (volume 2, chapter 3: Fish and Shellfish Ecology). Subsea noise modelling carried out showed that (recoverable) injury ranges extend out to a mean distance of 190 m (maximum 190 m) from the source for a 5,000 kJ hammer energy and out to a mean distance of 130 m (maximum 130 m) 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. Popper *et al*. (2014) stated that insufficient data is available to quantify behavioural impact ranges for fish, however it is possible to qualitatively assess the impacts using a risk matrix of likely impacts and estimates of ranges from the source. It is also recognised that fish sensitivity to sound is likely determined by the presence of a swim bladder and whether it is used in hearing. Those species where the swim bladder is used in hearing have a higher sensitivity to sound. As such, behavioural effects on species such as herring, sprat and gadoids (cod, whiting, etc.), with swim bladders involved in hearing are predicted to occur over tens of kilometres, while impacts of demersal and shellfish species are predicted to occur over tens to hundreds of metres and not more than 1 km from the source (volume 2, chapter 3: Fish and Shellfish Ecology). 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.

4.11.1.243 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 (volume 2, 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.

4.11.1.244 No significant adverse effects are predicted to occur to fish and shellfish as a result of the construction of Hornsea Three; therefore, the magnitude of the impact on marine mammals is deemed to be low.

Sensitivity of the receptor

4.11.1.245 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.

4.11.1.246 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. For the largest hammer energy (5,000 kJ), there is potential for avoidance of fish species over a range of tens of kilometres although this may not necessarily result in strong avoidance reactions (paragraph 3.11.69 of volume 2, chapter 3: Fish and Shellfish Ecology). 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*.). Therefore, the sensitivity is considered to be low.

Significance of the effect

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

4.11.1.248 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

Future monitoring

4.11.1.249 A commitment has been made to develop a Plan for Marine Mammal Monitoring in consultation with the SNCB and approved by the MMO prior to the commencement of offshore works. The Plan will be developed in line with the principles set out in the IPMP (Document Ref: A8.8 that accompanies the Hornsea Three DCO application). In addition, as set out in the IPMP, the applicant has committed to the provision of piling duration information (to the MMO following completion of construction activity) to validate the assumptions made within the impact assessment on this key concern.

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 4.15 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 300 turbines within the Hornsea Three array area (Table 4.15). 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) with more recent data available for larger 3.6 MW and 6 MW turbines (volume 4, annex 3.1: Subsea Noise Technical Report).

4.11.2.7 To determine the possible noise levels arising at Hornsea Three from operational wind turbines, subsea noise modelling was carried out for various turbine sizes, based on measured noise levels of operational turbines at existing wind farms (3.6 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 injury from turbine noise based on the marine mammal criteria given in NMFS (2016) were found to be less than 10 m, even for the largest 170 m rotor-diameter turbine (volume 4, annex 3.1: Subsea Noise Technical Report). Assuming the worst case source level operational noise predicted for the largest turbine of 158.8 dB re 1 µpa SPL RMS, the sound levels were predicted to decrease to ambient noise levels with a few hundred metres of each turbine (volume 4, annex 3.1: Subsea Noise Technical Report) Operational noise is a continuous noise and as such disturbance is considered to be a low risk within this range; additionally, operational noise is predominantly low frequency and as such, the impacts on MF HF marine mammals will be reduced as the majority of the noise may be outside of their hearing range (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 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 from operational (smaller) turbines 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). It has been noted that the effects of noise from operational wind farms is generally going to be small, especially in comparison to other underwater noise sources such as shipping vessels (Masden *et al*., 2006). Therefore, the magnitude is deemed to be negligible.

<u>Sensitivity of the receptor</u>

4.11.2.9 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.

4.11.2.10 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.

4.11.2.11 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. As such, the sensitivity is considered to be low.

Significance of the effect

4.11.2.12 Overall, 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.

4.11.2.13 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.2.14 The potential impacts of increased vessel movement have been detailed in paragraph 4.11.1.199 and have not been reiterated here.

4.11.2.15 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

4.11.2.16 Table 4.15 details the type and number of operation and maintenance vessels predicted to be used over the 35 year duration of the operational lifetime of Hornsea Three.

4.11.2.17 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 35 year operation and maintenance phase of Hornsea Three, there is expected to be an increase of 2,822 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.

4.11.2.18 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. Therefore, the magnitude of the impact is considered to be low.

Sensitivity of the receptor

4.11.2.19 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). As such, in line with the construction phase, the sensitivity is considered to be medium.

Significance of the effect

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

4.11.2.21 Due to the medium sensitivity of receptors and the low 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.

4.11.2.22 A full account of the screening and appropriate assessment is presented within the Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.2.23 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

4.11.2.24 Electromagnetic fields could arise from up to 830 km of alternating current (AC) array cable, up to 225 km of interconnector cables and up to 1,146 km of HVDC or HVAC export cable (Table 4.15).

4.11.2.25 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.

4.11.2.26 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.

4.11.2.27 Average magnetic fields of DC cables are higher than those of equivalent AC cables (Table 4.53). 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.

4.11.2.28 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 4.53; Normandeau *et al*., 2011).

Table 4.53: 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

4.11.2.29 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). Therefore, the magnitude is considered to be negligible.

Sensitivity of the receptor

4.11.2.30 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).

4.11.2.31 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).

4.11.2.32 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.

4.11.2.33 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.

4.11.2.34 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). Therefore, the sensitivity of marine mammals is considered to be low.

Significance of the effect

4.11.2.35 Overall, 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.

4.11.2.36 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.

4.11.2.37 A full account of the screening and appropriate assessment is presented within the Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.2.38 The potential impacts of accidental pollution on marine mammals have been outlined in paragraphs 4.11.1.229 to 4.11.1.231 and have not been re-iterated here.

Magnitude of impact

4.11.2.39 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 4.15 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.

4.11.2.40 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 4.11.1.232) in the unlikely event of a spill this MPCP will include mitigation measures, address all potential contaminant releases and include key emergency contact details. Therefore, the magnitude is considered to be negligible.

Sensitivity of the receptor

4.11.2.41 The sensitivity of marine mammals to accidental pollution has been described previously (paragraph 4.11.1.233 *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. However, marine mammals are likely to avoid any minor events. Therefore, the sensitivity is considered to be low.

Significance of the effect

4.11.2.42 Overall, 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.

4.11.2.43 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.2.44 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 (volume 2, chapter 3: Fish and Shellfish Ecology).

4.11.2.45 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

4.11.2.46 Long term habitat loss due to presence of foundations, scour protection and cable protection is estimated to be up to 4.21 km^2 which represents 0.36% of the area within the Hornsea Three project boundary. 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.

4.11.2.47 Up to 5,470,308 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.

4.11.2.48 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).

4.11.2.49 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 (volume 2, 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.

4.11.2.50 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.

4.11.2.51 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.

4.11.2.52 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.

4.11.2.53 No significant adverse effects above minor on fish and shellfish were predicted from increases to SSC. Therefore, the magnitude of this impact on marine mammals is deemed to be low.

Sensitivity of the receptor

4.11.2.54 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. Therefore, the sensitivity is considered to be low.

Significance of the effect

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

4.11.2.56 Due to the low sensitivity of receptors and the low 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

Future monitoring

4.11.2.57 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 4.15 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. The magnitude has been deemed to be negligible.

Sensitivity of the receptor

4.11.3.6 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. The sensitivity of the receptor is therefore, considered to be low.

Significance of the effect

4.11.3.7 Overall, for all decommissioning activities, 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.

4.11.3.8 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.3.9 The potential impacts of increased vessel movement have been detailed paragraphs 4.11.1.199 to 4.11.1.217 and have not been reiterated here.

4.11.3.10 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

4.11.3.11 Increased vessel movements during decommissioning of up to 319 foundations (300 turbines, 12 offshore transformer substations, four offshore HVDC substations and three accommodation platforms) and up to 2,113 km of cables is estimated to require up to 10,774 round trips by decommissioning vessels during the eight years of the decommissioning phase.

4.11.3.12 The number of vessels and duration of the decommissioning phase are predicted to be the same as for the construction period (paragraph 4.11.1.200). Therefore, as for the construction phase, the magnitude is considered to be low.

Sensitivity of the receptor

4.11.3.13 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). As per the construction phase, the sensitivity is considered to be medium.

Significance of the effect

4.11.3.14 Though there is predicted to be an increase in vessel movements during the eight 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.

4.11.3.15 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.

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

4.11.3.17 Due to the medium sensitivity of receptors and the low 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.11.3.18 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 4.11.1.219 *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 4.11.1.217)

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

4.11.3.19 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 4.11.1.230 *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 4.11.1.237)

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

4.11.3.20 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).

4.11.3.21 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

4.11.3.22 The total temporary loss of habitat during decommissioning is estimated at 57,639,112 m^2 equating to 4.87% of the seabed within the Hornsea Three project 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.

4.11.3.23 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 4.11.1.241 and 4.11.1.243 respectively). In both cases the impacts were of minor adverse significance.

4.11.3.24 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.

4.11.3.25 Removal of all foundations (assuming scour and cable protection is left *in situ*) is predicted to result in the loss of 1,158,303 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.

4.11.3.26 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 3,616,852 m^2 of seabed, equating to 0.3% of the seabed within the Hornsea Three project boundary. 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.

4.11.3.27 No significant adverse effects on fish and shellfish were predicted from increases to SSC and it likely that the noise and vessel presence associated with the activities causing the increase in SSC will displace marine mammals away from the affected zone. Therefore, the magnitude of this impact on marine mammals is deemed to be negligible.

<u>Sensitivity of the receptor</u>

4.11.3.28 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 4.11.1.245 *et seq*.). Therefore, the sensitivity of marine mammals is considered to be low.

<u>Significance of the effect</u>

4.11.3.29 Overall, 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. 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 4.11.1.248).

Future monitoring

4.11.3.30 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 volume 4, annex 5.3: Cumulative Effects Screening Matrix). 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 5.3: 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 with a legally secure consent (i.e. projects that are not subject to an ongoing judicial review process) that have been awarded a CFD but have not yet been implemented; 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 project/plans that have a legally secure consent but have no CFD; and/or
  - submitted but not yet determined; and/or
  - those with a non-legally secure consent (i.e. projects that are subject to an ongoing judicial review process); 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 and the adopted development plan including supplementary planning documents are the most relevant sources of information, along with information from the relevant planning authorities regarding planned major works being consulted upon, but not yet the subject of a consent application). Specifically, this Tier includes all projects where the developer has advised PINS in writing that they intend to submit an application in the future, those projects where a Scoping Report is available and/or those projects which have published a PEIR.

4.12.1.7 It is noted that offshore wind farms seek consent for a maximum design scenario and the '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 considered a maximum of turbines 332 turbines within the Environmental Statement, but has gained consent for 240 turbines. In addition, it is now known that Hornsea Project One 'as built' will consist of 174 turbines. 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 and the as built number of turbines is likely to be less than this. A similar pattern of reduction in the project envelope from that assessed in the Environmental Statement, to the consented envelope and the 'as built' project is also seen across other offshore wind farms of relevance to this CEA. This process of refinement can result in a reduction to associated project parameters, for example the number and length of cable to be installed and the number of offshore substations. 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. Given that this broadly represents a maximum design scenario, the level of cumulative impact on marine mammals would highly likely be reduced from those presented here.

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 significantly from those presented here.

4.12.1.9 For projects in Tier 3 the level of detail available is sometimes limited at this stage and therefore the assessments presented for this Tier are semi-quantitative.

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 4.54 and illustrated in Figure 4.38 and Figure 4.39. 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 4.54: 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	332 turbines assessed in the Environmental Statement (although 240 turbines actually consented), of which 174 turbines to be constructed.	2017 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	2017 - 2018	No	Yes
		Blyth demo	258	273	Up to 15 turbines consented, five constructed	2017	No	Yes
		East Anglia One	152	106	102 x 7 MW turbines consented	2018	No	Yes
		Hornsea Project Two	7	8	360 turbines assessed in the Environmental Statement. Up to 300 turbines consented	2020 to 2022	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
		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	2020 to 2021	Yes	Yes
		Inch Cape	384	401	Up to 110 turbines	2020 to 2021	Yes	Yes
		SeaGreen Phase 1 (Alpha, Bravo)	367	384	Up to 75 turbines per sub-project	2022 to 2024	Yes	Yes
		Norther (Belgium)	236	163	44 8 MW turbines consented	2017 to 2018	No	Yes
		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

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
		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
	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
		Inner Dowsing - 481	125	38	Operational	N/A	N/A	Yes
		Inner Dowsing - 481	125	38	Operational	N/A	N/A	Yes
		Humber (disposal site)	77	32	Operational	N/A	N/A	Yes
		Humber 4 and 7 - 506	13	8	Operational	N/A	N/A	Yes
	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

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
		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
	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
	Oil and Gas Decommissioning							
	Decommissioning	Leman BH	79 km	34 km	Gas platform	N/A	Yes (decommissioning activity overlapping with Hornsea Three construction	No
		Viking Charlie Drilling (CD)	39 km	22 km	Gas platform	N/A		No
		Viking Delta Drilling (DD)	37 km	21 km	Gas platform	N/A		No
		Viking Echo Drilling (ED	45 km	12 km	Gas platform	N/A		No
		Viking Golf Drilling (GD)	40 km	15 km	Gas platform	N/A		No
		Viking Hotel Drilling (HD)	33 km	13 km	Gas platform	N/A		No
		PL89 – Gas Pipeline (Decommissioning)	37.9 km	20.4 km	Pipelines associated with Viking field	N/A		No

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
		PL90 – Gas Pipeline (Decommissioning)	36.7 km	20.4 km		N/A		No
		PL91 – Gas Pipeline (Decommissioning)	37.9 km	11.5 km		N/A		No
		PL92 – Gas Pipeline (Decommissioning)	37.9 km	16.0 km		N/A		No
		PL93 – Gas Pipeline (Decommissioning)	33.3 km	17.7 km		N/A		No
		PL132 – Gas Pipeline (Decommissioning)	37.9 km	20.4 km		N/A		No
		PL131 – Gas Pipeline (Decommissioning)	36.7 km	20.4 km		N/A		No
		PL133 – Gas Pipeline (Decommissioning)	37.9 km	11.5 km		N/A		No
		PL66 – Gas Pipeline (Decommissioning)	37.9 km	16.0 km		N/A		No
		PL130 – Gas Pipeline (Decommissioning)	33.3 km	17.7 km		N/A		No
		Vulcan UR	67.4 km	12.9 km	Gas platform	N/A		No
		Viscount VO	50 km	15 km	Gas platform	N/A		No
		Vampire/Valkyrie	45 km	4 km	Gas platform	N/A		No
		PL462 - Vulcan UR to Vulcan RD	67.4 km	12.9 km	Pipeline associated with Vulcan platforms	N/A		No
		PL463 - Vulcan RD to Vulcan UR	67.4 km	12.9 km	Pipeline associated with Vulcan platforms	N/A		No
		PL1962 - Viscount VO to Vampire OD	44.7 km	4.5 km	Pipeline associated with Viscount and Vampire platforms	N/A		No
		PL1963 - Vampire OD to Viscount VO	44.7 km	4.5 km	Pipeline associated with Viscount and Vampire platforms	N/A		No
		PL1692 - Vampire OD to LOGGS PR	44.7 km	4.4	Pipeline associated with Vampire platform	N/A		No
		PL1693 - LOGGS PR to Vampire OD	44.7 km	4.4	Pipeline associated with Vampire platform	N/A		No
		Audrey A (WD)	39 km	1	Gas platform	N/A		No
		Audrey B (XW)	39 km	6	Gas platform	N/A		No
		PL496	39.0 km	0 (Crosses route)	Pipelines associated with Audrey field	N/A		No
		PL497	39.0 km	0 (Crosses route)		N/A		No
		PL723	38.6 km	1.3 km		N/A		No
		PL724	38.6 km	1.3 km		N/A		No
		PL575	39.0 km	1.3 km		N/A		No
		PL576	39.0 km	1.3 km		N/A		No

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
2	Offshore wind farms							
	Consented	Dogger Bank Teesside A and Dogger Bank Teesside B (now Sofia)	95	108	Up to 400 turbines consented	2023 to 2026	Yes	Yes
		Dogger Bank Creyke Beck A and B	76	91	Up to 200 turbines consented	2021 to 2024	Yes	Yes
	Submitted	East Anglia Three	103	87	Up to 172 turbines	2020 to 2022	Yes	Yes
	Aggregate extraction and disposal sites							
	Application	Humber 5 - 483	14 km	2 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 439	131 km	48 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
	Cables and pipelines							
	Proposed	Viking Link Interconnector	13	18	High voltage (up to 500 kV) DC electricity interconnector	2019 to 2021	Yes	Yes
		PL0221_HS D18-A to D15-FA-1	19 km	45 km	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 km	45 km	8-inch Proposed Gas pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes
3	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	Yes

Figure 4.38: Offshore wind farms and coastal development projects screened into the marine mammal CEA.

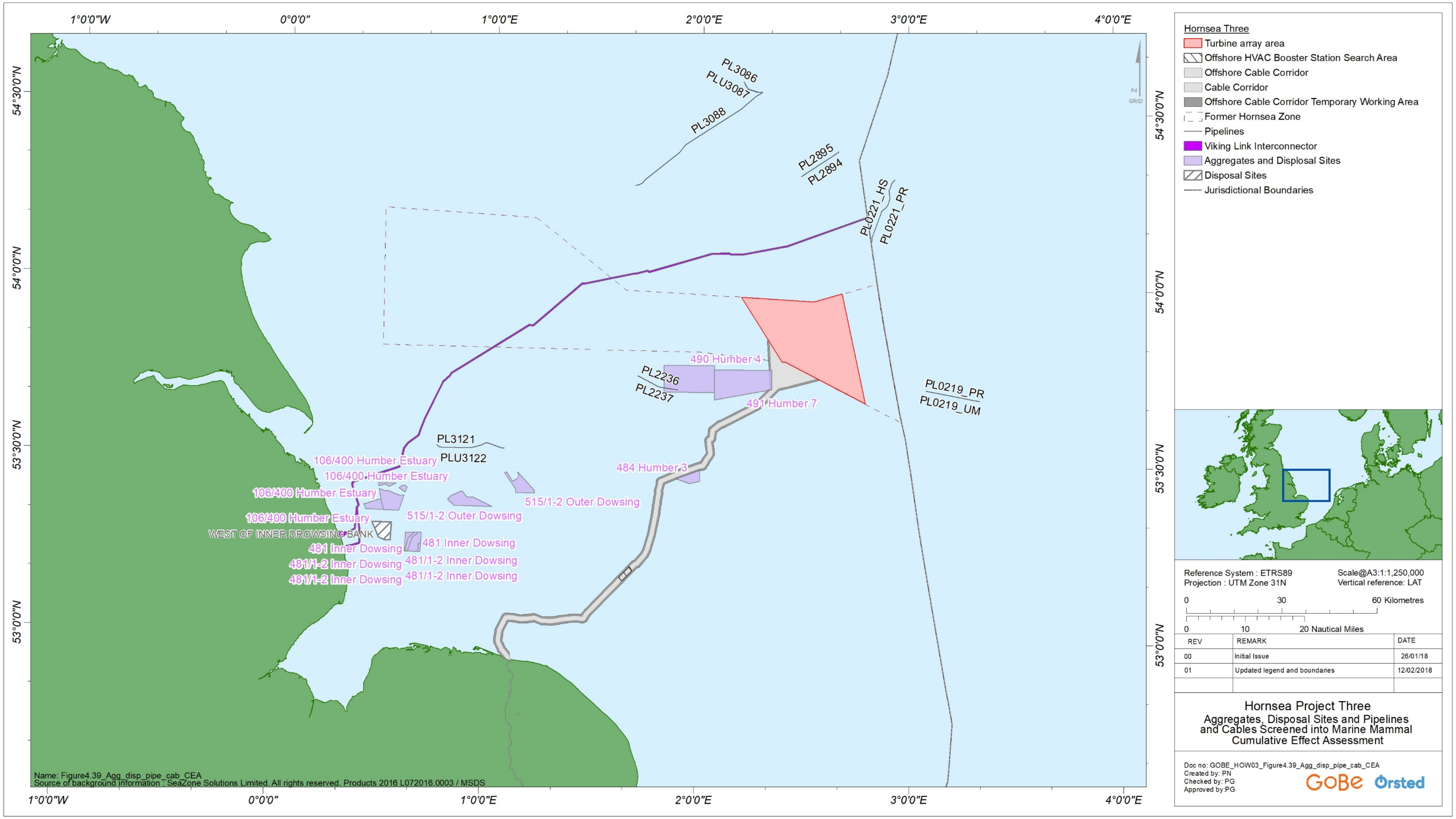

Figure 4.39: Aggregates, disposal sites, pipelines and cables screened into the marine mammal Cumulative Effects Assessment.

4.12.2 Maximum design scenario

4.12.2.1 The maximum design scenarios identified in Table 4.55 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 4.15 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. PEMMP, see Table 4.19).

Table 4.55 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 offshore wind farm applications: Blyth demo; East Anglia One; East Anglia Three; Hornsea Project Two; Kincardine; Triton Knoll; Hywind Scotland Pilot Park, Moray East, Borssele 3 and 4; • 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* • Consented offshore wind farm applications: Dogger Bank Creyke Beck A and B; Dogger Bank Teesside A and Dogger Bank Teesside B (now Sofia). *Tier 3* • Unconsented offshore wind farms: Norfolk Vanguard; Moray West. Wind farms undergoing applications for variations to consent: Inch Cape, Neart Na Gaoithe and Seagreen.	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 Dogger Bank Teesside B (now Sofia); 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 4.63; apart from the Viking Interconnector • Ports and harbour projects including: Yorkshire Harbour and Marina, Chatham Maritime Marina (two projects). *Tier 2* • Norfolk Vanguard, Moray West; 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.

Potential impact	Maximum design scenario	Justification
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* • All application aggregate extraction areas (i.e. Humber 5 – 483, Inner Dowsing - 439); and • Cables and pipelines (i.e. PL0221_HS D18-A to D15-FA-1 and PL0221_PR D18-A to D15-FA-1, Viking Interconnector) • 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 4.5).

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 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 4.11.1.6 to 4.11.1.8 and has not been re-iterated here. The projects included in this cumulative impact assessment are detailed in Table 4.55 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 4.38).

4.13.1.3 The maximum design scenario (temporal) for potential cumulative impact of increased underwater noise due to piling is 12 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 three years where currently no piling is predicted to occur. 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 one project is currently predicted as likely to have a directly overlapping piling period with Hornsea Three (Hornsea Two). Borssele 3 and 4, Moray East and Triton Knoll have also been included due to the proximity of predicted piling periods (current timelines for these projects put potential piling activity in the year immediately preceding piling activity at Hornsea Three). However, no quantitative information is available for the prediction of impact from Borssele 3 and 4, therefore these projects are not considered quantitatively. In Tier 2, five projects have the potential for direct overlap of piling phases (Dogger Bank Creyke Beck A & B, Dogger bank Teesside A, Dogger Bank Teesside B (now Sofia) and East Anglia Three). In Tier 3, three projects have been identified with potential direct overlap of piling phases (Moray West, Thanet Extension and Norfolk Vanguard).

4.13.1.4 Though piling is planned for construction of Inch Cape, Neart Na Gaoithe and Seagreen offshore wind farms in the outer Forth and Tay area, and these projects have been granted consent, these three projects are all in the process of applying for variations to consents and therefore the predicted level of impact from the likely build out scenarios are uncertain. However, in this CEA quantitative information on the potential level of impact on species and reference populations relevant to the Hornsea Three has been included from the original consent applications in lieu of publicly available predictions of impact from revised designs. The Scoping reports for these project revisions have been used to provide an indication of the likely timeline for construction. As a result of the uncertainty in relation to project variations which are as yet unconsented, these projects have been considered in Tier 3.

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. 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 suggests that there may be an overlap in the timing of piling of up to ten offshore projects with the Hornsea Three piling phase, construction timescales are indicative and subject to change, however the tiering approach is intended to take into account this uncertainty in timing and therefore more weight should be placed on tier one than on subsequent tiers.

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 three years between phases where no piling will occur (Table 4.56). 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 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 4.56: Projected estimated timelines of piling of CEA projects, and potential for likely 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	Blyth Demo																	
	Beatrice																	
	Borkum Riffgrund 2 (Germany)																	
	Borssele 1 and 2 (Netherlands)																	
	Borssele 3 and 4 (Netherlands)																	
	Deutsche Bucht Offshore Wind Farm (Germany)																	
	Dudgeon	commissioned by 2017																
	East Anglia One																	
	Galloper																	
	Hornsea Project One																	
	Hornsea Project Two																	
	Horns Rev 3 (Denmark)																	
	Hywind Scotland Pilot Park																	
	Kincardine																	
	MEG Offshore (now Merkur offshore windfarm)																	
	Moray East																	
	Nissum Bredning (Denmark)																	
	Nordergruende																	
	Norther (Belgium)																	
	Rentel Area A (Belgium)																	
	Sandbank 24																	
	Seastar (Belgium)																	
	Trianel Windpark Borkum (Germany																	
	Triton Knoll																	
	Chatham Maritime Marina and extension																	
	Convoys Wharf	Unknown																

Tier	Project	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033 to 2038
2	Dogger Bank Creyke A & B																	
	Dogger Bank Teesside A																	
	Dogger Bank Teesside B (now Sofia)																	
	East Anglia Three																	
3	Moray West																	
	Norfolk Vanguard																	
	Thanet Extension																	
	Inch Cape																	
	Neart na Gaoithe																	
	Seagreen																	

Tier 1

4.13.1.9 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. 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

4.13.1.10 The potential distances at which auditory injury (PTS) could occur in marine mammals during concurrent pile-driving at Hornsea Three are very small (paragraph 4.11.1.3 *et seq*). At 15% hammer blow energy, for all scenarios, the potential for auditory injury falls within the standard 500 m mitigation range recommended in the draft JNCC guidelines (2010). The potential distances at which PTS could occur as a result of cumulative exposure were up to a maximum of 1,200 m for harbour porpoises, 100 m for white-beaked dolphins, 1,500 m for minke whales and 100 m for seals. Assuming that mitigation is implemented as set out in the MMMP, which may include use of marine mammal observers and ADDs, the risk of auditory injury (PTS) will be reduced to negligible 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.

4.13.1.11 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.

Behavioural effects

4.13.1.12 As the potential for behavioural effects on seals due to concurrent piling at Hornsea Three is only predicted to affect small numbers of animals, these receptors are not considered further for the cumulative impact of behavioural effects from piling noise. The same applies to white-beaked dolphins and minke whales but as all cetaceans are afforded an additional degree of legal protection as European Protected Species, they are included in the cumulative assessment of behavioural effects from piling noise as a precautionary measure.

Harbour porpoise

Magnitude of impact

4.13.1.13 For projects whose piling phase overlaps with Hornsea Three, the ranges over which possible disturbance could occur and the associated estimates of the numbers of animals potentially affected are presented in Table 4.57).

Table 4.57: Maximum design scenario estimates of behavioural effects in harbour porpoise due to piling at CEA projects with potential overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Criteria	Maximum range (km)	Total number of animals predicted to be affected	Predicted significance of impact (from Environmental Statement)
Hornsea Project Two	145 SEL	62	Using dose response: 3,809 (single vessel) 6,570 (concurrent) Not using dose response: 5,576 (single vessel) 11,451 (concurrent):	Moderate (short to medium term) No significant effect in the long term
Moray East	75 dB_{ht} (behavioural displacement: High)	22	2993 per year (single vessel) 3442 per year (concurrent)	Major significance over medium term for individuals during construction phase with minor significance long term effects on the population.
Triton Knoll	75 dB_{ht} (behavioural displacement: High)	17	357 (single vessel) 948 (concurrent)	Minor adverse

4.13.1.14 The maximum design scenario based on all Tier 1 projects piling at exactly the same time, assuming no spatial overlap in impact areas, is that a total of 18,290 harbour porpoises could be affected if all projects were undertaking concurrent piling and 12,158 harbour porpoises could be affected if all projects were undertaking single piling operations. These figures correspond to a total of 5.3 % and 3.5 % of the North Sea MU reference population respectively. 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 also highly unlikely that all projects will realise their maximum design scenarios in terms of all elements of the assessment (duration, hammer energies, concurrent piling etc.). There is also likely to be a large element of overlap in the affected areas, particularly between Hornsea Project Two and Three which is impossible to quantify given the information available in the public domain. As a result of all of these factors, the addition of the numbers presented in individual assessments represents a significant over-estimate of the actual likely level of impact.

4.13.1.15 The PEIR for Norfolk Vanguard offshore wind farm used a different approach for the cumulative assessment (Vattenfall, 2017). Rather than relying on the numbers of individuals predicted in each project ES, they recalculated impact for each project based on assuming a standard range of impact of 26 km and the uniform porpoise density values from the appropriate blocks from the SCANS III surveys. Following this approach for the projects listed in Table 4.57 provides an estimate of impact of 11,962 porpoises, corresponding to 3.5 % of the North Sea MU reference population. Although this method can help eliminate variation as a result of variation in assessment methods (thresholds and noise modelling approaches), it does not take into account differences in hammer energy between projects or site specific variations in harbour porpoise density.

4.13.1.16 The cumulative impact on harbour porpoises for the maximum adverse spatial scenario is predicted to affect animals 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. The majority of the effects (e.g. disrupting communication, echolocation or threat detection) are considered to be reversible soon after cessation of the piling activity.

4.13.1.17 Temporally, piling could occur intermittently within a period of up to 12 years in total, with up to 33 Tier 1 offshore wind farm projects constructed within this cumulative period. 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.

4.13.1.18 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, medium duration (in relation to the life cycle of harbour porpoises), intermittent with the potential for large gaps between piling activity in different regions, 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 temporarily lead to the potential for loss of foraging areas during pile-driving (some potentially within harbour porpoise SAC/SCIs in the North Sea). In an attempt to quantify the magnitude of this level of effect at the population level, Booth *et al.,* (2017) carried out an assessment of the cumulative effects on the North Sea harbour porpoise population as a result of a number of scenarios of offshore wind farm construction in the North Sea.

4.13.1.19 In the absence of empirical data informing the effect of disturbance on individual survival and reproduction, this approach used a formal expert elicitation process to link disturbance with fitness consequences for individuals. Coupled with a population modelling framework, this allowed an estimate of the potential future population effects of impact. The maximum assessed was a scenario where up to 34,000 porpoises were displaced (15 % of total MU population). This approach concluded that even with 15 % of the population potentially affected, there was only a small (6 %) increase in the risk of an annual population decline of 1% per year and that overall, impacted population trajectories were not significantly different from baseline population trajectories. Although there are uncertainties inherent in this modelling approach given the reliance on expert elicitation, these results are based on current best evidence and expert judgement on how disturbance of this magnitude will affect individual porpoises and therefore how these effects will manifest themselves at the population level. In addition, preliminary outputs from individual based modelling approaches (van Beest *et al.,* 2015) have suggested that population level impacts from cumulative impact of offshore wind farm construction at the scale currently envisaged in the North sea might be negligible. Although both of these approaches are based on modelling with limited empirical data and therefore contain uncertainties, they represent the best current scientific knowledge on this subject. Overall, the assessment of the magnitude of potential disturbance for Tier 1 projects is assessed as low.

Sensitivity of the receptor

4.13.1.20 The impact ranges used to quantify the number of porpoises affected vary between the CEA projects given in Table 4.57, and as such cover the whole suite of behavioural responses from complete exclusion to possible avoidance. Therefore it is unlikely that all animals quantified will suffer reduced fitness as a result of exposure to the same extent. The sensitivity of harbour porpoise to disturbance from underwater noise is covered in paragraphs 4.11.1.80 *et seq*. The sensitivity of harbour porpoises to disturbance from underwater noise from piling is assessed as medium.

Significance of the effect

4.13.1.21 Overall, it is predicted that the sensitivity of harbour porpoises to disturbance is considered to be medium and the magnitude of all Tier 1 disturbance is deemed to be low. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

Minke whale

Magnitude of impact

4.13.1.22 The maximum design scenario based on Tier 1 projects piling at exactly the same time, assuming no spatial overlap in impact areas, is that a total of 306 minke whales could be affected if all projects were undertaking concurrent piling and 278 minke whales could be affected if all projects were undertaking single piling operations. These figures correspond to a total of 1.3 % and 1.2 % of the CGNS MU reference population respectively. As discussed for harbour porpoises, 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 also highly unlikely that all projects will realise their maximum design scenarios in terms of all elements of the assessment (duration, hammer energies, concurrent piling etc.). There is also likely to be a large element of overlap in the affected areas, which is impossible to quantify given the information available in the public domain. As a result of all of these factors, the addition of the numbers presented in Table 4.58 together with the numbers predicted to be affected at Hornsea Three represents a significant over-estimate of the actual likely level of impact. This is particularly the case for the combination of impact from Hornsea Project Two and Hornsea Three, where there will be a large overlap in the affected areas and therefore the actual numbers affected at the same time by any overlapping piling will be significantly less than this.

Table 4.58: Maximum design scenario estimates of behavioural effects in minke whales due to piling at Tier 1 CEA projects with overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Criteria	Maximum range (km)	Total number of animals predicted to be affected	Predicted significance of impact (from Environmental Statement)
Hornsea Project Two	SEL 142	82	Using dose response: 34 (single vessel) 37 (concurrent) Not using dose response: 49 (single vessel) 51 (concurrent)	Minor adverse (single) Minor adverse (concurrent)
Moray East	75 dB_{ht} (behavioural displacement: High)	23	206 per year (single vessel) 218 per year (concurrent)	Major significance over medium term for individuals during construction phase with minor significance long term effects on the population.
Triton Knoll	Not assessed	Not assessed	Not assessed	Not assessed

4.13.1.23 The total maximum level of impact is predicted at 1.3 % of the MU population. This is likely to be a large overestimate and it is not expected that this level of effect would adversely affect minke whale population size or trajectory. This is therefore considered to be of low magnitude.

Sensitivity of the receptor

4.13.1.24 The sensitivity of minke whales to disturbance from underwater noise is covered in paragraph 4.11.1.100 and has been assessed as medium.

Significance of the effect

4.13.1.25 Overall, it is predicted that the sensitivity of minke whales to disturbance is considered to be medium and the magnitude of all Tier 1 disturbance is deemed to be low. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

White-beaked dolphin

Magnitude of impact

4.13.1.26 Only one Tier 1 project, Hornsea Project Two, predicted effects on white-beaked dolphin. The maximum design scenario based on Tier 1 projects piling at exactly the same time, assuming no spatial overlap in impact areas, is that a total of 16 white-beaked dolphins could be affected if Hornsea Project Two and Hornsea Project Three were both carrying out concurrent piling operations with no overlap in affected areas. This corresponds to a total of 0.1 % of the CGNS MU reference population. As discussed for harbour porpoises and minke whales, there is likely to be a great deal of variation in timing, duration, and hammer energy used throughout the project construction periods detailed above. It is also highly unlikely that both projects will realise their maximum design scenarios in terms of all elements of the assessment (duration, hammer energies, concurrent piling etc.). Given the proximity of the two projects, there is also likely to be a large element of overlap in the affected areas, which has not been quantified. As a result of all of these factors, the addition of the numbers presented in both projects worst case assessments represents a significant over-estimate of the actual likely level of impact.

4.13.1.27 The total maximum level of impact is predicted at 0.1 % of the MU population. This is likely to be a large overestimate and it is not expected that this level of effect would adversely affect white-beaked dolphin population size or trajectory. This is therefore considered to be of low magnitude.

Sensitivity of receptor

4.13.1.28 The sensitivity of white-beaked dolphins to disturbance from underwater noise is covered in paragraph 4.11.1.121 and 0.0.0 and has been assessed as medium.

Significance of the effect

4.13.1.29 Overall, it is predicted that the sensitivity of white-beaked dolphins to disturbance is considered to be medium and the magnitude of all Tier 1 disturbance is deemed to be low. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

Tier 2

Auditory injury

4.13.1.30 As described for Tier 1 projects 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.

Behavioural effects

Harbour porpoise

Magnitude of impact

4.13.1.31 An additional five offshore wind farm projects could potentially have overlapping piling periods with Hornsea Three in Tier 2. The maximum design scenario based on all Tier 1 and Tier 2 projects piling at exactly the same time, assuming no spatial overlap in impact areas, is that a total of 36,905 harbour porpoises could be affected if all projects were undertaking concurrent piling and 22,546 harbour porpoises could be affected if all projects were undertaking single piling operations. As discussed for Tier 1, there is likely to be a great deal of variation in timing, duration, and hammer energy used throughout the various project construction periods detailed above. It is also highly unlikely that all projects will realise their maximum design scenarios in terms of all elements of the assessment (duration, hammer energies, concurrent piling etc.). There is also likely to be a large element of overlap in the affected areas, which is impossible to quantify given the information available in the public domain. As a result of all of these factors, the addition of the total numbers of animals predicted to be affected across all projects (Table 4.59) represents a significant over-estimate of the actual likely level of impact.

4.13.1.32 This brings the total percentage of the population potentially affected to a maximum of 11 % for concurrent scenarios and 7 % for single piling scenarios. It is considered that all projects piling concurrently is highly unrealistic therefore the assessment of magnitude is based on the cumulative single piling scenario.

4.13.1.33 The addition of two Tier 2 projects would also add to the total number of actual piling days within the 12 year cumulative period, although as described previously piling will only occur for a small proportion of the time during this period and will not significantly extend the duration of the cumulative period.

4.13.1.34 The magnitude of impact for the Tier 2 assessment is predicted to be of a higher magnitude compared to the Tier 1 assessment. 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).

Table 4.59: Maximum design scenario estimates of behavioural effects in minke whales due to piling at Tier 2 CEA projects with overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Criteria	Maximum range (km)	Total number of animals predicted to be affected	Predicted significance of impact (from Environmental Statement)
Dogger Bank Creyke Beck A	SEL 145	26	1,288 (single vessel) 3,119 (concurrent)	(single) Minor adverse (concurrent)
Dogger Bank Creyke Beck B	SEL 145	43	2,276 (single vessel) 4,394 (concurrent)	(single) Minor adverse (concurrent)
Dogger Bank Teesside A	SEL 145	33	1,920 (single vessel) 4,302 (concurrent)	(single) Minor adverse (concurrent)
Dogger Bank Teesside B (Sofia)	SEL 145	33.5	2,035 (single vessel) 3,931 (concurrent)	(single) Minor adverse (concurrent)
East Anglia Three	SEL 145	70	2,869 (75% response)	Minor adverse

4.13.1.35 The thresholds and impact ranges used to quantify the number of porpoises affected vary between the CEA projects in Tiers 1 and 2, and as such cover the whole suite of behavioural responses from complete exclusion to possible avoidance. Therefore, it is unlikely that all animals quantified will suffer reduced fitness as a result of exposure to the same extent. Taking 6% as a very precautionary maximum estimate of the potential magnitude of effect and comparison with the results from population modelling carried out by Booth *et al.* (2017). It is not considered that disturbance of this magnitude would have a significant effect on the population trajectory, even if every single affected porpoise experienced reduced breeding success. Therefore, the assessment of the magnitude of potential disturbance of Tier 1 and Tier 2 combined is assessed as moderate in the terms of the absolute numbers of animals affected (6%) over the period of overlapping piling but low in terms of the low potential for a long term effect on the population trajectory.

Sensitivity of receptor

4.13.1.36 The sensitivity of harbour porpoise to disturbance from underwater noise is covered in paragraphs 4.11.1.80 to 4.11.1.94. Overall the sensitivity of harbour porpoises to disturbance from underwater noise from piling is assessed as medium.

Significance of the effect

4.13.1.37 The cumulative impact of disturbance from Tier 2 projects with Hornsea Three has the potential to lead to individual-level effects in no more than 7 % of the management unit population. 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 12 year offshore cumulative period, could result in periods of exclusion from key habitats, including sites that have been internationally designated for harbour porpoise. However, given that this magnitude is still significantly lower than that considered in the modelling by Booth *et al.* (2017), it is considered likely, based on current best available scientific opinion, that the population trajectory would not be significantly affected in the long term.

4.13.1.38 It is expected that any effects would not adversely affect harbour porpoise population trends over or beyond this 12 year period. Therefore, the effect of potential disturbance resulting from piling at Tier 1 and Tier 2 combined is assessed as **moderate** (in terms of overall numbers of animals affected and the duration of effect) but of **minor** adverse significance in the long term, as a result of the lack of a long term effect on the size or trajectory of the population. Therefore, this is not considered significant in EIA terms.

Minke whale

Magnitude of impact

4.13.1.39 The maximum design scenario based on Tier 1 and Tier 2 projects piling at exactly the same time, assuming no spatial overlap in impact areas, is that a total of 473 minke whales could be affected if all projects were undertaking concurrent piling and 368 minke whales could be affected if all projects were undertaking single piling operations. These figures correspond to a total of 2.0 % and 1.6 % of the CGNS MU reference population respectively. As discussed for harbour porpoises, 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 also highly unlikely that all projects will realise their maximum design scenarios in terms of all elements of the assessment (duration, hammer energies, concurrent piling etc.). There is also likely to be a large element of overlap in the affected areas, which is impossible to quantify given the information available in the public domain. As a result of all of these factors, the addition of the numbers presented in Table 4.60 represents a significant over-estimate of the actual likely level of impact.

4.13.1.40 The total maximum level of impact is predicted at 2.0 % of the MU population. This is likely to be a large overestimate and it is not expected that this level of effect would adversely affect minke whale population size or trajectory. This is therefore considered to be of low magnitude.

Sensitivity of the receptor

4.13.1.41 The sensitivity of minke whales to disturbance from underwater noise is covered in paragraph 4.11.1.100 and has been assessed as medium.

Table 4.60: Maximum design scenario estimates of behavioural effects in minke whales due to piling at Tier 2 CEA projects with overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Criteria	Maximum range (km)	Total number of animals predicted to be affected	Predicted significance of impact (from Environmental Statement) [a]
Dogger Bank Creyke A	SEL 145	35	7 (single vessel) 14 (concurrent)	Negligible (single vessel) Minor (concurrent)
Dogger Bank Creyke B	SEL 145	56	13 (single vessel) 22 (concurrent)	Negligible (single vessel) Minor (concurrent)
Dogger Bank Teesside A	SEL 145	41	34 (single vessel) 69 (concurrent)	Negligible (single vessel) Minor (concurrent)
Dogger Bank Teesside B (Sofia)	SEL 145	41	36 (single vessel) 62 (concurrent)	Negligible (single vessel) Minor (concurrent)
East Anglia Three	Not assessed	Not assessed	Not assessed	Not assessed

Significance of the effect

4.13.1.42 Overall, it is predicted that the sensitivity of minke whales to disturbance is considered to be medium and the magnitude of all Tier 1 and Tier 2 disturbance is deemed to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

White-beaked dolphin

Magnitude of impact

4.13.1.43 The maximum design scenario based on all Tier 2 projects piling at exactly the same time, assuming no spatial overlap in impact areas, is that a total of 73 white-beaked dolphins could be affected if all projects were undertaking concurrent piling and 14 white-beaked dolphins could be affected if all projects were undertaking single piling operations. These figures correspond to a total of 0.5 % and 0.1 % of the CGNS MU reference population respectively. As discussed for the other species, 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 also highly unlikely that all projects will realise their maximum design scenarios in terms of all elements of the assessment (duration, hammer energies, concurrent piling etc.). There is also likely to be a large element of overlap in the affected areas, which is impossible to quantify given the information available in the public domain. As a result of all of these factors, the addition of the numbers presented in individual project assessments (Table 4.61) represents a significant over-estimate of the actual likely level of impact.

4.13.1.44 The total maximum level of impact is predicted at 0.5 % of the MU population. It is not expected that this level of effect would adversely affect white-beaked dolphin population size or trajectory. This is therefore considered to be of low magnitude.

Table 4.61: Maximum design scenario estimates of behavioural effects in white-beaked dolphins due to piling at Tier 2 CEA projects with overlapping piling periods with Hornsea Three (from published Environmental Statements).

Project	Criteria	Maximum range (km)	Total number of animals predicted to be affected	Predicted significance of impact (from Environmental Statement) [a]
Dogger Bank Creyke A	SEL 145	7.5	1 (single vessel) 9 (concurrent)	Negligible (single vessel) Minor (concurrent)
Dogger Bank Creyke B	SEL 145	9	1.1 (single vessel) 10 (concurrent)	Negligible (single vessel) Minor (concurrent)
Dogger Bank Teesside A	SEL 145	8.5	3 (single vessel) 21 (concurrent)	Negligible (single vessel) Minor (concurrent)
Dogger Bank Teesside B	SEL 145	8.5	3 (single vessel) 21 (concurrent)	Negligible (single vessel) Minor (concurrent)
East Anglia Three	Not assessed	Not assessed	Not assessed	Not assessed

Sensitivity of receptor

4.13.1.45 The sensitivity of white-beaked dolphins to disturbance from underwater noise is covered in paragraph 4.11.1.121 and 0.0.0 and has been assessed as medium.

Significance of the effect

4.13.1.46 Overall, it is predicted that the sensitivity of white-beaked dolphins to disturbance is considered to be medium and the magnitude of all Tier 1 and Tier 2 disturbance is deemed to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Tier 3

Harbour porpoises

4.13.1.47 In Tier 3, an additional four projects could overlap temporally with Hornsea Three during the construction phase: Moray West, Norfolk Vanguard, Thanet Extension and Seagreen (Firth of Forth). An additional two projects (Inch Cape and Neart Na Gaoithe) are predicted to be piling in the year immediately preceding piling at Hornsea Three and therefore have also been included. From the projects where some degree of information is available on the potential quantitative magnitude of impact (Thanet Extension and Norfolk Vanguard PEIRs, and the original Environmental Statements from the Forth and Tay projects) an additional 5,839 harbour porpoises are predicted to be affected behaviourally as a result of single piling operations, and an additional 8,153 as a result of concurrent piling (although all these projects conducting concurrent piling operations at the same time is extremely unlikely). No quantitative information is available as yet for Moray West. However, given the stage of development of these projects and the expected revised applications for the Forth and Tay projects, these numbers are highly uncertain and as such no additional assessment of magnitude or significance is possible with any confidence.

Minke whales

4.13.1.48 Out of the projects added to Tier 3, only those located in Scotland: Moray West, Seagreen, Inch Cape and Neart Na Gaoithe, have the potential to affect minke whales. From the projects where some degree of information is available on the potential quantitative magnitude of impact an additional 528 minke whales are predicted to be affected behaviourally as a result of single piling operations, and an additional 661 as a result of concurrent piling (although all these projects conducting concurrent piling operations at the same time is extremely unlikely). However, as above for harbour porpoises, given the stage of development of these projects and the expected revised applications for the Forth and Tay projects, these numbers are highly uncertain and as such no additional assessment of magnitude or significance is possible with any confidence.

White-beaked dolphin

4.13.1.49 Out of the projects added to Tier 3, only those located in Scotland: Moray West, Seagreen, Inch Cape and Neart Na Gaoithe, haves the potential to affect white-beaked dolphins. From the projects where some degree of information is available on the potential quantitative magnitude of impact an additional 193 white-beaked dolphins are predicted to be affected behaviourally as a result of single piling operations, and an additional 327 as a result of concurrent piling (although all these projects conducting concurrent piling operations at the same time is extremely unlikely). However, as above for harbour porpoises, given the stage of development of these projects and the expected revised applications for the Forth and Tay projects, these numbers are highly uncertain and as such no additional assessment of magnitude or significance is possible with any confidence.

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

4.13.1.50 The potential for significant impact from a combination of pile driving at Hornsea Three and oil and gas activities is largely related to the anticipated type, extent and duration of seismic survey. Seismic surveys involve a wide range of equipment, with various sound source levels. The information available for this assessment did not allow the separation of the equipment used or provide information on the noise source levels generated and therefore it is not possible to undertake a quantitative assessment. Oil and gas activities are licenced in the UK by the Department for Business, Energy & Industrial Strategy (BEIS) and there is no easily accessible central repository for detailed information on planned or likely future activities over the timescales required for this assessment. In 2016 JNCC launched the Marine Noise Registry (MNR; JNCC (2016)) which is a database that records the spatial and temporal distribution of impulsive noise generating activities in UK seas. In the absence of detailed information on likely future activity, this assessment has taken the outputs from the noise registry from 2015 as indicative of future levels of activity in the wider management unit, although it is unlikely that areas previously subject to detailed seismic survey will be subject to re-survey.

Magnitude of impact

4.13.1.51 Overall levels of seismic survey activity in 2015 as recorded in the Marine Noise Registry were low, generally between 1 and 10 days of activity across the year, with only a small number of blocks experiencing higher levels (>10 to 99 pulse block days). The Hornsea Three array area overlaps with a total of 6 licence blocks and the cable corridor overlaps with 7 licence blocks. Oil and Gas activities in adjacent North Sea waters have also been considered in this assessment. According to TNO (Heinis *et al.,* 2015) seismic surveying activity in the years 2016-2022 are not expected to differ from levels prior to 2016 and although year to year variations are expected, in general, ongoing activities can be considered as part of the baseline conditions.

4.13.1.52 It is also not possible to reliably estimate the number of potential seismic surveys that could be undertaken in the harbour porpoise North Sea MU area during the construction and potential piling activity at Hornsea Three. Therefore, the assessment has been based on a nominal prediction of a total of four seismic surveys ongoing at the same time as the piling activity for the construction of Hornsea Three.

4.13.1.53 Following advice from Natural England (Natural England, 2017), this assessment assumes an area of 10 km radius (314 km^2) around each seismic operation to assess the area of potential disturbance. Without knowing the actual location for any particular survey, a uniform harbour porpoise density has been used from SCANS III block O of 0.888 per km^2 to estimate the potential number of harbour porpoise that could be affected. This results in an estimate of up to 279 harbour porpoises being affected by each survey, assuming no overlap in impact area. Assuming a total of four surveys being undertaken at the same time, the potential disturbance area would be 1,256 km^2, affecting a total of 1116 porpoises. This represents 0.3% of the North Sea MU population and therefore is considered of low magnitude.

4.13.1.54 Under the same assumptions, the equivalent number of minke whales predicted to be affected is 13. This represents 0.1 % of the North Sea MU population and therefore is considered of low magnitude.

4.13.1.55 Under the same assumptions, the equivalent number of white-beaked dolphins predicted to be affected is 25. This represents 0.2 % of the North Sea MU population and therefore is considered of low magnitude.

Sensitivity of the receptor

4.13.1.56 There is much uncertainty regarding the potential for cumulative effects of noise disturbance from a combination of pile driving and seismic survey. There is little empirical data on the effect of seismic surveys on marine mammals. One study in the Moray Firth, Scotland, demonstrated that disturbance effects in harbour porpoises occurred over ranges of 5-10 km but that effects were short-lived and animals were typically detected again at affected sites within a few hours (Thompson *et al.,* 2013). This study demonstrated that there was no long-term displacement into sub-optimal or higher risk habitats. A follow up analysis using the same data (Pirotta *et al.*, 2014) demonstrated that feeding activity was reduced in the ensonified area (measured by the probability of measuring a porpoise echolocation 'buzz', a behaviour thought to be indicative of foraging attempts) by 15%. For the purposes of this assessment, the sensitivity of all marine mammal species to disturbance from underwater noise from seismic surveys in combination with pile driving at Hornsea Three, is considered medium.

Significance of the effect

4.13.1.57 Overall, the sensitivity of all marine mammals to disturbance from underwater noise from seismic surveys in combination with pile driving at Hornsea Threes considered to be medium and the magnitude of such disturbance is deemed to be low. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

Underwater noise from UXO clearance, foundation piling and other construction activities within Hornsea Three with underwater noise arising during detonation for UXO clearance by other offshore wind farm construction and during other marine construction activities has the potential to cause disturbance to marine mammals

4.13.1.58 There is the potential requirement for explosions for UXO clearance prior to construction of other wind farms in the North Sea, as well as UXO clearance by the Royal Netherlands Navy (as described in von Benda-Beckman *et al.,* 2015). It is not possible to carry out a reliable quantitative assessment of the extent of UXO clearance related detonations overlapping with noisy construction activities at Hornsea Three. However, taking a similar approach to that taken by Norfolk Vanguard in their PEIR, an assessment has been based on the following assumptions relating to overlap with UXO clearance operations elsewhere:

- Up to one UXO clearance operation in the UK northern North Sea area;
- Up to one UXO clearance operation in the UK southern North Sea area;
- Up to one UXO clearance operation in the Netherlands/Belgium area of the North Sea; and
- Up to one UXO clearance operation in the German/Denmark area of the North Sea.

4.13.1.59 Based on the North Sea average density of harbour porpoises from the SCANS III surveys and a standard deterrence range of 26 km, the number of harbour porpoise that could potentially be disturbed during one UXO clearance operation is 1,105, which is 0.3% of the North Sea MU. During up to four UXO clearance operations, up to 4,420 porpoises could be affected, which is 1 % of the Norths Sea MU. UXO detonations occur over a very short duration and any disturbance effect is assumed to be temporary. Therefore, the overall magnitude of the cumulative effect of underwater noise from the construction of Hornsea Three with UXO detonations elsewhere in the North Sea is considered to be low. The sensitivity of harbour porpoise to disturbance is considered medium. Therefore, the significance of this effect is considered minor, which is not significant in EIA terms.

4.13.1.60 The equivalent figures for disturbance to minke whales during four UXO clearance operations is 21, which is 0.4% of the CGNS MU. The equivalent figures for white-beaked dolphins is 42 animals, which is 1.1% of the CGNS MU. Therefore, the overall magnitude of the cumulative effect of underwater noise from the construction of Hornsea Three with UXO detonations elsewhere in the North Sea is considered to be low. The sensitivity of minke whale and white-beaked dolphins to disturbance is considered medium. Therefore, the significance of this effect is considered minor, which is not significant in EIA terms.

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

4.13.1.61 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.

4.13.1.62 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

4.13.1.63 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 4.62).

4.13.1.64 Thirteen offshore pipeline and cable projects and two coastal projects have been scoped into the CEA (Table 4.62). Vessel movements associated with cable and pipelines listed in Table 4.62 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.

4.13.1.65 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.

4.13.1.66 Table 4.62 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 10,774 over the construction period (two phases over eight years with up to three years between phases). It was assumed that a similar uplift would occur in vessel numbers during the decommissioning period. A total uplift of 2,822 per year was predicted over the operational lifetime of the project. As stated previously (paragraph 4.11.1.204) 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 Hornsea Three array area. Therefore, for Hornsea Three alone vessel movements are likely to be an overestimate.

4.13.1.67 Similarly, for each of the projects included in the CEA, the number of vessel movements represents a maximum design scenario (Table 4.62). 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.

4.13.1.68 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 4.11.1.205 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.

4.13.1.69 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 low.

<u>Sensitivity of receptor</u>

4.13.1.70 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.

Table 4.62: 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 Teesside 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 years	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

4.13.1.71 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.

4.13.1.72 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.

4.13.1.73 The marine mammals considered in this Environmental Statement are of international and national importance.

4.13.1.74 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

4.13.1.75 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 4.62).

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

4.13.1.77 Due to the medium sensitivity of receptors and the low 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.

4.13.1.78 Conclusions on the effect on the site integrity of European sites within the regional marine mammal study area are beyond the scope of this ES Chapter. A full account of the screening and appropriate assessment is presented within the Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

Tier 2

Magnitude of impact

4.13.1.79 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.

4.13.1.80 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).

4.13.1.81 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.

4.13.1.82 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 low.

Sensitivity of receptor

4.13.1.83 Details of marine mammal sensitivity and response to increased vessel traffic have been detailed in paragraph 4.11.2.19, 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

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

4.13.1.85 Due to the medium sensitivity of receptors and the low 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.

4.13.1.86 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

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

4.13.1.87 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 volume 2, chapter 3: Fish and Shellfish Ecology).

Tier 1

Magnitude of impact

4.13.1.88 A summary of the effects assessed in the fish and shellfish chapter is provided in Table 4.63 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 tens of kilometres 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.

4.13.1.89 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 low.

Sensitivity of receptor

4.13.1.90 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 4.11.1.245 and 4.11.2.54.

4.13.1.91 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.

Significance of effect

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

4.13.1.93 Due to the low sensitivity of receptors and the low 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

Tier 2

Magnitude of impact

4.13.1.95 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 been anticipated to occur over similar ranges as described for Tier 1 projects.

4.13.1.96 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 low.

Sensitivity of receptor

4.13.1.97 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

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

4.13.1.99 Due to the low sensitivity of receptors and the low 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.

4.13.1.100 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 Report to Inform the Appropriate Assessment for Hornsea Three (document reference A5.2).

Table 4.63: 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: • 147.40 km² from offshore wind farms; • 16.88 km² from aggregate extraction/disposal; • 3.02 km² from cables and pipelines; and • 28.96 km² from oil and gas decommissioning Total Tier 1: 196.26 km² Magnitude of effect is predicted to be low.	Demersal spawning species are considered to be most vulnerable to habitat loss (paragraph 4.11.1.240). 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: • 3.77 km² from cables and pipelines; and • 4.36 km² from aggregate dredging/ disposal. Total Tier 2: 204.39 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 low.	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 4.11.1.241) 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 eight 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 low.	Fish and shellfish range in sensitivity depending on their hearing group (see paragraph 4.11.1.242). 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: • 15.29 km² from physical presence of offshore wind farm foundations and scour protection • 0.02 km² from physical presence of cable and pipeline protection • 0.13 km² from physical presence of pipelines from oil and gas decommissioning. Total Tier 1: 15.44 km² Magnitude of effect is predicted to be low.	Demersal spawning species are considered to be most vulnerable to habitat loss (paragraph 4.11.2.46). 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 for Tier 1 plus: • 0.14 km² from Viking Link Interconnector Total for Tier 2 is 15.58 km².	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: • 21.75 km² from physical presence of offshore wind farm foundations and scour protection • 0.12 km² from physical presence of cable and pipeline protection • 0.13 km² from physical presence of pipeline protection for oil and gas decommissioning Total Tier 1: 22.00 km² Magnitude of effect is predicted to be low.	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 4.11.2.47). Potential negative effects could occur due to the introduction of non-native indigenous and invasive species (paragraph 4.11.2.48). Shellfish are considered to be of medium sensitivity, whilst fish are of low sensitivity. Minor adverse significance.
	Tier 2 As above for Tier 1 plus: • 0.14 km² from Viking Link Interconnector. Total for Tier 2 is 22.14 km².	As above. Minor adverse significance.

Cumulative impact	Predicted effect	Impact assessment
EMF emitted by subsea cables from offshore wind farms and interconnectors	*Tier 1* Cumulative length of array, substation interconnector and export cables: • 6,131 km from offshore wind farms Magnitude of effect is predicted to be low.	The most sensitive species are likely to be elasmobranchs, such as rays and dogfish, and migratory species, such as salmon and European eel (paragraph4.11.2.49). 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 for Tier 1 plus: • 186 km from Viking Link Interconnector. Total for Tier 2 is 6,317 km.	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 Hornsea Three array areas. Magnitude of effect is predicted to be low.	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 4.11.2.52). Due to the uncertainty associated with such benefits, sensitivity of fish and shellfish species is low. Minor beneficial significance.

4.14 Transboundary effects

4.14.1.1 A screening of transboundary impacts has been carried out and is presented in volume 4, 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 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** adverse or **negligible** 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. For injury effects (physical or auditory), Hornsea Three, both alone and cumulatively Is considered to result in effects of **minor** or **negligible** significance, which is not significant in EIA terms.

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. For all species assessed, except harbour porpoise, Hornsea Three, both alone and cumulatively is considered to result in effects of **minor** or **negligible** significance, which is not significant in EIA terms. For harbour porpoise, disturbance effects from Hornsea Three alone are considered to be of **minor** significance, which is not significant in EIA terms. Cumulatively, it is considered that behavioural effects on harbour porpoise populations in other EEA states will be of **moderate** significance in the short term, with this decreasing to **minor** significance in the long term.

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 volume 2, chapter 12: Inter-Related Effects (Offshore).

4.16 Conclusion and summary

4.16.1.1 This chapter presented the results of the EIA for the potential impacts of Hornsea Three on marine mammals, covering all impacts arising from Hornsea Three seaward of MHWS during its construction, operation and decommissioning phases. Detailed technical information underpinning the impact assessments presented within this chapter is contained within volume 5, annex 4.1: Marine Mammals Technical Report.

4.16.1.2 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 identified within the Hornsea Three marine mammal study area and assessed within this chapter are harbour porpoise, minke whale, white-beaked dolphin, grey seal and harbour seal. Harbour porpoise, in particular, were 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.

4.16.1.3 The impacts on marine mammal receptors from all stages of the project were assessed, including impacts from underwater noise, vessel interactions, pollution events, EMF and indirect impacts on prey species. The impact assessment has adopted a precautionary approach throughout in order to help to address any uncertainties. The effects are summarised in Table 4.64 below. Assuming successful implementation of the proposed mitigation measures, all impacts from Hornsea Three alone were assessed as being of minor adverse significance or less.

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 All of the impacts from Hornsea Three and other developments and activities (including offshore wind farms, aggregate extraction and oil and gas decommissioning and seismic surveys) assessed in the CEA, with the exception of underwater noise effect on harbour porpoise from piling, were predicted to be of minor adverse significance and not significant in EIA terms. The cumulative effects of underwater noise from piling harbour porpoise has been assessed as of moderate significance in the short term, with this expected to decrease to a minor effect in the long term.

4.16.1.6 The screening of transboundary impacts identified that there was potential for significant transboundary effects for marine mammals from Hornsea Three upon the interests of other European Economic Area (EEA) states, including direct impacts due to underwater noise from piling operations and indirect impacts from changes to prey availability. Following consideration of the relevant impact assessments, for all impacts except disturbance to harbour porpoise cumulatively, these impacts were not predicted to have significant effects on marine mammal populations of other EEA states. Cumulative disturbance to harbour porpoise was assessed as of moderate significance in the short term, with this decreasing to minor in the long term.

Table 4.64: 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.	Low	High	Minor adverse	None	N/A	A Plan for Marine Mammal Monitoring that will be developed in consultation with the SNCB and approved by the MMO prior to the commencement of offshore works. In addition, as set out in the IPMP, the applicant has committed to the provision of piling duration information (to the MMO following completion of construction activity).
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	Low	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 PEMMP and MPCP 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	A PEMMP and MPCP will be produced and followed and will include a MMMP (see chapter 3: Fish and Shellfish Ecology)	Low	Low	Minor adverse	None	N/A	N/A
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	Low	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

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
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 PEMMP and MPCP 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	Low	Low	Minor beneficial	None	N/A	N/A
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.	Low	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	Low	Low	Minor adverse	None	N/A	N/A

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