Hornsea Project Four: Environmental Statement (ES)

PINS Document Reference: A2.3
APFP Regulation: 5(2)(a)

Volume A2,
Chapter 3: Fish and Shellfish Ecology

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Accepted David King, Orsted. August 2021
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Doc. no. A2.3
Version: B

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Glossary

Term	Definition
Commitment	A term used interchangeably with mitigation and enhancement measures. The purpose of Commitments is to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms. Primary (Design) or Tertiary (Inherent) are both embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, Preliminary Environmental Information Report (PEIR) or ES). Secondary commitments are incorporated to reduce LSE to environmentally acceptable levels following initial assessment i.e. so that residual effects are acceptable.
Crustacea	Arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp, or barnacle
Cumulative effects	The combined effect of Hornsea Four in combination with the effects from a number of different projects, on the same single receptor/resource. Cumulative impacts are those that result from changes caused by other past, present, or reasonably foreseeable actions together with Hornsea Four.
Demersal	Relating to the seabed and area close to it. Demersal spawning species are those which deposit eggs onto the seabed.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Elasmobranchs	Cartilaginous fishes such as sharks, rays, and skates.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
EIA Regulations	The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Four array area to the Creyke Beck National Grid substation, within which the export cables will be located.
Fish larvae	The developmental stage of fish which have hatched from the egg and receive nutrients from the yolk sac until the yolk is completely absorbed.
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
Hornsea Project Four Offshore Wind Farm	The term covers all elements of the project (i.e. both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four.

Term	Definition
Maintain	Includes inspect, upkeep, repair, adjust, and alter and further includes remove, reconstruct and replace, to the extent assessed in the environmental statement; and "maintenance" must be construed accordingly.
Maximum Design Scenario (MDS)	The maximum design parameters of each Hornsea Four asset (both on and offshore) considered to be a worst case for any given assessment.
Mitigation	A term used interchangeably with Commitment(s) by Hornsea Four. Mitigation measures (Commitments) are embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, PEIR, or ES).
Nursery habitat	Habitats where high numbers of juveniles of a species occur, having a greater level of productivity per unit area than other juvenile habitats.
Order Limits	The limits within which Hornsea Four (the 'authorised' project) may be carried out.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).
Pelagic	Any part of the water column (i.e. the sea from surface to bottom sediments) that is not close to the seabed. Pelagic spawning species release their eggs into the upper layers of the sea.
Planning Inspectorate (PINS)	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
Semi-pelagic (or benthopelagic)	Partially living their life on the seabed (benthic) and partially living their life in the water column above (pelagic).
Sound Pressure Level (SPL)	The sound pressure level or SPL is an expression of the sound pressure using the decibel (dB) scale and the standard reference pressures of 1 µPa for water and biological tissues, and 20 µPa for air and other gases.
Spawning	The release or deposition of eggs and sperm, usually into water, by aquatic animals.

Acronyms

Acronym	Definition
AET	Apparent Effects Thresholds
AfL	Agreement for Lease
BGS	British Geological Society
CCS	Carbon Capture and Storage
CEA	Cumulative Effects Assessment
CFE	Controlled Flow Excavation
CIEEM	Chartered Institute of Ecology and Environmental Management
CPEMMP	Construction Project Environmental Management and Monitoring Plan
CPUE	Catch Per Unit Effort
DCO	Development Consent Order
dML	Deemed Marine Licence
DP	Dynamically Positioned
DTI	Department of Trade and Industry
ECC	Export Cable Corridor

Acronym	Definition
EEA	European Economic Area
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
ES	Environmental Statement
EUNIS	The European Nature Information System
GBS	Gravity Based Structure
GES	Good Environmental Status
HDD	Horizontal Directional Drilling
HFIG	Holderness Fishing Industry Group
HVAC	High Voltage Alternating Current
IBTS	International Bottom Trawl Surveys
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Survey
INNS	Invasive Non-Native Species
IPC	Infrastructure Planning Commission
JUV	Jack Up Vessel
LAT	Lowest Astronomical Tide
LSE	Likely Significant Effect
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zones
MDS	Maximum Design Scenario
MHWS	Mean High Water Springs
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MPA	Marine Protected Area
MPCP	Marine Pollution Contingency Plan
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
NE IFCA	North Eastern Inshore Fisheries and Conservation Authority
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
O&M	Operation and Maintenance
ORJIP	Offshore Renewable Joint Industry Project
OSPAR	Oslo Paris Convention (also known as Convention for the Protection of the Marine Environment of the North-East Atlantic)
OSS	Offshore Substation
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PSA	Particle Size Analysis
PTS	Permanent Threshold Shift
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SEL	Sound Exposure Level
SPA	Special Protection Area

Acronym	Definition
SPL	Sound Pressure Levels
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
TTS	Temporary Threshold Shift
UKCS	UK Continental Shelf
UKOOA	United Kingdom Offshore Operators Association
UXO	Unexploded Ordinance
VER	Valued Ecological Receptor
WTG	Wind Turbine Generator

Units

Unit	Definition
cm	Centimetres
dB	Decibel
dB re 1 µPa	Sound pressure level
dB re 1 µPa2 s	Sound exposure level
kJ	Kilojoules
km	Kilometre
l	Litre
m	Metre
mm	Millimetres
mg	Milligram
s	Seconds

3.1 Introduction

3.1.1.1 Orsted Hornsea Project Four Limited (hereafter the 'Applicant') is proposing to develop Hornsea Project Four Offshore Wind Farm (hereafter 'Hornsea Four') which will be located approximately 69 km from the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone (please see **Volume A1, Chapter A1: Introduction** for further details on the former Hornsea Zone). Hornsea Four will include both offshore and onshore infrastructure including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network (please see **Volume A1, Chapter 4: Project Description** for full details on the Project Design).

3.1.1.2 The Hornsea Four Agreement for Lease (AfL) area was 846 km^2 at the Scoping phase of project development. In the spirit of keeping with Hornsea Four's approach to Proportionate Environmental Impact Assessment (EIA), the project has due consideration to the size and location (within the existing AfL area) of the final project that is being taken forward to Development Consent Order (DCO) application. This consideration is captured internally as the "Developable Area Process", which includes Physical, Biological and Human constraints in refining the developable area, balancing consenting and commercial considerations with technical feasibility for construction.

3.1.1.3 The combination of Hornsea Four's Proportionality in EIA and Developable Area process has resulted in a marked reduction in the array area taken forward at the point of DCO application. Hornsea Four adopted a major site reduction from the array area presented at Scoping (846 km^2) to the Preliminary Environmental Information Report (PEIR) boundary (600 km^2), with a further reduction adopted for the Environmental Statement (ES) and DCO application (468 km^2) due to the results of the PEIR, technical considerations and stakeholder feedback. The evolution of the Hornsea Four Order Limits is detailed in **Volume A1, Chapter 3: Site Selection and Consideration of Alternatives** and **Volume A4, Annex 3.2: Selection and Refinement of the Offshore Infrastructure**.

3.1.1.4 This chapter of the ES presents the results of the EIA for the potential impacts of Hornsea Four on fish and shellfish ecology. Specifically, this chapter considers the potential impact of Hornsea Four seaward of Mean High Water Springs (MHWS) during its construction, operation and maintenance, and decommissioning phases.

3.1.1.5 The chapter provides a summary of the **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report** which should be reviewed alongside this chapter. The technical report provides a detailed characterisation of the Hornsea Four fish and shellfish study area and the wider southern North Sea fish and shellfish study area, based on existing literature sources, survey data from across the former Hornsea Zone, site-specific survey data of the Hornsea Four array area and offshore Export Cable Corridor (ECC), and includes information on fish and shellfish species of ecological importance and of commercial and conservation value.

3.2 Purpose

3.2.1.1 This primary purpose of this ES is to support the DCO application for Hornsea Four under the Planning Act 2008 (the 2008 Act).

3.2.1.2 The ES has been finalised following the completion of the pre-application consultation (see **B1.1: Consultation Report** and **Table 3.5**) and will accompany the application to the Planning Inspectorate (PINS) for development consent.

3.2.1.3 This ES chapter:

- Summarises the existing environmental baseline established from desk studies, project survey data and consultation;
- Presents the potential environmental effects on fish and shellfish ecology receptors arising from Hornsea Four, based on the information gathered and the analysis and assessments undertaken;
- Identifies any assumptions and limitations encountered in compiling the environmental information; and
- Highlights any necessary monitoring and/or mitigation measures which could prevent, minimise or reduce the possible environmental effects identified in the EIA process.

3.3 Planning and Policy Context

3.3.1.1 Planning policy on offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to fish and shellfish ecology, 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).

3.3.1.2 NPS EN-1 and NPS EN-3 include guidance on what matters are to be considered in the assessment. These are summarised in **Table 3.1** below.

Table 3.1: Summary of NPS EN-1 and EN-3 policy relevant to fish and shellfish ecology and consideration of the Hornsea Four assessment.

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the ES
"*Assessment of offshore ecology and biodiversity should be undertaken by the applicant for all stages of the lifespan of the proposed Offshore Wind Farm (OWF) and in accordance with the appropriate policy for OWF EIAs.*" (NPS EN-3 Paragraph 2.6.64)	Construction, operation, maintenance and decommissioning phases of Hornsea Four have been assessed in **Section 3.11**.
"*Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate.*" (NPS EN-3 Paragraph 2.6.65)	Consultation with relevant statutory and non-statutory stakeholders has been carried out from the early stages of Hornsea Four (see **Table 3.5** for a summary of consultation with regard to fish and shellfish).
"*Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational OWFs should be referred to where appropriate.*" (NPS EN-3 Paragraph 2.6.66)	Relevant data collected as part of post-construction monitoring from other OWF projects has informed the assessment of Hornsea Four (see **Section 3.11**).
"*The assessment should include the potential of the scheme to have both positive and negative effects on marine ecology and biodiversity.*" (NPS EN-3 Paragraph 2.6.67)	The assessment methodology includes the provision for assessment of both

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the ES
	positive and negative effects (see **Table 3.13**).
"The applicant should identify fish species that are the most likely receptors of impacts with respect to: *Spawning grounds;* *Nursery grounds;* *Feeding grounds;* *Over-wintering areas for crustaceans; and* *Migration routes."* (NPS EN-3 Paragraph 2.6.74)	Particular attention has been given to impacts on fish species at key life stages such as during spawning or on known nursery habitats (see **paragraph 3.7.1.5** *et seq.*).
"Where the development is subject to EIA the applicant should ensure that the ES clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance, on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity. The applicant should provide environmental information proportionate to the infrastructure where EIA is not required to help the Infrastructure Planning Commission (IPC) consider thoroughly the potential effects of a proposed project." (paragraph 5.3.3 in NPS EN-1)	The potential effects of Hornsea Four have been assessed in regard to international, national and local sites designated for ecological or geological features of conservation importance (See **Section 3.7.2**). Direct or indirect effects on features of relevant Special Area of Conservation (SAC) and Special Protection Area (SPA) sites are also considered in **B2.2: Report to Inform Appropriate Assessment** (RIAA).
"Many Sites of Special Scientific Interest (SSSI) are also designated as sites of international importance; those that are not, should be given a high degree of protection. Where a proposed development within or outside a SSSI is likely to have an adverse effect on a SSSI (either individually or together with other developments), development consent should not normally be granted. Where an adverse effect, after mitigation, on the site's notified special interest features is likely, an exception should only be made where the benefits (including need) of the development at this site clearly outweigh both the impacts on site features and on the broader network of SSSIs. The Secretary of State should use requirements and/or planning obligations to mitigate the harmful aspects of the development, and where possible, ensure the conservation and enhancement of the site's biodiversity or geological interest." (NPS EN-1 Paragraphs 5.3.10 and 5.3.11)	SSSIs within the region have been identified in **Section 3.7.2**, and any potential impacts to features of SSSIs have been assessed in **Section 3.11**.
"Marine Conservation Zones (MCZs) introduced under the Marine and Coastal Access Act (MCAA) 2009 are areas that have been designated for the purpose of conserving marine flora and fauna, marine habitat or features of geological or geomorphological interest. The Secretary of State is bound by the duties in relation to MCZs imposed by Sections 125 and 126 of the Marine and Coastal Access Act 2009." (NPS EN-1 Paragraph 5.3.12)	MCZs within the region have been identified in **Section 3.7.2**, and any potential impacts to fish and shellfish features of MCZs have been assessed in **Section 3.11**. A full assessment of impacts to MCZs is undertaken in **Volume A5, Annex 2.3: Marine Conservation Zone Assessment**.
"Development proposals provide many opportunities for building-in beneficial biodiversity or geological features as part of good design. When considering proposals, the IPC should maximise such opportunities in and around developments, using requirements or planning obligations where appropriate." (paragraph 5.3.15 in NPS EN-1)	Designed-in measures to be adopted as part of the Hornsea Four project are presented in **Section 3.8.2.**

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the ES
"Other species and habitats have been identified as being of principal importance for the conservation of biodiversity in England and Wales and thereby requiring conservation action. The Secretary of State should ensure that these species and habitats are protected from the adverse effects of development by using requirements or planning obligations." (NPS EN-1 Paragraph 5.3.17)	All species receptors, including those of principal importance for the conservation of biodiversity in England are summarised in **Section 3.7.1** (full description in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**), with valuation of these receptors in the context of their conservation importance considered in **Section 3.7.3**.
"The applicant should include appropriate mitigation measures as an integral part of the proposed development. In particular, the applicant should demonstrate that: *• During construction, they will seek to ensure that activities will be confined to the minimum areas required for the works;* *• During construction and operation best practice will be followed to ensure that risk of disturbance or damage to species or habitats is minimised, including as a consequence of transport access arrangements;* *• Habitats will, where practicable, be restored after construction works have finished; and* *• Opportunities will be taken to enhance existing habitats and, where practicable, to create new habitats of value within the site landscaping proposals."* (paragraph 5.3.18 in NPS EN-1)	As part of Hornsea Four's approach to delivering a proportionate EIA, the project has proposed a suite of Commitments to reduce or eliminate the effects of Hornsea Four. These Commitments are detailed in **Volume A4, Annex 5.2: Commitments Register**, with the Commitments of relevance to fish and shellfish are detailed in **Table 3.9**.

3.3.1.3 NPS EN-3 also highlight several factors relating to the determination of an application and in relation to mitigation. These are summarised in **Table 3.2** below.

Table 3.2: Summary of NPS EN-1 and EN-3 policy on decision making relevant to fish and shellfish ecology.

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the ES
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 potential effects on fish and shellfish ecology are presented within this chapter, with the assessment of effects presented within **Section 3.11** and the criteria for assessment presented in **Section 3.10**.
"The designation of an area as a European 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).	Designated sites within the region have been identified in **Section 3.7.2**, and any potential impacts to features of the sites have been assessed in **Section 3.11**. The offshore ECC has been routed to avoid passing through the Holderness Inshore MCZ and the Holderness Offshore MCZ, as part of the proportionate approach to EIA.

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the ES
"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).	As part of Hornsea Four's approach to delivering a proportionate EIA, the project has proposed a suite of Commitments to reduce or eliminate the effects of Hornsea Four. These Commitments are detailed in **Volume A4, Annex 5.2: Commitments Register**, with the Commitments of relevance to fish and shellfish are detailed in **Table 3.9**.
"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).	The requirement for fish and shellfish monitoring has been considered within the impact assessment in **Section 3.11**. In summary, no fish and shellfish monitoring for the construction, operation or decommissioning phases of Hornsea Four is considered necessary at this stage.
Fish and Shellfish Ecology	
"Where it is proposed that mitigation measures are applied to offshore export cables to reduce electromagnetic fields (EMF) (see below) the residual effects of EMF on sensitive species from cable infrastructure during operation are not likely to be significant. Once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement." (paragraph 2.6.75 of NPS EN-3)	The impacts of EMF on fish and shellfish receptors have been considered and scoped out at the Scoping stage (see **Section 3.8.1** and **Volume A4, Annex 5.1: Impacts Register**).
"EMF during operation may be mitigated by use of armoured cable for inter array and export cables which should be buried at a sufficient depth." (paragraph 2.6.76 of NPS EN-3).	The impacts of EMF on fish and shellfish receptors have been considered and scoped out at the Scoping stage (see **Section 3.8.1** and **Volume A4, Annex 5.1: Impacts Register**).
"During construction, 24 hour working practices may be employed so that the overall construction programme and the potential for impacts to fish communities are reduced in overall time." (paragraph 2.6.77 of NPS EN-3).	Hornsea Four can confirm that 24 hour working practices will be employed for offshore construction works (**Volume A1, Chapter 4: Project Description**).

3.3.1.4 A number of other policies are relevant to fish and shellfish ecology. The Marine Policy Statement (MPS) (2011) 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 the conservation of ecologically sensitive areas throughout the planning process and the need for mitigation or compensatory actions where significant harm cannot be avoided (paragraph 2.6.1 of the MPS).

3.3.1.5 The assessment of potential changes to fish and shellfish ecology has also been made with consideration to the specific policies set out in the East Inshore and East Offshore Coast Marine Plans (Marine Management Organisation (MMO) 2014a). Key provisions are set out in **Table 3.3** along with details as to how these have been addressed within the EIA.

Table 3.3: East Marine Plan Policies of relevance to fish and shellfish ecology.

Policy	Key provisions	How and where considered in the ES chapter
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 3.12.
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 within the Hornsea Four study area have been described Volume A5: Annex 3.1 Fish and Shellfish Technical Report. The predicted changes to fish and shellfish ecology have been considered in Section 3.11.

3.3.1.6 The Marine Strategy Framework Directive (MSFD), adopted in July 2008, has also been considered in the Hornsea Four assessment for fish and shellfish ecology. The overarching goal of the Directive 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 fish and shellfish ecology assessment for Hornsea Four are listed in Table 3.4, including a brief description of how and where these have been addressed in the Hornsea Four assessment.

Table 3.4: Summary of the Marine Strategy Framework Directive's (MSFD) high level descriptors of GES relevant to fish and shellfish ecology and consideration in the Hornsea Four assessment.

Summary of MSFD high level descriptors of GES relevant to fish and shellfish ecology	How and where considered within the ES chapter
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 have been described and considered within the assessment for Hornsea Four alone and in the Cumulative Effects Assessment (CEA) (see Section 3.12).
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 fish and shellfish ecology within Hornsea Four have been scoped out of the assessment (see Section 3.8.1 and Volume A4, Annex 5.1: Impacts Register).
Descriptor 3: Commercial species. The population of commercial fish species is healthy.	The effects on commercial fish and shellfish species has been described and considered within the assessment for Hornsea Four alone and in the CEA (see Sections 3.11 and 3.12.2, respectively).
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	The effects on fish and shellfish ecology has been described and considered within the assessment for Hornsea Four alone and in the CEA (see Sections 3.11 and 3.12), respectively).

Summary of MSFD high level descriptors of GES relevant to fish and shellfish ecology	How and where considered within the ES chapter
species and the retention of their full reproductive capacity.	
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 on fish and shellfish ecology has been described and considered within the assessment for Hornsea Four alone and in the CEA (see Sections 3.11 and 3.12)., respectively).
Descriptor 8: Contaminants. Concentrations of contaminants are at levels not giving rise to pollution effects	The effects of contaminants on fish and shellfish ecology have been assessed in paragraphs 3.11.1.41 *et seq.* (construction) and paragraphs 3.11.3.10 *et seq.* (decommissioning).
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 fish and shellfish ecology have been assessed in paragraphs 3.11.1.41 *et seq.* (construction) and paragraphs 3.11.3.10 *et seq.* (decommissioning).
Descriptor 10: Marine litter. Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	A Construction Project Environmental Management and Monitoring Plan (CPEMMP) will be produced for Hornsea Four (Co111). The CPEMMP will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details. A Decommissioning Programme (Co181) will be developed prior to construction as part of the pre-commencement documentation to cover the decommissioning phase.
Descriptor 11: Energy incl. Underwater Noise. Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.	The effects of underwater noise on fish and shellfish ecology have been assessed in paragraphs 3.11.1.45 *et seq.* (construction) and paragraphs 3.11.3.12 *et seq.* (decommissioning).

3.4 Consultation

3.4.1.1 Consultation is a key part of the DCO application process. Consultation regarding fish and shellfish ecology has been conducted through Evidence Plan Technical Panel meetings, the EIA scoping process (Orsted 2018), and formal consultation on the PEIR. An overview of the project consultation process is presented within Volume A1, Chapter 6: Consultation.

3.4.1.2 Agreements made with consultees within the Evidence Plan process are set out in the topic specific Evidence Plan Logs which are appendices to the Hornsea Four Evidence Plan (Volume B1, Annex 1.1: Evidence Plan), an annex of the Hornsea Four Consultation Report (Volume B1, Chapter 1: Consultation Report). All agreements within the Evidence Plan Logs have unique identifier codes which have been used throughout this document to signpost to the specific agreements made (e.g. OFF-ME&P-2.1).

3.4.1.3 The key issues raised during consultation specific to fish and shellfish ecology are outlined below in Table 3.5, together with how these issues have been considered in the production of this ES.

Table 3.5: Consultation Responses.

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting One 12 September 2018	Cefas noted that they were aware of high levels of arsenic in the muds across the former Hornsea Zone and this should be considered in the assessment.	Sediment contaminants are assessed in **Section 3.11**.
PINS	Scoping Opinion 23 November 2018	The ES must include a full noise modelling methodology and demonstrate how it has been applied to the assessment. Effort should be made by the Applicant to agree the methodology with relevant consultees.	The methodology for the noise modelling undertaken for this assessment has been agreed by the relevant consultees via the Evidence Plan process (OFF-ME&P-2.1), and is detailed in **Volume A4, Annex 4.5: Subsea Noise Technical Report**. Impacts of subsea noise on fish and shellfish receptors have been assessed in **Section 3.11**.
		The ES must ensure a robust assessment and should demonstrate that the data applied to identify sensitive receptors is relevant and up to date. Any limitations should be acknowledged and their implications for the assessment should be discussed in the ES.	Relevant and up-to-date data has been used to inform the baseline and to identify sensitive species in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**. Data limitations have been acknowledged in **Section 3.7.5**.
MMO	Scoping Opinion 23 November 2018	The MMO state that the data presented to inform the EIA must acknowledge survey limitations, including survey methods, timings and the limitations of survey and gear types including whether selected gear types will adequately target all species.	Data limitations have been acknowledged in **Section 3.7.5**.
		The MMO recommends that spawning and nursery ground maps are presented separately from trawl catch data.	The spawning and nursery grounds of fish and shellfish and trawl catch data are presented separately in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.
		The MMO recommended that trawl catch data should be presented in standardised units, e.g. Catch Per Unit Effort (CPUE).	The trawl catch data are presented in CPUE where applicable in the **Volume A5, Annex 3.1: Fish and Shellfish Ecology Baseline Technical Report**.
		Information on the assessment of impacts to migratory fish is	It was agreed with the Evidence Plan Technical Panel that herring and sandeel

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
		limited in the Scoping Report. Potential impacts from construction and operational activities should be adequately assessed in relation to migratory fish transiting the area to/from the river Humber. The Environment Agency carry out fisheries surveys to monitor coastal and transitional waters, including the river Humber.	would be the key marine species which may be vulnerable to the impacts of the construction and operation of Hornsea Four (OFF-ME&P-2.2). Migratory fish are considered in **Section 3.7**, with further detail provided in Section 3.3 of **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.
		The MMO agree with the identification of herring and sandeel as the key marine species which may be vulnerable to the impacts of the construction and operation of Hornsea Four.	Noted. It was agreed with the Evidence Plan Technical Panel that herring and sandeel would be the key marine species which may be vulnerable to the impacts of the construction and operation of Hornsea Four (OFF-ME&P-2.2).
		The MMO do not consider it possible to conduct a robust analysis of potential herring spawning or sandeel habitat due to the lack of Particle Size Analysis (PSA) data for this area. The MMO recommend that an assessment of sandeel habitat suitability is undertaken as part of the EIA. This should use PSA data from grab samples collected within the array and export cable corridor areas, and the assessment carried out using the method described in Latto et al. (2013).	Particle size data has been collected along the offshore ECC, and within the array area, and a robust assessment of habitat suitability for herring spawning and sandeel habitat has been undertaken in **Section 3.11**.
		The MMO considers that potential cumulative impacts to sandeel should be adequately assessed.	Potential cumulative impacts on sandeel have been assessed in **Section 3.12**.
		The MMO recommend that a species-specific assessment of potential spawning habitat is undertaken as part of the EIA, using the method described in MarineSpace (2013). The assessment should be supported by 10 years of	A species-specific assessment on the potential impacts to herring has been undertaken in **Section 3.11**, which is supported by 10 years of IHLS data.

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
		International Herring Larvae Survey (IHLS) data.	
Environment Agency	Scoping Opinion 23 November 2018	Piling activities may affect salmonoid fish returning to the Humber estuary, so appropriate mitigation should be in place for this activity.	Mitigation measures of relevance to fish and shellfish ecology are detailed in Section 3.8.2.
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting Two 12 December 2018	The use of IHLS data was discussed in relation to it being used to identify areas of recent spawning activity.	IHLS data have been presented as 'heat maps' in Figure 3.8 to Figure 3.15.
MMO	Response to Marine Ecology and Processes Fish Technical Note from the MMO received on 25 February 2019	The MMO agreed that IHLS data will provide the greatest confidence for determining areas where active spawning is taking place.	IHLS data have been presented as 'heat maps' in Figure 3.8 to Figure 3.15.
		The MMO supports the use of International Bottom Trawl Surveys (IBTS) data to inform the characterisation of spawning herring habitat and to provide data on herring functional maturity analysis. The MMO recommends that complete datasets for the North Sea are utilised i.e. from all participating countries.	Analysis of complete IBTS datasets are used to provide data on the presence of functionally mature herring, these data have been used to inform the Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report.
		The MMO recommends that maturity class 62 is included in the functionally mature group along with class 63 (actively spawning fish) and 64 (recently spawned fish).	Maturity classes 62, 63 and 64 are all considered functionally mature for the purposes of the Hornsea Four assessment. The distribution of these classes are presented in Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report.
		The MMO stated that in order to delineate the spawning grounds, the specific substrate requirements of herring required for them to spawn need to be considered.	The specific substrate requirements of herring required to spawn have been identified and the characterisation of them has been supported with PSA data as illustrated in Figure 3.6.
		It was agreed that the EIA must accurately characterise and assess impacts to spawning herring caused by disturbance to and/or loss of spawning herring habitat using PSA data	Impacts to spawning herring (using PSA data) are assessed in paragraphs 3.11.2.20 *et seq*.

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
		of sufficient coverage to characterise the array and ECC.	
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting Three 30 April 2019	Agreement from Cefas on the fish and shellfish assessment only considering herring and sandeel (OFF-ME&P-2.2).	These assessments are undertaken in **Section 3.11**.
Holderness Fishing Industry Group (HFIG) and MMO	Section 42 consultation, 20 September 2019	Request for consideration of the potential impacts to shellfish fisheries, particularly edible crab and lobster.	Additional information on edible crab and lobster have been added to **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**. Impacts on edible crab and lobster have been considered in **Section 3.11**. Potential impacts to shellfish fisheries have also been considered in **Chapter 6: Commercial Fisheries**.
HFIG	Section 42 consultation 20 September 2019	Request for a monitoring programme to be commissioned for edible crab and lobster.	Disturbance impacts to shellfish, such as crab and lobster, are expected to be limited during construction and maintenance activities on a very localised scale, and as such it is not expected that there will be any detrimental impacts on spawning grounds or settlement of larvae (see **Volume A4, Annex 5.1: Impacts Register**). As such, no monitoring has been proposed.
North Eastern Inshore Fisheries and Conservation Authority (NE IFCA)	Section 42 consultation, 23 September 2019	Concern raised over the potential for impacts on brown crab spawning, particularly within the array area.	Additional justification has been provided within **Section 3.11** to justify why impacts to brown crab spawning grounds will not be significant.
MMO and Natural England	Section 42 consultation, 23 September 2019	Concerns raised over the lack of data for the ECC, which crosses a main area for herring spawning.	Particle size data has been collected along the offshore ECC, and figures and assessments have been updated accordingly in **Section 3.11**.
MMO and Natural England	Section 42 consultation, 23 September 2019	Noted that underwater noise modelling did not take account of simultaneous piling	Updated noise modelling and an assessment of simultaneous piling has been undertaken and the assessment updated accordingly in **Section 3.11**.
MMO and Natural England	Section 42 consultation, 23 September 2019	Noted that the CEA needs to consider all relevant projects.	The CEA in **Section 3.12** has been updated to include all relevant projects.
MMO and Natural	Section 42 consultation,	Request for consideration of seasonal restrictions to	Mitigation options have been discussed through the Evidence Plan process and a

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
England	23 September 2019	mitigate impact to herring during the spawning season.	commitment has been made to a seasonal piling restriction at the High Voltage Alternating Current (HVAC) booster stations during the herring spawning season (Co190) as detailed in Section 3.8.2.
Natural England	Section 42 consultation, 23 September 2019	Concerns raised that no monitoring of herring and sandeel has been proposed.	Updated data and assessments have been provided in Section 3.11 to provide additional confidence that no significant effects are predicted (with the inclusion of mitigation where appropriate).
Natural England	Section 42 consultation, 23 September 2019	Clarity requested on the size of the buffers used to delineate the fish and shellfish study area.	Additional marine processes modelling was undertaken (as presented in Appendix C of Volume A5, Annex 1.1: Marine Processes Technical Report), the results of which have been used to define a study area around both the array area and the offshore ECC in relation to the appropriate tidal cycles.
Natural England	Section 42 consultation, 23 September 2019	Requested that the assessment considers the direct disturbance resulting from maintenance during operation.	This impact has been scoped into the assessment for fish and shellfish (FSE-O-10) and is considered in paragraph 3.11.2.43 *et seq.*
MMO	Section 42 consultation, 23 September 2019	Full assessment requested for Unexploded Ordnance (UXO) clearance works with associated mitigation in place.	It is not proposed to licence UXO clearance as part of this DCO application, and therefore the need for specific mitigation measures is not considered within this assessment. Nevertheless, UXO clearance activities have been considered within the assessment in Section 3.11 and updated to include reference to mitigation options for UXO clearance works to be agreed with the regulator at the relevant time.
MMO	Section 42 consultation, 23 September 2019	Noted that spawning for the Banks/Dogger herring population in the North Sea occurs from August to October inclusive, rather than September to October inclusive.	Spawning timings of herring have been updated in Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report in accordance with the International Council for the Exploration of the Sea (ICES) Report of the Herring Assessment Working Group (2018), and Coull et al. (1998).
MMO	Section 42 consultation, 23 September 2019	Monitoring of shellfish populations requested.	The assessment presented in Section 3.11 has been updated with additional consideration of impacts to shellfish species to provide additional confidence that no significant effects are predicted

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
			(with the inclusion of mitigation where appropriate).
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting Three 13 November 2019	It was agreed that scallop, crab, lobster and *Nephrops* would be considered within the fish and shellfish ecology assessment.	The potential for impacts on scallop, crab, lobster and *Nephrops* have been assessed in **Section 3.11**.
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting Four 11 May 2021	Discussions around the spawning seasonal restriction proposed by Hornsea Four – Hornsea Four agreed to submit a technical note to detail the justification for the suggested restriction timings.	Hornsea Four are producing a technical note that will be submitted to the MMO and its advisors post-application which details the justification for the suggested seasonal restriction timings and which will be subject to discussion in developing the SoCG..

3.5 Study area

3.5.1.1 The Hornsea Four fish and shellfish study area (**Figure 3.1**) has been defined based on the relevant potential impacts on fish and shellfish receptors, including the direct and indirect impacts from sediment disturbance.

3.5.1.2 The study area has been determined based on the equivalent distance of tidal excursion on a mean spring tide; this is defined by a 14 km buffer surrounding the offshore ECC based on nearshore flows, and a 10 km buffer encompassing the array area, representing the slightly weaker offshore flows as informed by **Chapter 1: Marine Geology, Oceanography and Physical Processes**, in order to incorporate the maximum distance sediments will travel in one tidal cycle (Appendix C of **Volume A5, Annex 1.1: Marine Processes Technical Report**).

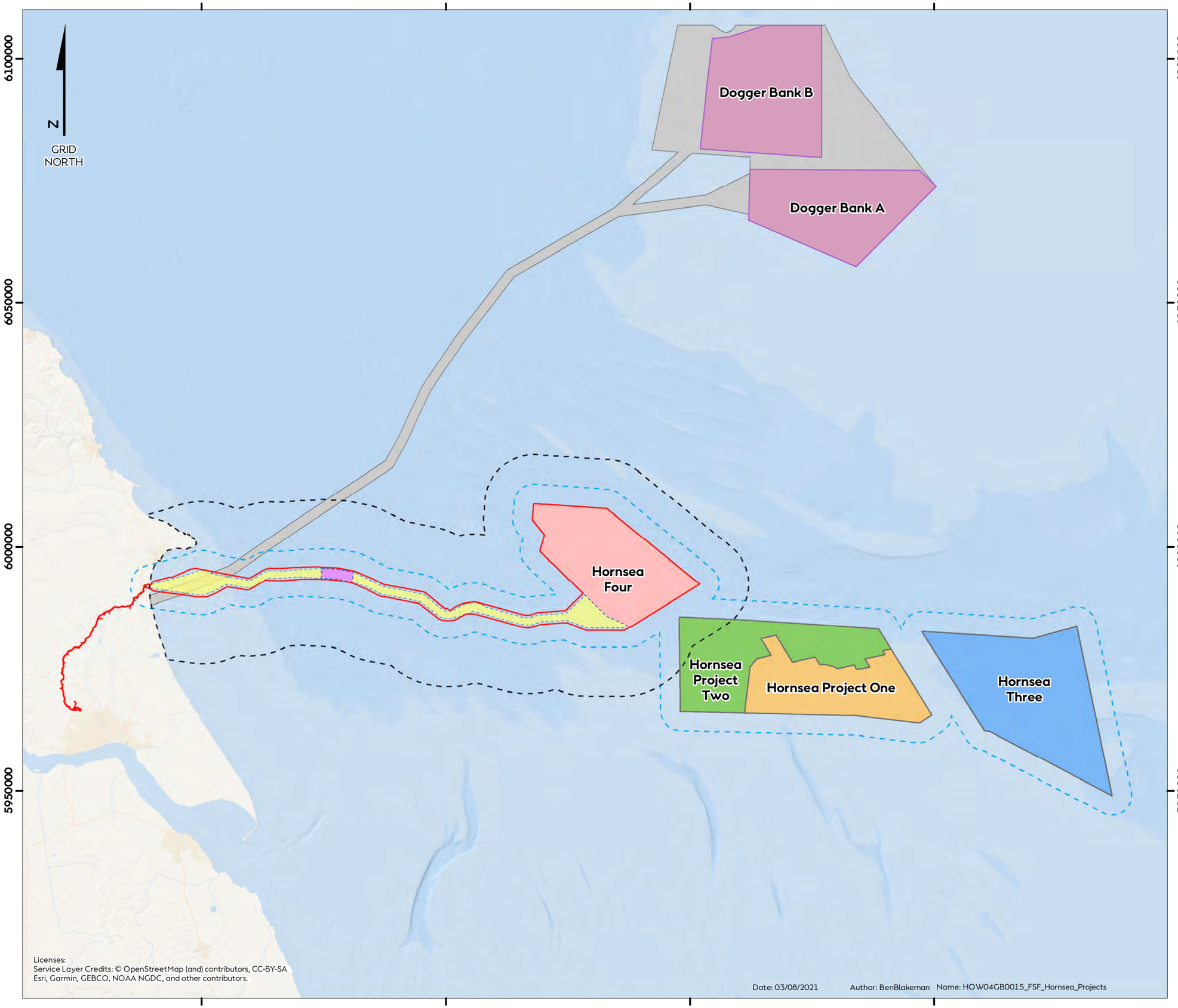
3.5.1.3 Impacts from underwater noise have been considered in relation to the habitats found throughout the wider Southern North Sea biogeographic region and data available on the spawning and nursery grounds for species within this area.

3.5.1.4 A wider study area has also been used to provide regional context; this extends to encompass Hornsea Project One Offshore Wind Farm (hereafter Hornsea Project One), Hornsea Project Two Offshore Wind Farm (hereafter Hornsea Project Two) and Hornsea Project Three Offshore Wind Farm (hereafter Hornsea Three), plus a 4 km buffer which was surveyed as part of the former Hornsea Zone surveys (**Table 3.7**).

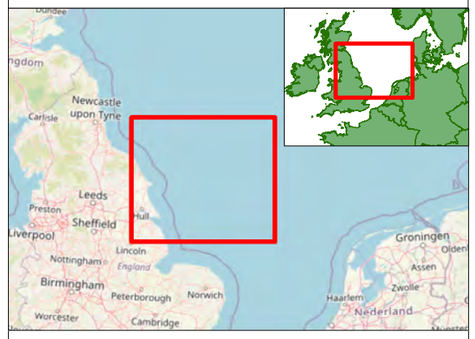
Hornsea Four

Figure 3.1

Hornsea Four Fish and Shellfish Study Area



- Fish and Shellfish Study Area
- 4km Buffer from Hornsea projects, Hornsea Four array and Hornsea Four Offshore Export Cable Corridor
- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Hornsea Project One
- Hornsea Project Two
- Hornsea Three
- Dogger Bank A & B
- Dogger Bank A & B Export Cable Corridor



Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:750,000

0 20 40 Kilometres

0 10 20 Nautical Miles

REV	REMARK	DATE
...	First Issue for PEIR	08/05/2019
A	Updated following PEIR consultations, for DCO	03/08/2021

The location of Hornsea Four and other Hornsea projects
Document no: HOW04GB0015
Created by: BPHB
Checked by: AdB
Approved by: LK

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3.6 Methodology to inform baseline

3.6.1 Evidence-Based Approach

3.6.1.1 The approach taken to develop a robust characterisation of the fish and shellfish ecology baseline environment for Hornsea Four was evidence-based, combining a review of existing data and information from sufficiently similar or analogous studies to inform the baseline understanding (and/or impact assessments) for a new proposed development with the analysis of site-specific survey data, and a comprehensive desktop study. Further details on the evidence-based approach undertaken are detailed in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.

3.6.2 Desktop Study

3.6.2.1 Information on fish and shellfish ecology within the Southern North Sea and within the nearshore area of the offshore ECC was collected through a detailed desktop review of existing studies and datasets. The key data sources are summarised in **Table 3.6** below, although this should not be considered an exhaustive list of references, with further detail, including species specific information sources, presented within **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.

3.6.3 Site-Specific Surveys

3.6.3.1 In order to inform the EIA, survey data collected from across the former Hornsea Zone, along with site specific surveys, have been used to inform the baseline characterisation, as discussed with the Marine Processes and Ecology Evidence Plan Technical Panel. A summary of these historic surveys and the Hornsea Four site-specific surveys are outlined in **Table 3.7**. Further detail on these surveys is presented within **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.

3.6.4 Herring larval data analysis

3.6.4.1 Technical guidance from the Offshore Renewable Joint Industry Project (ORJIP) report (Boyle and New 2018), a report on the methodology undertaken for data analysis to determine impacts from piling, was utilised to categorise herring larval data to display 'hot spots' for herring spawning activity. The full methodology followed is detailed in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.

Table 3.6: Key Sources of Fish and Shellfish data.

Source	Summary	Spatial coverage	Temporal coverage
IBTS (2021)	Data collected annually in spring and autumn using demersal fishing gear to estimate stock abundance of commercially important demersal species.	Broadscale data that covers much of the North Sea including the Hornsea Four array area and offshore ECC.	1972 – 2021
Cefas 2015 full coverage Folk and European Nature Information System (EUNIS) map (Stephens and Diesing 2015)	Spatial Folk and EUNIS dataset.	Dataset with regional coverage of the northern North Sea and the southern North Sea.	Continuous
Creyke Beck Environmental Statement and survey data (Forewind 2013) (hereafter referred to as Dogger Bank A and B).	An inshore shellfish survey was carried out in 2011 and 2012. Three inshore trammel net surveys were completed in 2011, 2012 and 2013. An epibenthic beam trawl survey was undertaken in 2011.	Data within the nearshore area of the Hornsea Four offshore ECC.	2011-2013
Fish spawning and nursery areas in UK waters (Coull et al. 1998; Ellis et al. 2010; 2012)	Both studies map the distribution of predicted spawning and nursery habitats of a number of key species in waters around the UK based on a review of extant data.	Data across the North Sea, English Channel, Celtic Sea and the Irish Sea.	Coull et al. (1998) 1991-1996; and Ellis et al. (2010; 2012) 1990-2008
IHLS data (ICES 2007–2021)[1]	The surveys are designed to provide a quantitative estimate of herring larval abundance to be used as a relative index of the changes in herring spawning stock biomass.	Dataset with regional coverage across the northern North Sea and the southern North Sea.	1967-2021
Technical reports for Strategic Environmental Assessment (SEA) Areas 2 and 3 (Department of Trade and Industry (DTI) 2001a; DTI 2001b)	Description of survey data published in the SEA for the northern North Sea and the southern North Sea.	Broadscale data with regional coverage of the northern North Sea and the southern North Sea.	Continuous
British Geological Society (BGS) Marine Sediment Particle Size dataset sourced from the BGS GeoIndex Offshore portal[2]	Spatial dataset of a range of remotely sensed and physical ground-truthing data showing the distribution of sea-bed sediment types.	Spatial data within The UK Continental Shelf (UKCS) area.	1966-2019
Hornsea Project Two Array Survey (2012)	An epibenthic beam trawl campaign was completed in July 2012.	The Hornsea Project Two sampling locations are located to the east of the Hornsea Four array area.	2012

[1] http://www.ices.dk/marine-data/data-portals/pages/eggs-and-larvae.aspx).
[2] https://www.bgs.ac.uk/GeoIndex/offshore.htm#BGSOffMar

Source	Summary	Spatial coverage	Temporal coverage
Hornsea Project One Array Survey (2010 - 2011)	An epibenthic beam trawl campaign was completed in July 2010.	The Hornsea Project One sampling locations are located to the east of the Hornsea Four array area.	2010-2011
Hornsea Three baseline characterisation study (Orsted 2018)	An epibenthic beam trawl campaign was completed in 2017.	The Hornsea Three sampling locations are located to the east of the Hornsea Four array area.	2017

Table 3.7: Summary of site-specific survey data.

Source	Summary	Coverage of Hornsea Four Order Limits
Hornsea Four Offshore Wind Farm Array Area, Habitat Classification Report (Gardline 2019) **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report Appendix A**	Site specific grab surveys within the Hornsea Four array were undertaken, with PSA conducted using the grab samples.	Samples collected from within the Hornsea Four array area; the sampling locations are detailed in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.
Hornsea Four Offshore Wind Farm Export Cable Corridor, Benthic Ecology Baseline Characterisation Report (GoBe 2020) **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report Appendix D**	Site specific grab surveys along the Hornsea Four array ECC were undertaken, with PSA conducted using the grab samples.	Samples collected along the Hornsea Four ECC; the sampling locations are detailed in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.
Hornsea Zone Characterisation (ZoC) Survey (2010 - 2011)	Otter trawl surveys (2011) and epibenthic beam trawl surveys (2010).	Distributed across the whole former Hornsea zone, and within the Hornsea Four array area.

3.7 Baseline environment

3.7.1 Existing baseline

3.7.1.1 A detailed characterisation of the fish and shellfish baseline environment is provided in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**, with a summary provided here. This ES chapter should therefore be read alongside the detailed fish and shellfish characterisation annex. The baseline characterisation is informed by data collected across the former Hornsea Zone (**Table 3.7**).

3.7.1.2 The fish communities within the study area (including the wider 4 km buffer around all Hornsea projects) are broadly comprised of demersal species, with high abundances of whiting *Merlangius merlangus*, dab *Limanda limanda*, plaice *Pleuronectes platessa,* solenette *Buglossidium luteum* and grey gurnard *Eutrigula gurnardus* observed within Hornsea Three and Dogger Bank A and B baseline characterisation surveys. Spatial variability could be a factor influencing species composition across the study area, with deeper offshore areas (**Figure 3.2**), including the Hornsea Four array area having increased abundances of whiting, and shallower inshore areas, proximal to the nearshore section of the ECC having higher occurrences of dab and crustaceans (from Hornsea Three and Dogger Bank A and B baseline characterisation surveys.

3.7.1.3 Pelagic species recorded within the study area included sprat *Sprattus sprattus*, herring *Clupea harengus*, and mackerel *Scomber scombrus*, with sprat and herring being a key characterising species of the otter and beam trawl surveys (noting that these survey methods are not specifically designed to sample pelagic species). All three species showed seasonal variability in abundance, with sprat and herring having higher abundances in spring, and mackerel being more abundant in autumn within the proposed array area.

3.7.1.4 Sandeel *Hyperoplus lanceolatus* and *Ammodytes tobianus* were generally recorded at low abundances during otter and bream trawl surveys proximal to the array area, compared to many of the other characterising species. It should be noted however, these survey methods are not specifically designed to sample sandeel. Sandeel abundances as recorded during trawl surveys across the study area were generally found to be highest to the west of the Hornsea Four array area.

3.7.1.5 Nursery and spawning habitats within the Hornsea Four study area were categorised by Ellis et al. (2012) as either high or low intensity, dependant on the level of spawning activity or abundance of juveniles recorded within these habitats. Coull et al. (1998) does not provide this level of detail but has been used for species where spawning activity data is scarce. These spawning and nursery habitats (including mapping of these relative to Hornsea Four) are fully discussed in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**. Herring and sandeel are of particular relevance when considering impacts to spawning areas as they are demersal spawners, laying their eggs in the sediment. It has been confirmed within the Marine Processes and Ecology Evidence Plan Technical Panel meetings, and supported by Cefas, that these species should be the focus of the assessment (OFF-ME&P-2.2).

3.7.1.6 Potential sandeel habitats were mapped using PSA data (using data from EUNIS and Folk (1954) and Stephens and Diesing (2015)), and site-specific PSA data across the array from the Hornsea Four Offshore Wind Farm Array Area Habitat Classification Report (Gardline 2019) (Appendix A of **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**) as well as data from the Hornsea Four Offshore Wind Farm Export Cable Corridor, Benthic Ecology Baseline Characterisation Report (GoBe 2020) (Appendix D of **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**) showing the PSA data along the ECC. These data were processed according to the methodologies described in Latto et al. (2013). This analysis allowed for identification of "preferred", "marginal" and "unsuitable" sandeel habitats in the Hornsea Four fish and shellfish study area (full details of these methodologies are presented in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**). The results of these analyses largely reflected the patterns identified by the Hornsea Three and Dogger Bank A and B surveys discussed above (note that sandeel preferred habitats are contiguous with potential sandeel spawning habitat). Sandeel habitats were considered to be "preferred" across most of the Hornsea Four array, and offshore section of the ECC. The nearshore ECC was characterised by coarser gravelly sediments and assigned a "marginal" to "unsuitable" preference for sandeel (**Figure 3.5**).

3.7.1.7 Herring spawning areas were identified using the IHLS dataset (ICES 2007-2021), showing areas of high intensity spawning activity within the region (**Figure 3.4**). This data largely reflects patterns shown by PSA data (data from EUNIS and Folk (1954) and Stephens and Diesing 2015)) and from site specific PSA data across the array and along the ECC (Appendix A and Appendix D of **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**, respectively). These data were processed according to the methodologies described in Reach et al. (2013), which allowed the classification of "preferred", "marginal" and "unsuitable" herring habitats in the study area (**Figure 3.6**) (full details of these methodologies and results are detailed in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**. High intensity spawning areas, as identified by the IHLS data, are located north of the ECC and HVAC booster station search area, with areas of generally low intensity spawning overlapping with the ECC and HVAC booster station search area (**Figure 3.4**). Whilst for the 2019/2020 and 2020/2021 seasons, the highest densities for herring spawning appear to partially overlap with the ECC, this represents a minor overlap with the high density area which extends over a wide region. The 2019/2020 and 2020/2021 seasons also present generally high values across the survey area, giving a somewhat exaggerated appearance due to the standardised scaling of the IHLS data year to year of the relative importance of the ECC to the spawning grounds for herring on the fixed scale used in the figures (i.e., the fixed scale between years shows the relative change in abundance recorded year to year but can therefore result in a loss of detail regarding "hot spot" locations if wider areas have high abundances in that year). Herring spawning habitats, as identified by the PSA datasets, were considered to be "preferred" and "marginal" across the nearshore section of the ECC, with "unsuitable" spawning habitats located north of the ECC and across much of the offshore section of the ECC and the array area. The general spawning period for North Sea herring stocks (namely the Buchan, Shetland and Banks stocks) is considered to be from August to October, with spawning activity commencing earlier for the more northern stocks (Buchan and Shetland) and being somewhat delayed for the Banks stock, with spawning onset for herring being temperature dependant (ICES 2013). As

such, it is considered that the peak spawning period for the Banks stock is September to October, with this being aligned with the timings used for the IHLS for this stock.

3.7.1.8 Shellfish of commercial importance to the region include brown crab *Cancer pagurus*, *Nephrops norvegicus*, European lobster *Homarus gammarus*, velvet swimming crab *Necora puber*, common whelk *Buccinum undatum*, brown and pink shrimp *Crangon crangon*, *Pandulus montagui* and king scallop *Pecten maximus*. European common squid *Alloteuthis subulate* were identified as the most common cephalopod in the region, and velvet swimming crab were recorded in the greatest abundance in potting surveys carried out in the nearshore section of the ECC. The European common squid and the velvet swimming crab are both widespread across the North Sea.

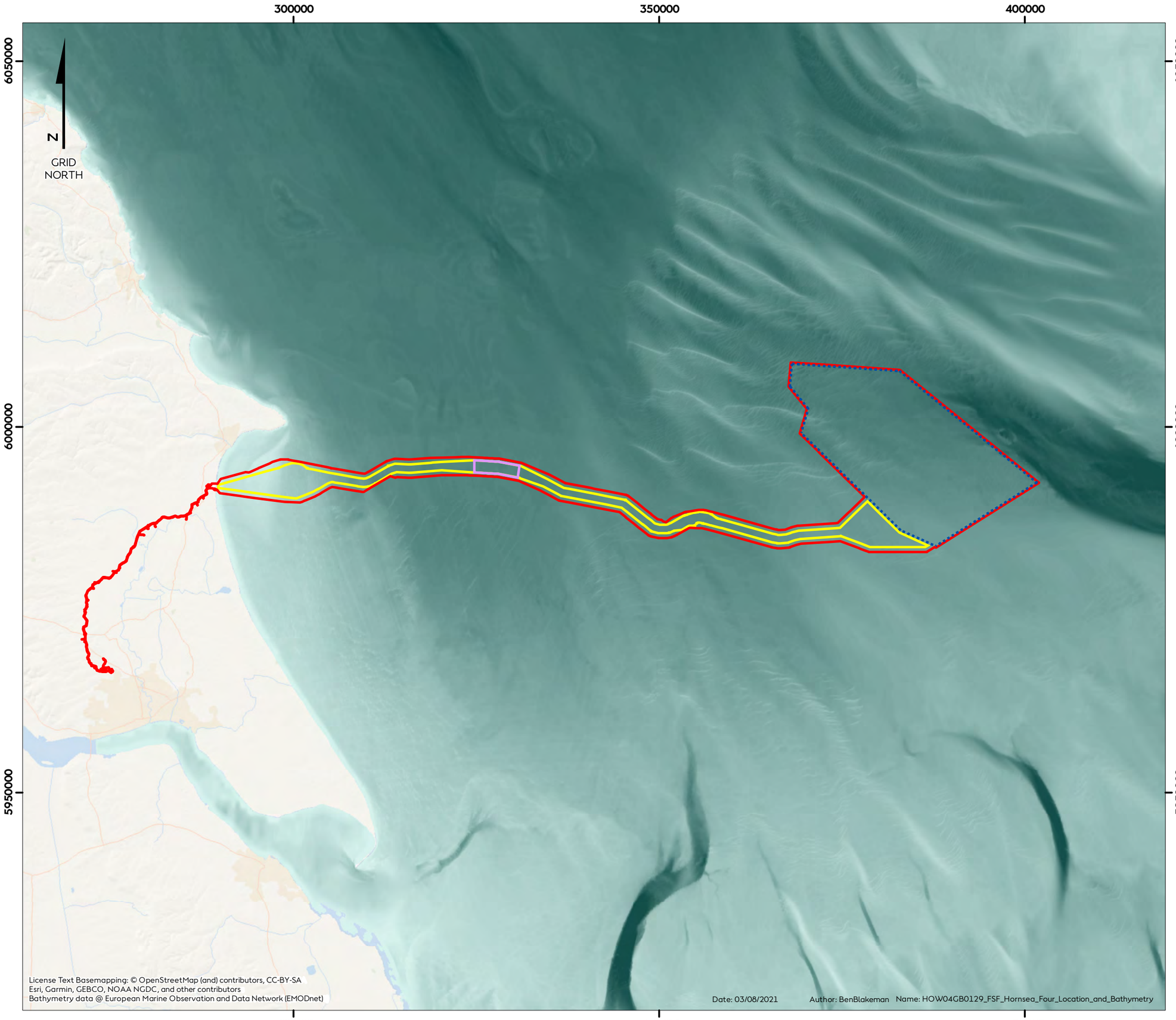
3.7.1.9 Low abundances of brown and pink shrimp were recorded in the study area; both species of shrimp are common across the North Sea. Brown crabs were recorded in relatively low abundances across the array. Two brown crab spawning grounds (Eaton et al. 2004) were identified in the fish and shellfish study area, with one spawning ground directly overlapping the ECC, and the other intersecting the north west corner of the array area. *Nephrops* were recorded across the study area, with spawning and nursery habitats (Coull et al. 1998) identified within the eastern side of the study area but absent in the array and offshore ECC area. Lobster was recorded in potting surveys in the nearshore section of the ECC, and sporadically south of the study area in low abundances. Lobster overwintering and nursery grounds are typically located on rocky coastal areas (Bennet et al. 2006) and may be present in nearshore waters closer to the Humber Estuary (SMart Wind 2015a), although this is hard to determine due to the lack of data for this species. Despite common whelk being a commercial important species in the region, no common whelk was recorded within the study area, however, they are common off all British coasts, and are distributed from Iceland and Norway to the Bay of Biscay and throughout the North Atlantic (Ager 2008). Scallop were recorded within the more nearshore section of the ECC, and in low abundances along the ECC. Two main king scallop beds have been identified in the region (Cefas 2019), with one bed directly overlapping the ECC and part of the proposed HVAC booster station search area.

3.7.1.10 The current baseline description above provides an accurate reflection of the current state of the existing environment. The earliest possible date for the start of construction is August 2026, with an expected operational life of 35 years, and therefore there exists the potential for the baseline to evolve between the time of assessment and point of impact. Outside of short-term or seasonal fluctuations, changes to the baseline in relation to fish and shellfish ecology usually occur over an extended period of time (considered below). Based on current information regarding reasonably foreseeable events over the next six years, the baseline is not anticipated to have fundamentally changed from its current state at the point in time when impacts occur. The baseline environment for operational/decommissioning impacts is expected to evolve as described in the next section, with the additional consideration that any changes during the construction phase will have altered the baseline environment to a degree as set out in this chapter.

Hornsea Four

Figure 3.2

Hornsea Four Location and Bathymetry



Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:500,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
...	First Issue fo PEIR	17/06/2019
A	Updated following PEIR consultations, for DCO	03/08/2021

Hornsea Four Location and Bathymetry
Document no: HOW04GB0129
Created by: BPHB
Checked by: RM
Approved by: LK

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Hornsea Four

Figure 3.3

Herring and sandeel spawning grounds in relation to Hornsea Four array and ECC (Coull et al, 1998)

250000 300000 350000 400000 450000

6050000 6000000 5950000 5900000

N

GRID NORTH

- Fish and Shellfish Study Area
- Order Limits
- Herring Spawning Grounds (Coull *et al.*, 1998)
- Sandeel Spawning Grounds (Coull *et al.*, 1998)

Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:750,000

0 10 20 Kilometres

0 10 20 Nautical Miles

REV	REMARK	DATE
---	First Issue	03/08/2021

Herring and Sandeel Spawning Plan
Document no: HOW04GB0239
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

Date: 03/08/2021 Author: BenBlakeman Name: HOW04GB0239_FSF_Herring_Sandeel_Spawning

Hornsea Four

Figure 3.4

Hornsea Four with Herring Spawning Grounds IHLS Comparison, full 2007/08 - 2020/21 dataset

250000 300000 350000 400000 450000

6050000 6000000 5950000 5900000

N

GRID NORTH

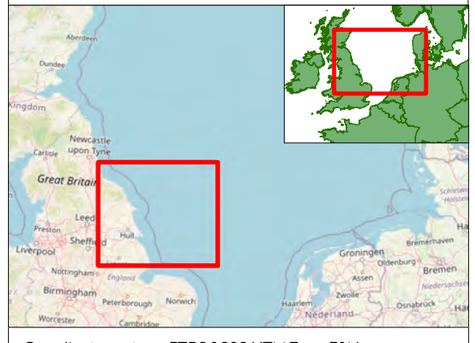
Fish and Shellfish Study Area

Order Limits

Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:750,000

0 10 20 Kilometres

0 10 20 Nautical Miles

REV	REMARK	DATE
---	First Issue for PEIR	08/05/2019
A	Updated folllowing PEIR consultations, for DCO	10/08/2021

Herring Spawning Plan
Document no: HOW04GB0031
Created by: BPHB
Checked by: AL
Approved by: LK

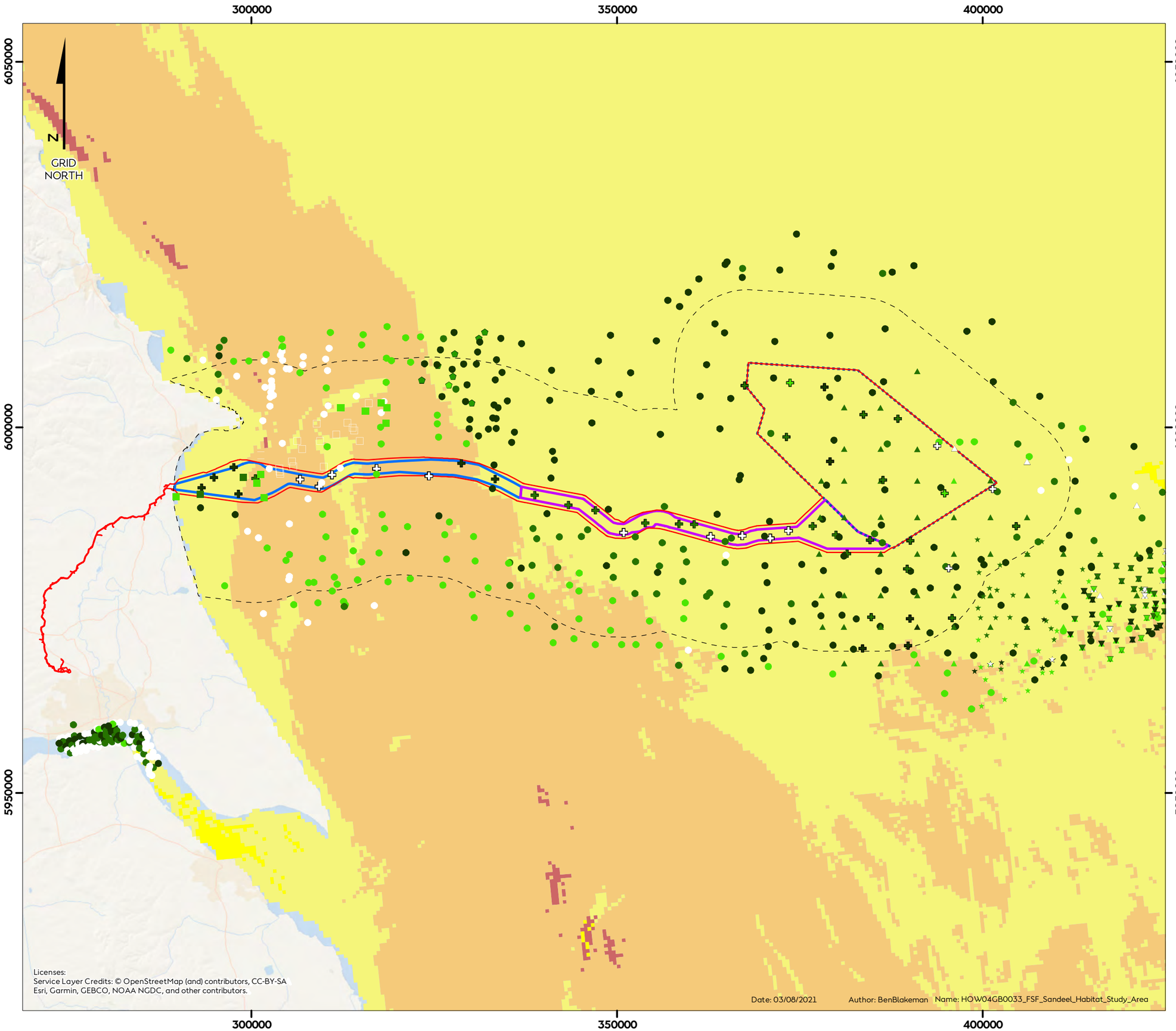
GoBe Ørsted

Date: 10/08/2021 Author: BenBlakeman Name: HOW04GB0031_FSF_2007_2021_Seasons

Hornsea Four

Figure 3.5

Potential Sandeel Habitat Sediment Classifications within the Hornsea Four Study Area



- Fish and Shellfish Study Area
- Order Limits
- Array Area
- Nearshore Export Cable Corridor
- Offshore Export Cable Corridor

Cefas 2015 Folk and EUNIS map

- Coarse Sediments
- Mixed Sediments
- Mud and Sandy Mud
- Sand and Muddy Sand

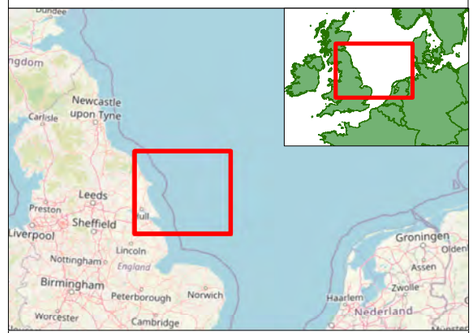
Sandeel Habitat Suitability (Latto *et al.*, 2013)

- Prime/Preferred
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Source of Data

- BGS UK (Various Years)
- Creyke Nearshore Tranch A (2012)
- Creyke Offshore Tranch A (2012)
- Hornsea Zonal (2011)
- Hornsea One Array (2010)
- Hornsea Two Array (2012)
- Hornsea Four Array and ECC (2018, 2019)

Data in Array (Gardline 2019), Data in ECC (GoBe (2020)



Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:500,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue for PEIR	08/05/2019
A	Updated folllowing PEIR consultations, for DCO	03/08/2021

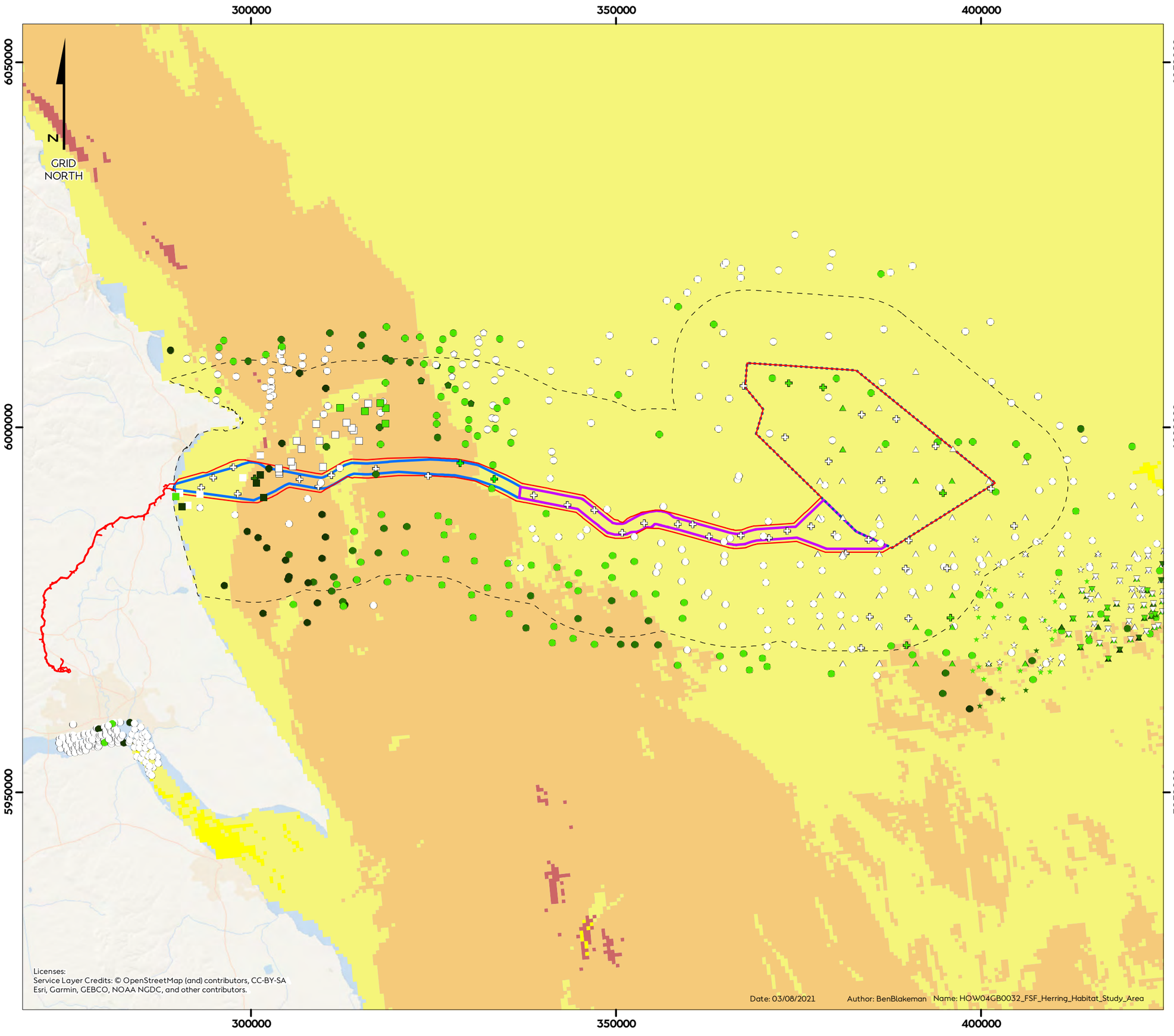
Potential Sandeel Habitat Class
Document no: HOW04GB0033
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

Hornsea Four

Figure 3.6

Potential Herring Habitat Sediment Classifications within the Hornsea Four Study Area



Fish and Shellfish Study Area
Order Limits
Array Area
Nearshore Export Cable Corridor
Offshore Export Cable Corridor

Cefas 2015 Folk and EUNIS map

Coarse Sediments
Mixed Sediments
Mud and Sandy Mud
Sand and Muddy Sand

Herring Habitat Suitability (Reach *et al.*, 2013)

Prime/Preferred
Sub-Prime, Preferred
Suitable, Marginal
Unsuitable

Source of Data

BGS UK (Various Years)
Creyke Nearshore Tranch A (2012)
Creyke Offshore Tranch A (2012)
Hornsea Zonal (2011)
Hornsea One Array (2010)
Hornsea Two Array (2012)
Hornsea Four Array and ECC (2018, 2019)

Data in Array (Gardline 2019), Data in ECC (GoBe (2020)

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:500,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
...	First Issue for PEIR	08/05/2019
A	Updated folllowing PEIR consultations, for DCO	03/08/2021

Potential Herring Habitat Class
Document no: HOW04GB0032
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

3.7.1.11 A number of migratory fish species have the potential to occur across the southern North Sea, and within the Hornsea Four fish and shellfish study area, migrating to and from rivers and other freshwater bodies in the area which they use either for spawning habitat (e.g. sea lamprey *Petromyzon marinus*, river lamprey *Lampetra fluviatilis*, twaite shad *Alosa fallax*, allis shad *Alosa alosa*, Atlantic salmon *Salmo salar* and sea trout *Salmo trutta)*, or for growth and development to the adult phase with spawning occurring at sea (e.g. European eel *Anguilla Anguilla*). These species were scoped out of the assessment during the Scoping process (see **Volume A4, Annex 5.1: Impacts Register**), and are discussed further in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.

3.7.2 Designated sites and protected species

3.7.2.1 All designated sites within the Hornsea Four study area (**Figure 3.7**), for which impacts to fish or shellfish receptors arising from Hornsea Four could have implications for the conservation objectives or features of the site, are described below and discussed in full in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**.

3.7.2.2 A number of the key species identified as having the potential to be present within the Hornsea Four fish and shellfish study area are listed under conservation legislation, with three of these species listed as Annex II species under the EU Habitats Directive: the Atlantic salmon; sea lamprey; and river lamprey. Both sea lamprey and river lamprey are listed as qualifying features of the Humber Estuary SAC, and under the Humber Estuary Ramsar and Humber Estuary SSSI designations. Sea lamprey, river lamprey and Atlantic salmon are all known to migrate through the Humber estuary to freshwater spawning habitats. A full assessment of the impacts on these species is undertaken within the RIAA (**B2.2: Report to Inform Appropriate Assessment**) which has examined the potential impacts on the Humber Estuary SAC, which overlaps with the Humber Estuary SSSI and the Humber Estuary Ramsar designations.

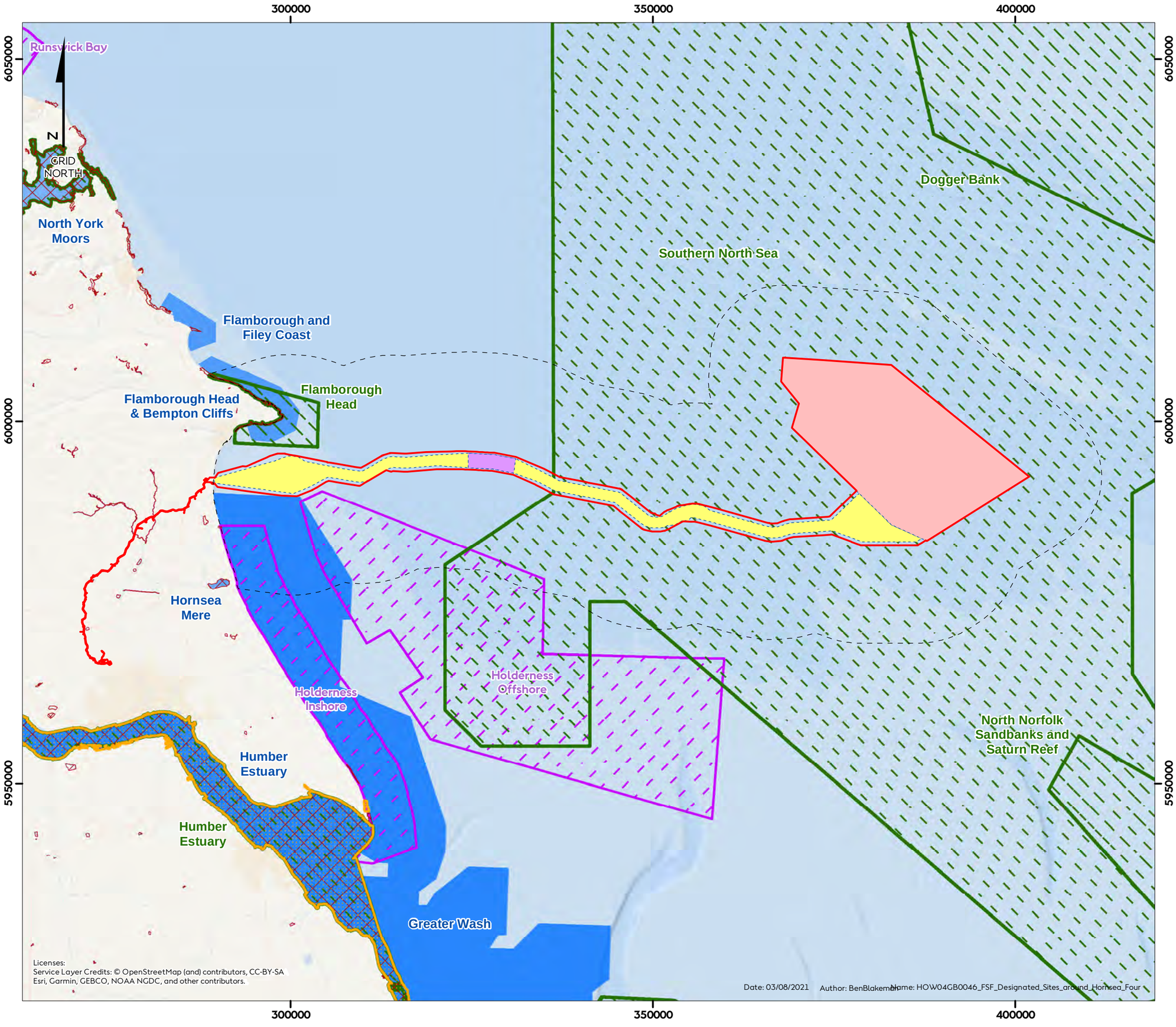
3.7.2.3 The Southern North Sea SAC is designated for the Annex II species Harbour Porpoise *Phocoena phocoena*. The SAC has a conservation objective to maintain the availability of prey habitats and species for the harbour porpoise (which typically consists of non-spiny fish such as herring, whiting and cod, squid and sprat).

3.7.2.4 Two MCZs lie within the Hornsea Four study area; the Holderness Inshore MCZ and the Holderness Offshore MCZ (4.4 km and 0.75 km from the Hornsea Four ECC respectively). The only MCZ of relevance to fish and shellfish receptors is the Holderness Offshore MCZ which is designated for the Ocean Quahog *Arctica islandica*, a species found in sandy seabed throughout the North Sea. An MCZ Assessment forms part of this ES (**Volume A5, Annex 2.3: Marine Conservation Zone Assessment**).

Hornsea Four

Figure 3.7

Designated Sites Surrounding Hornsea Four



- Fish and Shellfish Study Area
- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Marine Conservation Zones
- Special Areas of Conservation
- Special Protection Areas
- Sites of Special Scientific Interest
- Ramsar

Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:500,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
----	First Issue for PEIR	08/05/2019
A	Updated following PEIR consultations, for DCO	03/08/2021

Designated Sites around Hornsea Four
Document no: HOW04GB0046
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

3.7.3 Valued Ecological Receptors

3.7.3.1 Hornsea Four have taken a Valued Ecological Receptor (VER) approach which allows the assessment to focus on the ecological importance of the features. This is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM 2016). Full details of the methods used to provide valuations of fish and shellfish receptors, following the Chartered Institute for Ecology and Environmental Management (CIEEM 2016) guidelines, are provided in **Section 4** of **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**. A number of VERs have been identified within the fish and shellfish study area these are detailed in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**, and include species which have:

- Populations present within the fish and shellfish study area;
- Spawning, nursery and migratory behaviour within the fish and shellfish study area; and
- Commercial, conservation and ecological interest, including importance in supporting species of high trophic levels (e.g. prey species for bird and marine mammal species).

3.7.3.2 In the case of this assessment, a number of fish or shellfish species are grouped based on their sensitivities to the pressures, spawning behaviours, ecological and conservation interest, and locations of spawning and nursery grounds in relation to the Hornsea Four study area.

3.7.3.3 Due to the demersal nature of herring and sandeel spawning behaviours, the proximity of their known or potential spawning and nursery grounds, and the relatively high sensitivity of herring in particular to noise disturbances, these species are the primary focus of this assessment.

3.7.3.4 Shellfish of particularly high commercial value, or with known or potential spawning habitats overlapping the Hornsea Four study area, have also been considered. These include brown crab, scallop, *Nephrops,* European lobster and common whelk (see **Volume A5, Annex 6.1: Commercial Fisheries Technical Report**).

3.7.4 Evolution of the Baseline

3.7.4.1 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 ES (EIA Regulations, Schedule 4, Paragraph 3). From the point of assessment, over the course of the development and operational lifetime of Hornsea Four (operational lifetime anticipated to be 35 years), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that Hornsea Four is not constructed, using available information and scientific knowledge of fish and shellfish ecology.

3.7.4.2 Recent research has suggested that there have been substantial changes in the fish communities in the northeast Atlantic over several decades as a result of a number of factors including climate change and fishing activities (DECC 2016). These communities consist of species that have complex interactions with one another and the natural environment. Fish and shellfish populations are subject to natural variations in population size and distributions, largely as a result of year to year variation in recruitment success and these population trends will be influenced by broad-scale climatic and hydrological variations, as well as anthropogenic effects such as climate change and overfishing.

3.7.4.3 Fish and shellfish play a pivotal role in the transfer of energy from some of the lowest to the highest trophic levels within the ecosystem and serve to recycle nutrients from higher levels through the consumption of detritus. Consequently, their populations will be determined by both top-down factors such as predation, and bottom-up factors such as ocean climate and plankton abundance. Fish and shellfish are important prey items for top marine predators including elasmobranchs, seabirds and cetaceans, and small planktivorous species such as sandeel and herring act as important links between zooplankton and top predators (Frederiksen et al. 2006).

3.7.4.4 Climate change may influence fish distribution and abundance, affecting growth rates, recruitment, behaviour, survival and response to changes of other trophic levels. Within the southern North Sea, increased sea surface temperatures may lead to an increase in the relative abundance of species associated with more southerly areas. For example, data on herring and sardine *Sardina* sp. landings at ports in the English Channel and southern North Sea showed that higher herring landings were correlated with colder winters, while warm winters were associated with large catches of sardine (Alheit and Hagen 1997). Studies have shown that anchovy *Engraulis encrasicolus* have extended their distribution throughout the North Sea, from which they were largely absent until the mid-1990s (Alheit et al. 2012).

3.7.4.5 One potential effect of increased sea surface temperatures is that some fish species will extend their distribution into deeper, colder waters. In these cases, however, habitat requirements are likely to become important, with some shallow water species having specific habitat requirements in shallow water areas which are not available in these deeper areas. For example, sandeel is less likely to be able to adapt to increasing temperatures as a result of its specific habitat requirements for coarse sandy sediment; declining recruitment in sandeel in parts of the UK has been correlated with increasing temperature (Heath et al. 2012). Climate change may also affect key life history stages of fish and shellfish species, including the timing of spawning migrations (BEIS 2016). However, climate change effects on marine fish populations are difficult to predict and the evidence is not easy to interpret and therefore it is difficult to make accurate estimations of the future baseline scenario for the entire lifetime of the Hornsea Four project (35 years).

3.7.4.6 In addition to climate change, overfishing subjects the populations of many fish species to considerable pressure, reducing the biomass of commercially valuable species, and non-target species. Overfishing can reduce the resilience of fish and shellfish populations to other pressures, including climate change and other anthropogenic impacts. For example, a study on cod in an area where trawl fishing has been banned since 1932

indicated that this population was significantly more resilient to environmental change (including climate change) than populations in neighbouring fished areas (Lindegren et al. 2010). Conversely modelling by Beggs et al. (2013) indicated that cod may be more sensitive to climate variability during periods of low spawning stock biomass. There are indications that overfishing in UK waters is reducing to some degree, with declines in fishing mortality estimates in recent years for crustacean, demersal and benthic stock groups. ICES advice also suggests that some of the stocks (benthic and demersal) have shown signs of recovery since 2000. Similar, but less dramatic, changes are also evident for pelagic species (ICES 2018). The most recent OSPAR Quality Status Report (OSPAR 2010) concluded that many fish stocks are still outside safe biological limits, although there have been some improvements in some stocks. Should these improvements continue, this may not result in significant changes in the species assemblage in the southern North Sea fish and shellfish study area, although may result in increased abundances of the characterising species present in the area.

3.7.4.7 It should be noted that there is also uncertainty surrounding the conditions of the withdrawal of the UK from the EU, with the UK becoming an independent coastal state and in control of waters out to 200 NM. Following the exit of the UK from the EU on 31st January 2020, the Common Fisheries Policy applied during the transition period, which rans until the end of 2020. Following the withdrawal, the UK and the EU have agreed to a Trade and Cooperation Agreement (TCA), applicable on a provisional basis from 1 January 2021. The TCA sets out fisheries rights and confirms that from 1 January 2021 and during a transition period until 30 June 2026, UK and EU vessels will continue to access respective Excusive Economic Zones (EEZs, 12-200 NM) to fish. In this period, EU vessels will also be able to fish in specified parts of UK waters between 6-12 NM. Twenty-five percent of the EU's fisheries quota in UK waters will be transferred to the UK over the five-year transition period.

3.7.4.8 The Hornsea Four fish and shellfish baseline characterisation described in the preceding sections (and presented in detail in **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**) represents a 'snapshot' of the fish and shellfish assemblages of the southern North Sea, within a gradual and continuously changing environment. Any changes that may occur during the lifetime of the project (i.e. construction, operation and decommissioning) should be considered in the context of the natural variability and other existing anthropogenic effects, including climate change, overfishing and other environmental impacts.

3.7.4.9 It is acknowledged that IHLS surveys in recent years have been extended further east towards the Dogger Bank due to anecdotal evidence of increases in larvae abundances in this historical spawning ground. While the survey data do not show this currently happening, the recolonisation of herring spawning grounds has occurred elsewhere (Corten et al. 1999) and is recognised as having the potential to occur in the currently disused spawning ground closer to Hornsea Four. However, despite this potential for recolonisation it is not considered likely that there would be any significant changes to the current location of the core spawning grounds which are found around Flamborough Head (**Figure 3.3**) and as such would not result any significant changes in the future baseline which may affect the conclusions of this assessment.

3.7.5 Data Limitations

3.7.5.1 The description of spawning and nursery grounds is primarily based on the information presented in Ellis et al. (2012), Coull et al. (1998) and the IHLS data. The IHLS data is used to complement the Ellis et al. (2012) and Coull et al. (1998) papers, providing a composite of interannual variation from 2007/2008 – 2020/2021. The limitations of these latter two sources of information are recognised. These publications provide an indication of the general location of spawning and nursery grounds, particularly in the context of the relatively small footprint of the Hornsea Four development. Similarly, the spawning times given in these publications represent the maximum duration of spawning on a species/stock basis. In some cases, the duration of spawning may be much more contracted, on a site-specific basis, than reported in Ellis et al. (2012) and Coull et al. (1998). Therefore, additional research publications have also been reviewed to provide site specific information.

3.7.5.2 Fish exhibit varying spatial and temporal patterns. All of the wind farm project site specific surveys including the former Hornsea Zone surveys (**Table 3.6** and **Table 3.7**), were undertaken to provide a semi-seasonal description of the fish and shellfish. It should be noted, the data collected during these characterisation surveys (Hornsea Projects One (2010-2011), Two (2012) and Three (2018) epibenthic beam trawl surveys, and otter trawl surveys across the former Hornsea Zone (2010-2011)) represent snapshots of the fish and shellfish assemblage at the time of sampling and whilst the surveys were conducted in the autumn and spring to account for seasonal variation the fish and shellfish assemblages may vary both seasonally and annually. The description of the existing environment also draws upon the data collected for former Hornsea Zone projects (Hornsea Project One, Hornsea Project Two and Hornsea Three) and from the Dogger Bank A and B ES. The surveys conducted are considered sufficient to inform the baseline and follow best practice.

3.8 Project basis for assessment

3.8.1 Impact register and impacts not considered in detail in this ES

3.8.1.1 Upon consideration of the baseline environment, the project description outlined in **Volume A1, Chapter 4: Project Description,** the commitments detailed within **Volume A4, Annex 5.2: Commitments Register** and in response to formal consultation on the PEIR, a number of impacts are "not considered in detail" in the ES. These impacts are outlined, together with appropriate justification for this, in **Table 3.8** alongside impacts that were scoped out during the Scoping process. Further detail is provided in **Volume A4, Annex 5.1: Impacts Register**.

Table 3.8: Impacts scoped out of assessment and justification.

Project activity and impact	Likely significance of effect	Approach to assessment	Justification
Construction Phase: Accidental pollution events during the construction phase resulting in potential effects on fish and shellfish receptors (FSE-C-5).	No likely significant effect	Scoped Out	Scoped out based on PINS Scoping Opinion (PINS Scoping Opinion, November 2018, ID: 4.4.4). Accidental release of pollutants will be managed and mitigated through implementation of a CPEMMP (Co111), which will include details of a Marine Pollution Contingency Plan (MPCP) to address the risks, methods and procedures to deal with any spills and collision incidents of the authorised project in relation to all activities carried out below MHWS.
Operation phase: Underwater noise as a result of operational turbines (FSE-O-8)	No likely significant effect	Not considered in detail in the ES	Assessed at PEIR as no Likely Significant Effect (LSE) and confirmed no change to either magnitude or sensitivity of the species and therefore not considered further in the EIA. Noise levels will only be detected in very close proximity to the operational turbines (as evidenced by monitoring (**Volume A4, Annex 4.5: Subsea Noise Technical Report**) and the routine presence of fish and shellfish in close proximity to operational turbines.
Operation phase: EMF effects arising from cables (FSE-O-9).	No likely significant effect	Scoped Out	Scoped out based on PINS Scoping Opinion (PINS Scoping Opinion, November 2018, ID: 4.4.8). The spatial extent of EMFs will be limited to the immediate vicinity of the cable, and where possible cable burial will be the preferred option for cable protection (Co83).
Operation phase: Indirect disturbance resulting from the accidental release of pollutants (FSE-O-11).	No likely significant effect	Scoped Out	Scoped out based on PINS Scoping Opinion (PINS Scoping Opinion, November 2018, ID: 4.4.10). Accidental release of pollutants will be managed and mitigated through implementation of a CPEMMP (Co111), which will include details of a Marine Pollution Contingency Plan to address the risks, methods and procedures to deal with any spills and collision incidents of the authorised project in relation to all activities carried out below MHWS.
Operation Phase: Potentially reduced fishing pressure within the Hornsea Four array area an increased fishing pressure outside the array area due to	No likely significant effect	Not considered in detail in the ES	Assessed at PEIR as no Likely Significant Effect (LSE) and confirmed no change to either magnitude or sensitivity of the species and therefore not considered further in the EIA. The exclusion of fishing activity will be spatially restricted to safety zones in the immediate vicinity of the turbine infrastructure, and therefore any

Project activity and impact	Likely significance of effect	Approach to assessment	Justification
displacement (FSE-O-12)			potential for fishing pressure displacement will be minimal.
Decommissioning: Accidental pollution events during the decommissioning phase resulting in potential effects on fish and shellfish receptors (FSE-D-17).	No likely significant effect	Scoped Out	Scoped out based on PINS Scoping Opinion (PINS Scoping Opinion, November 2018, ID: 4.4.16). Accidental release of pollutants will be managed and mitigated through implementation of a CPEMMP (Co111), which will include details of a Marine Pollution Contingency Plan to address the risks, methods and procedures to deal with any spills and collision incidents of the authorised project in relation to all activities carried out below MHWS.

Notes:
Grey – Scoped out - Agreement reached between Hornsea Four and the Planning Inspectorate at Scoping
Purple – Impact not Considered in detail in the ES. No likely significant effect at PEIR.

3.8.2 Commitments

3.8.2.1 Hornsea Four has adopted commitments (primary design principles inherent as part of Hornsea Four, installation techniques and engineering designs/modifications) as part of the pre-application phase, to eliminate and/or reduce the LSE arising from a number of impacts (as far as possible). These are outlined in **Volume A4, Annex 5.2 Commitments Register**. Further commitments (adoption of best practice guidance), referred to as tertiary commitments are embedded as an inherent aspect of the EIA process. Secondary commitments are incorporated to reduce LSE to environmentally acceptable levels following initial assessment i.e. so that residual effects are reduced to environmentally acceptable levels.

3.8.2.2 The commitments adopted by Hornsea Four in relation to fish and shellfish ecology are presented in **Table 3.9**. The full list of Commitments can be found in **Volume A4, Annex 5.2: Commitments Register**.

Table 3.9: Relevant fish and shellfish commitments.

Commitment ID	Measure Proposed	How the measure will be Secured
Co2	Primary: A range of sensitive historical, cultural and ecological conservation areas (including statutory and non-statutory designations) have been directly avoided by the permanent Hornsea Four footprint, at the point of Development Consent Order Submission (DCO). These include, but are not restricted to: Listed Buildings (564 sites); Scheduled Monuments (30 sites); Registered Parks and Gardens (Thwaite Hall and Risby Hall); Onshore Conservation Areas (18 sites); Onshore National Site Network (one site); Offshore	DCO Works Plan - Onshore; and DCO Works Plan - Offshore

Commitment ID	Measure Proposed	How the measure will be Secured
	National Site Network (three sites); Offshore Marine Conservation Zones (two sites); Sites of Special Scientific Interest (two sites); Local Nature Reserves (none have been identified); Local Wildlife sites (33 sites); Yorkshire Wildlife Trust Reserves (none have been identified); Royal Society for the Protection of Birds (RSPB) Reserves (none have been identified); Heritage Coast; National Trust land; Ancient Woodland (10 sites and known Tree Preservation Orders (TPOs)); non-designated built heritage assets (334 sites); and historic landfill (none have been identified). Where possible, unprotected areas of woodland, mature and protected trees (i.e. veteran trees) have and will also be avoided.	
Co44	Primary: The Holderness Inshore Marine Conservation Zone (MCZ) will not be crossed by the offshore export cable corridor including the associated temporary works area.	DCO Works Plan - Offshore (**Volume D1, Annex 4.1: Works Plan – Offshore**)
Co45	Primary: The Holderness Offshore MCZ will not be crossed by the offshore export cable corridor including the associated temporary works area.	DCO Works Plan - Offshore (**Volume D1, Annex 4.1: Works Plan – Offshore**)
Co83	Primary: Where possible, cable burial will be the preferred option for cable protection.	DCO Schedule 11, Part 2 - Condition 13(1)(h) and; DCO Schedule 12, Part 2 - Condition 13(1)(h) (Cable specification and installation plan)
Co85	Primary: No more than a maximum of two foundations are to be installed simultaneously.	DCO Schedule 11, Part 2 - Condition 13(1)(g) and; DCO Schedule 12, Part 2 - Condition 13(1)(g) (Marine mammal mitigation protocol) DCO Schedule 11, Part 2 - Condition 13(1)(c) and; DCO Schedule 12, Part 2 - Condition 13(1)(c) (Construction Method Statement)
Co110	Tertiary: A piling Marine Mammal Mitigation Protocol (MMMP) will be developed in accordance with the Outline MMMP and will be implemented during construction. The piling MMMP will include measures to ensure the risk of instantaneous permanent threshold shift (PTS) to marine mammals is negligible and will be in line with the latest relevant available guidance. The piling MMMP will include details of soft starts to be used during piling operations with lower hammer energies used at the beginning	DCO Schedule 11, Part 2 - Condition 13(1)(g) and; DCO Schedule 12, Part 2 - Condition 13(1)(g) (Marine mammal mitigation protocol)

Commitment ID	Measure Proposed	How the measure will be Secured
	of the piling sequence before increasing energies to the higher levels.	
Co111	Tertiary: A Construction Project Environmental Management and Monitoring Plan (CPEMMP) will be developed and will include details of: - a marine pollution contingency plan to address the risks, methods and procedures to deal with any spills and collision incidents of the authorised project in relation to all activities carried out below MHWS; - a chemical risk review to include information regarding how and when chemicals are to be used, stored and transported in accordance with recognised best practice guidance; - a marine biosecurity plan detailing how the risk of introduction and spread of invasive non-native species will be minimised; - waste management and disposal arrangements; - a vessel management plan, to determine vessel routing to and from construction sites and ports, to include a code of conduct for vessel operators; and - the appointment and responsibilities of a company fisheries liaison officer.	DCO Schedule 11, Part 2 - Condition 13(1)(d) and; DCO Schedule 12, Part 2 - Condition 13(1)(d) (Construction Project Environmental Management and Monitoring Plan)
Co113	Tertiary: A Decommissioning Marine Mammal Mitigation Protocol (MMMP) will be implemented during decommissioning. The Decommissioning MMMP will be approved by the Marine Management Organisation (MMO) in consultation with Natural England. The Decommissioning MMMP will include measures to ensure the risk of instantaneous permanent threshold shift (PTS) to marine mammals is negligible and will be in line with the latest relevant available guidance.	A separate Marine Licence will be applied for at the point of decommissioning which will include Conditions relevant to minimising impacts on marine mammals where appropriate.
Co181	Tertiary: An Offshore Decommissioning Plan will be developed prior to decommissioning.	DCO Schedule 11, Part 1(6) and; DCO Schedule 12, Part 1(6) (General Provisions)
Co190	Secondary: No impact piling within the HVAC search area (DCO Works No. 3) will be undertaken between 1st September and 16th October unless otherwise agreed with the relevant stakeholders.	DCO Schedule 12, Part 2 - Condition 23 (Piling Restriction)
Co201	Primary: Gravity Base Structure (GBS) foundations (WTG type) will be utilised at a maximum of 110 of the 180 WTG foundation locations. The location of GBS foundations, if used for WTG, will be confirmed through a construction method statement which will include details of foundation installation methodology.	DCO Schedule 11, Part 2 - Condition 13(1(c) (Construction Method Statement)

3.9 Maximum Design Scenario

3.9.1.1 This section describes the MDS parameters on which the fish and shellfish ecology assessment has been based. These are the parameters which are judged to give rise to the maximum levels of effect for the assessment undertaken, as set out in **Volume A1, Chapter 4: Project Description**. Should Hornsea Four be constructed to different parameters from those stated but within the design envelope, then impacts would not be any greater than those set out in this ES using the MDS presented in **Table 3.10**.

Table 3.10: MDS for impacts on fish and shellfish ecology.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Construction			
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities (FSE-C-1).	Primary: Co44 Co45 Co48 Co84 Co86 Co201 Secondary: Co188 Co189 Tertiary: Co111	**Total area of direct disturbance = 75,895,509 m²** **Array Area = 39,792,306 m²** **Foundation seabed preparation = 779,106 m²** • 110 gravity-based structure (GBS) (wind turbine generator (WTG)-type) foundations for WTGs = 411,321 m²; • 70 suction caisson jacket (WTG type) foundations for WTGs = 198,870 m²; • Six small offshore substations (OSS) on suction caisson jacket (small OSS) foundations and three large OSS on GBS (large OSS) foundations = 156,594 m²; and • One accommodation platform on a suction caisson jacket foundation (small OSS) = 12,321 m². **Jack up and anchoring operations = 1,063,200 m²** • WTG installation jack up vessel (JUV) footprint (six legs, 170 m² per foot, four jack-up operations per turbine) = 734,400 m²; • WTG installation vessel anchor footprints (100 m² per anchor, eight anchors per vessel, two anchored vessels per turbine) = 288,000 m²; and • OSS and accommodation platform installation JUV footprint (six legs, 170 m² per foot, four jack-up operations per structure) = 40,800 m². **Cable seabed preparation and installation = 37,950,000 m²** • Boulder and sandwave clearance for array and interconnector cables in the array area - (690 km length, 40 m width) = 27,600,000 m²; and • Burial of array and inter-connector cables (690 km length, 15 m width) = 10,350,000 m². **Offshore ECC = 36,103,203 m²** • Three suction caisson foundations (small OSS) for up to three HVAC booster stations = 36,963 m²;	Direct damage and disturbance relates to seabed preparation and cable installation. The footprint of infrastructure is assessed as a temporary impact in construction, and as a permanent impact in operation and maintenance (O&M). It should be noted that for GBS foundations, the seabed preparation area is less than the footprint of the foundation scour protection. The MDS presents a precautionary approach to temporary habitat disturbance because it counts both the total footprint of seabed clearance as well as cable burial across both the array and offshore ECC. This approach effectively counts the footprint of seabed habitat to be impacted by construction in the same area twice. However, this precautionary approach has been taken because there is some potential for recovery of habitats between the activities due to project timescales.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• OSS installation JUV footprint (six legs, 170 m^2 per foot, four jack-up operations per structure) = 12,240 m^2; • Boulder and sandwave clearance for export cables in offshore ECC (654 km length, 40 m width) = 26,160,000 m^2; • Burial of export cables (654 km length, 15 m width) = 9,810,000 m^2; and • Cable jointing (four joints per cable, six cables, 3,500 m2 per joint) = 84,000 m^2.	
Temporary localised increases in Suspended Sediment Concentrations (SSC) and smothering (FSE-C-2).	Primary: Co44 Co45 Co201 Tertiary: Co111	**Total volume 12,214,451 m^3** **WTG Foundations:** • 110 turbines on GBS foundations (WTG-type) requiring seabed preparation, resulting in the suspension of 685,794 m^3 of sediment; and • 70 Suction Caisson Jacket (WTG type) foundations requiring seabed preparation, resulting in the suspension of 359,427 m^3 of sediment. **OSS Foundations:** • Six small OSS on suction caisson jacket (small OSS) foundations and three large OSS on GBS (large OSS) foundations requiring seabed preparation, resulting in the suspension of 737,130 m^3 of sediment. **Offshore Accommodation Platform Foundations:** • One suction caisson jacket (small OSS) foundation requiring seabed preparation, resulting in the suspension of 57,245 m^3 of sediment. **HVAC Booster Station Foundations:** • Three suction caisson jacket (small OSS) foundations requiring seabed preparation, resulting in the suspension of 171,735 m^3 of sediment. **Sandwave Clearance:** • Sandwave clearance for 600 km of array cables resulting in the suspension of 769,000 m^3 of sediment; • Sandwave clearance for 90 km of interconnector cables resulting in the suspension of 115,000 m^3 of sediment; and	The MDS for foundation installation results from the largest volume suspended from seabed preparation (GBS foundations and suction caisson foundations) with the maximum number of foundations (180) and associated offshore platform infrastructure. For cable installation, the MDS results from the greatest volume from sandwave clearance and installation using energetic means (CFE). This also assumes the largest number of cables and the greatest burial depth. It is important to note that three HVDC converter substations in the array area are mutually exclusive with three HVAC booster stations along the ECC in a single transmission system. As secured by **C1.1 Draft DCO including Draft DML**, a maximum of ten OSS and platforms will be constructed within the Hornsea Four Order Limits, however in order to assess the MDS for both the array and the ECC, the presence of the maximum numbers of OSS and platforms in each area has been considered

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Sandwave clearance for 654 km of export cables resulting in the suspension of 834,000 m^3 of sediment. **Cable Trenching:** • Installation of 600 km of array cables by Controlled Flow Excavation (CFE) resulting in the suspension of 3,600,000 m^3 of sediment; • Installation of 90 km of interconnector cables resulting in the suspension of 540,000 m^3 of sediment; • Installation of 654 km of export cables resulting in the suspension of 3,903,000 m^3 of sediment (excluding the part of the export cable within the array); and • Up to 420,000 m^3 of sediment from up to four cable joints per export cable (six) in the ECC. **Landfall Area:** Eight offshore cofferdam Horizontal Directional Drilling (HDD) exit pits require excavation of 2,500 m^3 each which will be side-cast onto the adjacent seabed. Backfilling of exit pits will recover a similar amount to be from the surrounding seabed, as required. Total excavated = 20,000 m^3. HDD Bentonite drilling fluid loss per cable 265 m^3. Total drilling fluid loss = 2,120 m^3	(ten and three, respectively). As a result, the outcome of the assessment is therefore inherently precautionary. The maximum volume of bentonite which could be released as part of the landfall activities is considered. For this assessment, it is considered that the bentonite would not be captured and is released into the marine environment.
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-C-3).	Primary: Co44 Co45 Co201 Tertiary: Co111	The MDS for seabed disturbance are presented in the rows above (FSE-C-2).	As above.
Mortality, injury, behavioural changes and auditory masking arising from	Primary: Co85 Secondary:	**Array Area (spatial MDS):** • 180 monopile WTG foundations (15 m diameter) with a maximum of two foundations installed concurrently; • Six small OSS (15 m diameter monopiles);	Piling: For the array area, the spatial MDS results from the concurrent installation of monopile foundations for 180 WTGs in the NW and E corners of the array, and the

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
noise and vibration (FSE-C-4).	Co190 <u>Tertiary:</u> Co110	• Three large OSS (15 m diameter monopiles); • One offshore accommodation platform (15 m diameter monopiles); • Maximum hammer energy 5,000 kJ; • Four-hour piling duration; • 1.2 days per monopile; • 216 piling days (single vessel); • 106 piling days (two vessels); and • Maximum separation distance between piling events will be the maximum extent of the array area. **Array Area (temporal MDS):** • 180 WTGs on piled jacket (WTG-type) foundations (three 4 m diameter pin piles per jacket) – 540 pin piles; • Six OSS on piled jacket (small OSS) foundations (six legs per jacket and four 3.5 m pin piles per leg) – 144 pin piles; • Three OSS on piled jacket (large OSS) foundations (eight legs per jacket and two piles per leg) – 48 pin piles; • One offshore accommodation platform on a piled jacket (small OSS) foundation (six legs and four 3.5 m pin piles per leg – 24 pin piles; • Total of 756 pin piles in the array; • Maximum hammer energy 3,000 kJ; • 1.5 days per foundation; • 270 piling days (single vessel); and • 135 days (two vessels). **HVAC Booster Area of Search (spatial MDS):** • Three HVAC booster stations on 15 m diameter monopile foundations; • Maximum hammer energy 5,000 kJ; • Four-hour piling duration; and • 1.2 days per monopile. **HVAC Booster Area of Search (temporal MDS):**	sequential installation of monopile foundations for nine OSS and an offshore accommodation platform using 5,000 kJ hammer energy. This would result in the largest spatial noise impact at any given time. The temporal MDS for the array area would be associated with the installation of the maximum number of piles; the MDS would be the installation of 180 WTGs using piled jacket (WTG-type) foundations, and seven structures (OSS and an accommodation platform) on piled jackets (small OSS) and three OSS on piled jackets (large OSS). For HVAC booster stations, the spatial MDS is based on three OSS monopiles, and the temporal MDS is based on three OSS on piled jacket (small OSS) foundations. It is important to note that three HVDC converter substations in the array area are mutually exclusive with three HVAC booster stations along the ECC in a single transmission system. As secured by **C1.1 Draft DCO including Draft DML**, a maximum of ten OSS and platforms will be constructed within the Hornsea Four Order Limits, however in order to assess the MDS for both the array and the ECC, the presence of the maximum numbers of OSS and

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Three HVAC booster stations on piled jacket (small OSS) foundations (six legs per jacket and four 3.5 m diameter pin piles per leg) – 72 pin piles. **UXO Clearance:** • Estimated 2,263 targets; • 86 UXOs may require clearance; • Up to five UXO will be cleared every 24 hours; and • Up to 86 detonations in 86 days.	platforms in each area has been considered (ten and three, respectively). As a result, the outcome of the assessment is therefore inherently precautionary. UXO clearance: Estimated MDS based on the recent internal analysis report for Hornsea Three, the number of UXO requiring inspection and detonation has been scaled for Hornsea Four. A detailed UXO survey will be completed prior to construction. The type, size and number of possible detonations and duration of UXO clearance operations is therefore not known at this stage. Seabed clearance and installation activities such as cable laying, dredging and vessel movements may introduce an effect-receptor pathway for underwater noise, however these activities are established as producing low levels of noise, in the case of vessel movement no greater than the existing baseline of regional vessel noise, affecting a relatively small area in the immediate vicinity of activities. These general activities are therefore considered to fall within the impacts associated with piling and as such are not considered separately.
Operation			

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Temporary localised increases in SSC and smothering (FSE-O-18).	Primary: Co44 Co45	**Total volume: 692,916 m^3** **Array Cable Activities:** • Remedial burial of array cable (42 km total length reburied) by CFE – 252,000 m^3; and • Array cable repairs = 218,258 m^3. **Interconnector Cable Activities:** • Remedial burial of interconnector cables (7 km total length reburied) by CFE = 42,000 m^3; and • Interconnector cable repairs = 11,153 m^3. **Export Cable Activities:** • Remedial burial of export cables (14 km total length reburied) by CFE = 84,000 m^3; and • Export cable repairs = 85,505 m^3.	The maximum impacts from remedial cable burial and cable repairs of array, interconnector and export cables result from the use of CFE. This assumes the largest number of cables, repair events, the greatest burial depth and greatest length/area of maintenance. This results in the maximum sediment volume disturbance.
Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (FSE-O-6).	Primary: Co44 Co45 Co83 Co201	**Total Habitat Loss/Change: 3,730,671 m^2** **WTGs:** • Turbine footprint with scour protection, based on 110 GBS (WTG-type) foundations = 504,540 m^2; and • Turbine footprint with scour protection, based on 70 suction caisson Jacket (WTG type) foundations = 296,881 m^2. **OSS foundations:** • Offshore OSS foundation footprint and scour protection based on six small OSS on GBS (Box-type) foundations and three large OSS (on GBS (large OSS) foundations = 371,250 m^2. **HVAC Booster Station Foundations:** • Offshore HVAC booster substations and associated scour protection based on three GBS (Box-type) foundation = 91,875 m^2. **Offshore Accommodation Platform Foundations:**	The maximum design scenario is defined by the maximum area of seabed lost by the footprint of structures on the seabed, scour protection, cable protection and cable crossings. Habitat loss from drilling and drill arisings is of a smaller magnitude than presence of project infrastructure. It is important to note that three HVDC converter substations in the array area are mutually exclusive with three HVAC booster stations along the ECC in a single transmission system. As secured by **C1.1 Draft DCO including Draft DML**, a maximum of ten OSS and platforms will be constructed within the Hornsea Four Order Limits, however in order to assess the MDS for both the array and the ECC, the presence

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Offshore accommodation platform and associated scour protection based on one GBS (Box-type) foundation = 30,625 m^2. **Array Cables:** • Maximum rock protection area = 624,000 m^2; • Pre- and post-lay rock berm area, based on 32 cable crossings = 204,000 m^2; and • 25% replenishment of scour protection during operation and maintenance phase = 156,000 m^2. **Interconnector Cable Protection:** • Maximum rock protection area = 94,000 m^2; and • 25% replenishment of scour protection during operation and maintenance phase = 23,500 m^2. **Offshore ECC:** • Maximum rock protection area = 792,000 m^2; • Pre- and post-lay rock berm area, based on 54 cable crossings = 344,000 m^2; and • 25% replenishment of scour protection during operation and maintenance phase = 198,000 m^2.	of the maximum numbers of OSS and platforms in each area has been considered (ten and three, respectively). As a result, the outcome of the assessment is therefore inherently precautionary.
Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection (FSE-O-7).	Primary: Co83 Co201	**Total surface area of introduced hard substrate in the water column = 4,759,171 m^2 .** **Total area of introduced hard substrate at seabed level = 3,730,671 m^2 (see FSE-O-6).** **Total surface area of subsea portions of foundations in contact with the water column: 1,028,500 m^2.** • 110 WTGs on GBS (WTG-type) foundations, assuming 15 m diameter cylinder atop a conical/frustum base which tapers at 35 m above seabed level, with a base diameter of 53 m. Average water depth of 47.5 m, giving a per-foundation surface area of 5,650 m^2, with a total area of 621,500 m^2; • 70 WTGs on suction caisson jacket (WTG type) foundations, which has a base diameter of up to 40 m (extending 10 m above the seabed). Average water depth of 47.5 m, giving a per foundation surface area of 2,512 m^2, with a total area of 175,850 m^2.	Defined by the maximum area of structures, scour protection, cable protection and cable crossings introduced to the water column, including surface area of vertical structures. It is important to note that three HVDC converter substations in the array area are mutually exclusive with three HVAC booster stations along the ECC in a single transmission system. As secured by **C1.1 Draft DCO including Draft DML**, a maximum of ten OSS and platforms will be constructed within the Hornsea Four Order

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Six small OSS on GBS (Box-type) foundations, each with a length and width of 75 m at seabed level and at Lowest Astronomical Tide (LAT). Average water depth of 47.5 m, giving a per-foundation surface area of 14,250 m^2, with a total area of 85,500 m^2; • Three large OSS on GBS (Box-type) foundations, each with a length and width of 150 m at seabed level and at LAT. Average water depth of 47.5 m, giving a per-foundation surface area of 28,500 m^2, with a total area of 85,500 m^2; • One accommodation platform on a GBS (Box-type) foundation (small OSS), with a length and width of 75 m at seabed level and at LAT. Average water depth of 47.5 m, giving a total surface area of 14,250 m^2; and • Three HVAC booster stations on GBS (Box-type) foundations (small OSS), each with a length and width of 75 m at seabed level and at LAT. Average water depth of 51 m in the HVAC Booster Station Search Area, giving a per-foundation surface area of 15,300 m^2, with a total area of 45,900 m^2.	Limits, however in order to assess the MDS for both the array and the ECC, the presence of the maximum numbers of OSS and platforms in each area has been considered (ten and three, respectively). As a result, the outcome of the assessment is therefore inherently precautionary.
Direct disturbance resulting from maintenance during operation (FSE-O-10).	Primary: Co44 Co45 Co83	**Direct disturbance to seabed from jack-up vessels and cable maintenance activities = 8,579,812 m^2.** **WTG O&M activities – jack up operations:** • Component replacement = 378,000 m^2; • Access ladder replacement = 378,000 m^2; • Foundation anode replacement = 378,000 m^2; and • J-Tube repair/ replacement = 108,000 m^2. **Array cable activities:** • Remedial burial of array cables (42 km total length reburied) = 4,200,000 m^2; • Array cable repairs = 363,736 m^2; and • Cable protection replacement = 156,000 m^2.	Defined by the maximum number of jack-up vessel operations and maintenance activities that could have an interaction with the seabed anticipated during operation.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		OSS and accommodation platform activities: • OSS component replacement = 6,000 m^2; • Access ladder replacement = 90,000 m^2; • Foundation anode replacement = 21,000 m^2; and • J-Tube repair/ replacement = 6,000 m^2. **Offshore export cable activities:** • Remedial burial of export cables (14 km total length reburied) = 1,400,000 m^2; • Export cable repairs = 153,548 m^2; and • Cable protection replacement = 198,000 m^2. **Interconnector cable activities:** • Remedial burial of interconnector cables (7 km total length reburied) = 700,000 m^2; • Interconnector cable repairs = 20,028 m^2; and • Cable protection replacement = 23,500 m^2.	
Decommissioning			
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from decommissioning activities (FSE-D-13).	Primary: Co44 Co45 Co48 Co84 Co86 Secondary: Co188 Co189 Tertiary: Co181	MDS is identical (or less) to that of the construction phase (FSE-C-1). **Total area of direct disturbance = 75,895,509 m^2**	MDS is assumed to be similar to the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables and rock protection is considered the MDS, however the necessity to remove cables and rock protection will be reviewed at the time of decommissioning.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Temporary localised increases in SSC and smothering (FSE-D-14).	Primary: Co44 Co45 Tertiary: Co181	MDS is identical (or less) to that of the construction phase (FSE-C-2). **Total volume = 12,213,921 m^3**	MDS is assumed to be as per the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables is considered the MDS, however the necessity to remove cables will be reviewed at the time of decommissioning.
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-D-15).	Primary: Co44 Co45 Tertiary: Co181	MDS is identical (or less) to that of the construction phase (FSE-C-3). **Total volume = 12,213,921 m^3**	MDS is assumed to be as per the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables is considered the MDS, however the necessity to remove cables will be reviewed at the time of decommissioning.
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-D-16).	Tertiary: Co113 Co181	Maximum levels of underwater noise during decommissioning would be from underwater cutting required to remove structures. This is much less than pile driving and therefore impacts would be less than as assessed during the construction phase/ piled foundations would likely be cut approximately 1 m below the seabed.	This would result in the maximum potential disturbance associated with noise associated with decommissioning activities including foundation decommissioning.

3.10 Assessment methodology

3.10.1 Impact assessment criteria

3.10.1.1 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 (see **Volume A1, Chapter 5: Environmental Impact Assessment Methodology**). The terms used to define sensitivity and magnitude are based on those used in the CIEEM (2016) methodology.

3.10.1.2 The criteria for defining sensitivity and magnitude are outlined in **Table 3.11** and **Table 3.12** below.

Table 3.11: Definition of terms relating to receptor sensitivity.

Sensitivity	Definition used in this chapter
Very High	Nationally and internationally important receptors with high vulnerability and no ability for recovery.
High	Regionally important receptors with high vulnerability and no ability for recovery. Nationally and internationally important receptors with medium to high vulnerability and low to medium recoverability.
Medium	Locally important receptors with medium to high vulnerability and low recoverability. Regionally important receptors with low vulnerability and medium recoverability. Nationally and internationally important receptors with low vulnerability and medium to high recoverability.
Low	Receptor is not vulnerable to impacts regardless of value/ importance. Locally important receptors with low vulnerability and medium to high recoverability.

Table 3.12: Definition of terms relating to magnitude of an impact.

Magnitude of impact	Definition used in this chapter
Major	Loss of resource and/or quality and integrity of resource; severe damage to key characteristics, features or elements (Adverse)
	Large scale or major improvement or resource quality; extensive restoration or enhancement; major improvement of attribute quality (Beneficial)
Moderate	Loss of resource, but not adversely affecting integrity of resource; partial loss of/damage to key characteristics, features or elements (Adverse)
	Benefit to, or addition of, key characteristics, features or elements; improvement of attribute quality (Beneficial)
Minor	Some measurable change in attributes, quality or vulnerability, minor loss or, or alteration to, one (maybe more) key characteristics, features or elements (Adverse)
	Minor benefit to, or addition of, one (maybe more) key characteristics, features or elements; some beneficial impact on attribute or a reduced risk of negative impact occurring (Beneficial)
Negligible	Very minor loss or detrimental alteration to one or more characteristics, features or elements (Adverse)

Magnitude of impact	Definition used in this chapter
	Very minor benefit to, or positive addition of one or more characteristics, features or elements (Beneficial)

3.10.1.3 The significance of the effect upon fish and shellfish ecology is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The method employed for this assessment is presented in **Table 3.13**, where a range of significance of effect is presented, the final assessment for each effect based upon expert judgement.

3.10.1.4 For the purposes of this assessment, any effects with a significance level of slight or less have been concluded to be not significant in terms of the EIA Regulations.

Table 3.13: Matrix used for the assessment of the significance of the effect.

		Magnitude of impact (degree of change)			
		Negligible	*Minor*	*Moderate*	*Major*
Environmental value (sensitivity)	*Low*	Neutral or Slight (Not Significant)	Neutral or Slight (Not Significant)	Slight (Not Significant)	Slight (Not Significant) or Moderate (Significant)
	Medium	Neutral or Slight (Not Significant)	Slight (Not Significant) or Moderate (Significant)	Moderate or Large (Significant)	Moderate or Large (Significant)
	High	Slight (Not Significant)	Slight (Not Significant) or Moderate (Significant)	Moderate or Large (Significant)	Large or Very Large (Significant)
	Very High	Slight (Not Significant)	Moderate or Large (Significant)	Large or Very Large (Significant)	Very Large (Significant)

3.10.1.5 This chapter summarises the assessments made on the interest features of internationally designated sites protected under the Habitats and Birds Directives and Ramsar Convention, as described within **Section 3.7.1.11** of this chapter (with the assessment on the site itself deferred to **B2.2 Report to Inform Appropriate Assessment**). The RIAA Report has been prepared in accordance with PINS Advice Note Ten: Habitats Regulations Assessment Relevant to Nationally Significant Infrastructure Projects (PINS 2017) and is submitted as part of this DCO Application.

3.10.1.6 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 RIAA), 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). However, where a nationally designated site falls outside the boundaries of an international site, but within the study area, an assessment of the impacts on the overall site is made in this chapter using the EIA methodology.

3.11 Impact assessment

3.11.1 Construction

3.11.1.1 The potential environmental impacts arising from the construction of Hornsea Four are listed in **Table 3.10** along with the MDS against which each construction phase impact has been assessed. A description of the potential effect on fish and shellfish receptors caused by each identified impact is given below.

Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities (FSE-C-1)

3.11.1.2 Direct damage and disturbance in the Hornsea Four fish and shellfish study area will be a likely occurrence from foundation seabed preparation, the use of jack-ups and anchored vessels and cable seabed preparation and installation works during the construction phase of the development.

Magnitude of impact

3.11.1.3 Up to 75,895,509 m^2 of subtidal seabed is predicted to be directly impacted during the construction of Hornsea Four, which equates to approximately 1.8% of the fish and shellfish study area. This impact has the potential to result in direct damage and disturbance to fish and shellfish receptors and their habitats within this footprint. The impact is predicted to be of local spatial extent (only affects the areas directly within the construction footprint), of short-term duration, intermittent and reversible. It is predicted that the impact will affect fish and shellfish receptors directly, through direct damage (crushing) and disturbance.

3.11.1.4 In general, fish are able to avoid temporary direct disturbance (EMU 2004). Shellfish species are considered to have a more limited ability to avoid direct effects due to the relative energetic costs or speed of movement (i.e. scallops) or behaviours (e.g. during breeding) that may make them more susceptible to direct effects due to a sedentary habit.

3.11.1.5 The nearshore section of the Hornsea Four ECC is located in relatively close proximity to, but does not directly overlap with, the highest intensity herring spawning grounds (**Figure 3.4** and **Figure 3.6**) as defined by the IHLS data sets. The proposed location of the ECC and the HVAC booster station search area does directly overlap with areas of low - medium intensity spawning activity. Taking into consideration the proximity of herring spawning grounds (based on the IHLS data and also Coull et al. 1998) to Hornsea Four but also the relatively small overlap from the works on this spawning ground and lack of overlap with the core highest density spawning areas to the north of Flamborough Head, and the localised and short-term nature of the impact, the magnitude of impact from direct disturbance, associated with the construction of Hornsea Four (export cable installation and HVAC booster installation) on herring spawning grounds is assessed as **minor** (adverse).

3.11.1.6 The Hornsea Four offshore section of the proposed ECC and the array area are located within areas classified as 'preferred' potential sandeel spawning and nursery habitats (**Figure 3.5**), however the proportion of preferred habitat within the Hornsea Four fish and

shellfish study area is small within the context of known sandeel habitats in the wider Southern North Sea (see **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report** for further detail on the extent of sandeel spawning). Therefore, taking into account the wide distribution of sandeel habitats across the Southern North Sea, and the short term and localised nature of the impact arising during construction, the magnitude of impact of direct damage and disturbance from the construction of Hornsea Four is considered to be **minor** (adverse).

3.11.1.7 Brown crab spawning grounds (Eaton et al. 2003) are located to the west of the HVAC booster station, clipping the far western edge of the proposed location of the booster station, and inshore of the array area, however in a broader context the grounds are also located across the English Channel and Western Approaches, with spawning areas also apparent in the Bay of Biscay and the Celtic Sea (Thompson et al. 1995; Pawson 1995). There is evidence that overwintering grounds for lobster may be located nearshore, close to the Humber Estuary (SMart Wind 2015a), however there is no direct overlap with the Hornsea Four study area. Lobster also has a wide distribution in northeast Atlantic waters, from Northern Norway south to the Atlantic coast of Morocco (Prodöhl et al. 2007). *Nephrops* spawning grounds (Coull et al. 1998) overlap the proposed array area and also extend further offshore across the central North Sea. The proposed Hornsea Four ECC also overlaps with a large scallop ground located along the Hornsea coast (Cefas 2019), although it should be noted that key scallop grounds are also located across the English Channel, the Irish Sea and off the coasts of Scotland (Cappell 2018). Common whelk are reportedly common off all British coasts. Due to the commercial value and importance of scallop, brown crab, European lobster, *Nephrops* and common whelk to the region, and proximity of important shellfish habitats, spawning grounds and overwintering areas to the project, due consideration is given to the potential for impacts on these species from direct disturbance during construction. Taking the widespread occurrence of these species across UK waters and the expected high recoverability of these species to direct disturbance (i.e., rapid recolonisation of affected areas from immediate surrounding areas or recruitment) into account and given the highly localised and short-term nature of the impact, the magnitude of effect on these shellfish receptors is assessed as **minor** (adverse).

3.11.1.8 All other VERs and their respective spawning grounds are distributed widely throughout the Southern North Sea, with all other species being mobile and having a pelagic spawning habit. Therefore, taking the wider environment into context, and the localised and temporary nature of the impact, the magnitude of effect on all other VERs is assessed as being **negligible** (adverse). Irrespective of the sensitivity of the receptor, the significance of the impact on all other VERs is **not significant** as defined in the assessment of significance matrix (**Table 3.13**) and is therefore not considered further in this assessment.

Sensitivity of receptor

3.11.1.9 On account of the demersal spawning nature of herring and sandeel they are considered to be vulnerable to the effects of direct damage and disturbance during the construction phase of development. Herring and sandeel are considered most vulnerable during spawning when they are less mobile, with their eggs and larvae also considered to be unable to avoid this impact; therefore, in the case of this assessment, herring and sandeel are considered stationary receptors. In addition to this, both species are considered to

be reliant on the presence of suitable spawning substrates (i.e. gravelly sediments for herring and sandy sediments for sandeel). Therefore, herring and sandeel are considered to be more vulnerable to direct damage and disturbance compared to other fish receptors as a result of this reliance on a specific habitat type. Consequently, herring and sandeel are deemed to be of high vulnerability to direct damage and disturbance, with medium recoverability (due to the temporary nature of the impact) and are considered to be of regional importance in the southern North Sea, and both species are therefore considered to be of **high** sensitivity to direct damage and disturbance during the construction phase.

3.11.1.10 Typically, less mobile species (such as shellfish) are considered likely to have a greater vulnerability to direct damage and disturbance. Berried female brown crab, for example, exhibit a largely sedentary lifestyle during the overwintering period; for the purposes of the assessment brown crab are therefore considered a stationary receptor, and are considered unlikely to be able to move away from physical impacts to the seabed. Taking this into account, brown crab is considered to be of high vulnerability particularly during the overwintering period, but with high recoverability (Neal and Wilson 2008) and are considered to be of regional importance, and therefore the sensitivity of the receptor to direct damage and disturbance during the construction phase is **medium**.

3.11.1.11 European lobster are considered a key species within the area (ecologically and commercially), however the species are not known to exhibit a sedentary overwintering habit, being typically mobile and therefore the species are considered to have a greater ability to move away from disturbances by comparison to brown crab. European lobster are therefore considered to be of medium vulnerability, are considered to have a high recoverability and to be of regional importance, and are therefore considered to be of **low** sensitivity to direct damage and disturbance from construction activities.

3.11.1.12 Scallop are currently considered to be the highest value shellfish species in the UK. The area surrounding the Hornsea Four ECC is currently fished for scallop and therefore the species are typically exposed to a degree of disturbance under normal circumstances as a result of this dredge fishery. The species exhibits limited swimming, with this behaviour generally limited to predator avoidance. Scallops are therefore considered unlikely to be able to actively avoid disturbance. Scallop are therefore considered to be of medium vulnerability, high recoverability (Marshall and Wilson 2008) and of regional importance, and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is **medium**.

3.11.1.13 Berried female *Nephrops* tend to be considered largely sedentary and confined to particular habitat types, remaining in their burrows during the overwintering period. They are therefore considered unlikely to be able to move away from disturbance. Given the relatively high abundances of this species in the east of the array area but also the distribution of this species outside of the project area (Cefas 2012), *Nephrops* are therefore considered to be of high vulnerability during the overwintering period, are considered to exhibit high recoverability (Sabatini and Hill 2008) and to be of regional importance, and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is **medium**.

3.11.1.14 Common whelk has been identified as a species of commercial importance to the area surrounding Hornsea Four. Common whelk are not thought to make extensive

movements and are known to burrow into muds to overwinter, and are therefore considered a stationary receptor for the purposes of assessment. Taking this into account but also considering their broad distribution along British coasts, common whelk are considered to be of medium vulnerability, high recoverability and to be of local importance, and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is **medium**.

Significance of the effect

3.11.1.15 Direct damage and disturbance during the construction phase will represent a short-term and localised effect, within only a small portion of herring and sandeel spawning habitats being affected in the context of the wider habitats in the area. Overall, the magnitude of impact on herring and sandeel has been assessed as **minor**. The sensitivity of herring and sandeel is assessed as **high**. The minor magnitude and high sensitivity of herring and sandeel could result in either a slight or moderate effect (as per the matrix in **Table 3.13**). The majority of the ECC was identified as being of unsuitable habitat for herring spawning (as per the PSA data as presented in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report** and **Figure 3.6**), with the centre of the IHLS hotspot data suggesting herring spawning primarily occurs within the sub-prime and suitable sediments to the north of the ECC (**Figure 3.6**) and therefore outwith any areas affected directly by construction works. Whilst the PSA data showed suitable spawning sediments for sandeel, it showed large areas of suitable habitat throughout the study area and the spawning grounds for sandeel are very widely spread throughout the North Sea and any impacts from the works would only affect an extremely small proportion of the available suitable habitat. Taking into account the localised and short-term nature of the impacts, and the small area of direct impact compared to the overall extent of the spawning grounds (and the impact being restricted to an area avoiding the highest intensity herring spawning grounds based on the IHLS data), the significance of effect therefore is deemed **slight** for herring and sandeel, which is not significant in EIA terms.

3.11.1.16 The magnitude of impact on shellfish receptors was assessed as being **minor**, and the sensitivities of brown crab, scallop, *Nephrops* and common whelk were all assessed as **medium**. The medium sensitivities and minor magnitude of the impact could result in either a slight or moderate effect (as per the matrix in **Table 3.13**). Taking into account the extensive distribution of these species along the coasts of the UK, the small degree of overlap of Hornsea Four with identified shellfish resources and spawning grounds, and the short-term nature of the impact, it is concluded that the impact will be of **slight** significance, which is not significant in EIA terms. European lobster were assessed as having **low** sensitivity from direct disturbance during construction, and therefore the significance of effect is **slight**, which is also considered not significant in EIA terms.

Temporary localised increases in SSC and smothering (FSE-C-2)

3.11.1.17 Temporary localised increases in suspended sediment concentration (SSC) and associated sediment deposition and smothering are expected from foundation and cable installation works and seabed preparation works (including sandwave clearance). This assessment should be read in conjunction with **Chapter 1: Marine Geology, Oceanography and Physical Process** and **Volume A5, Annex 1.1: Marine Processes Technical Report** which provides the detailed offshore physical environment assessment (including project specific modelling of sediment plumes).

Magnitude of impact

3.11.1.18 Background surface SSCs at the inshore extents of the offshore ECC are known to vary seasonally between 2 to 14 mg/l, reducing offshore to around 2 to 3 mg/l. Surface turbidity (represented by suspended particulate matter (SPM) is relatively low across the offshore array area, with monthly averaged concentrations typically less than 5 mg/l across the whole year (Cefas 2016). The relatively low concentrations are due to both a low content of fine material in the seabed sediments and the area being distant from any terrestrial sources for finer sediments, such as the Humber Estuary and the Holderness Cliffs.

3.11.1.19 **Table 3.10** presents the MDS associated with increases in SSC and deposition. The MDS for SSC and deposition during the construction phase of Hornsea Four would result from the total release of up to 12,214,451 m^3 of sediment into the water column in the array area and offshore ECC, from seabed preparations for GBS and suction caisson foundations.

3.11.1.20 Seabed preparation for foundations, sandwave clearance for cable installation, cable trenching, drilling for foundations and spoil disposal are all predicted to result in sediment plumes and localised increases in SSC. Site-specific modelling of sediment plumes and deposition (Appendix C of **Volume A5, Annex 1.1: Marine Processes Technical Report**) from seabed preparation and installation activities along the proposed Hornsea Four offshore ECC, and within the offshore array area has been undertaken to quantify the potential footprint of the plumes, their longevity and the concentration of SSC as well as the subsequent deposition of plume material on the seabed.

3.11.1.21 **Table 3.14** summarises the potential for increases in SSC and subsequent sediment deposition as a result of construction activities at Hornsea Four as informed by the site-specific modelling.

Table 3.14 Temporary increases in SSC and sediment deposition as a result of construction activities at Hornsea Four.

Construction Impact	Location	Maximum sediment plume distance	Details of increase in SSC and deposition
Sandwave clearance	Nearshore ECC	14 km (springs) and 6 km (neaps)	• SSCs within sediment plumes associated with overspill can be in the order of hundreds of mg/l in the vicinity of the dredger, reducing to tens of mg/l with distance, but also quickly dissipating with time after release;

Construction Impact	Location	Maximum sediment plume distance	Details of increase in SSC and deposition
			• The deposition of fine sediment under low flow conditions is predicted to be less than 2 mm from overspill; • Dredge spoil disposal plume concentrations remain less than 10 mg/l for all locations 2 km beyond the point of release and are not detectable after about 20 hours; and • The depth of spoil deposition (for all sediments) is typically very small (around 0.1 mm) but reaches 5.9 cm for the spring tide in a confined area and 10 cm for a neap release. These depths of deposition cover a very small area and are due to coarser grained sediments (gravels).
Seabed preparation for foundations	Offshore array	7 km (neaps) and 10 km (springs) along the axis of the tide	• SSCs within sediment plumes associated with overspill can be in the order of hundreds of mg/l in the vicinity of the dredger, reducing to tens of mg/l with distance, but also quickly dissipating with time after release; • Dredge spoil disposal plume concentrations will remain less than 2 mg/l, 2 km from the point of release and will not be detectable after 40 hours; and • The depth of spoil deposition after three days is typically very small (around 0.1 mm) but reaches 3.8 cm for the neap tide scenario and 2.9 cm for spring tides, in a confined area (where deposition material consists primarily of coarser materials).
	HVAC booster station search area	7 km (springs) and 12 km (neaps) along the axis of the tide	• SSCs within sediment plumes associated with overspill can be in the order of hundreds of mg/l in the vicinity of the dredger, reducing to tens of mg/l with distance, but also quickly dissipating with time after release; • Dredge spoil disposal plume concentrations will remain under 10 mg/l, 2 km from the point of release and will not be detectable after 60 hours; and • The depth of spoil deposition after three days is typically small (0.1 mm) but reaches 0.4 cm for a spring tide, but in a confined area.
Offshore trenching for cables	Offshore ECC	14 km along the axis of the tide	• Within 5 m of trenching very high plume concentrations are expected. SSC could be millions of mg/l. This is only expected to occur while the CFE is active; • At 2 km from the source, the silt content will be approximately 100 mg/l during the trenching period and will fully dissipate after around 65 hours; and • The maximum depth of deposition is 7.1 cm on neaps and 5.3 cm on springs, along the trench. The maximum settlement depth reduces exponentially in range from the trench reaching 0.12 m at 50 m and 0.06 m at 100 m.
	Offshore array	10 km along the axis of the tide	• Concentrations of SSC can reach 1,000 mg/l in the vicinity of the trenching with only the silt fraction

Construction Impact	Location	Maximum sediment plume distance	Details of increase in SSC and deposition
			dispersing away from the trench with plume concentrations of around 100 mg/l up to 2 km; • The maximum depth of deposition is 11.6 cm on neaps and 13.2 cm on springs along the trench; • A wider spread of deposition under spring tides, with the lowest depth of sediment deposition (circa 0.1 mm); and • The silt contribution to the sediment deposition represents 2.3 mm on neaps and 1.6 mm on spring tides.
Drilling at foundations	Offshore array/ /HVAC booster station search area	10-14 km along the axis of the tide	Results comparable to sediment plumes and deposition of fines to those presented for sandwave clearance, but considerably less in proportion.

3.11.1.22 In summary, sediment plumes caused by seabed preparation and installation activities are expected to be restricted to within a single tidal excursion from the point of release, with plumes expected to occur over a maximum distance of 14 km over a spring tide, from the source. Sediment plumes are expected to quickly dissipate after cessation of the construction activities, due to settling and wider dispersion with the concentrations reducing quickly over time to background levels. Sediment deposition will consist primarily of coarser sediments deposited close to the source, with a small proportion of silt deposition (reducing exponentially from source).

3.11.1.23 Taking the above into consideration, the impact of increased SSC and smothering from sediment deposition from construction activities is expected to be short-term, intermittent and of localised extent and reversible. Taking into consideration the localised nature of herring spawning grounds within the study area and the location of the highest intensity spawning grounds currently in use (based on the IHLS data), the magnitude of impact from an increase in SSC and deposition from construction within the array area, at the HVAC booster station, and along the ECC on herring is considered to be **minor** (adverse).

3.11.1.24 Due to the presence of sandeel habitats across the southern North Sea and given the localised nature of the impact of SSC and sediment deposition, the magnitude of impact from increased SSC from construction within the array area, the HVAC booster station search area and along the ECC on sandeel is also considered to be **minor** (adverse).

3.11.1.25 Brown crab spawning grounds (Eaton et al. 2003) are located predominantly inshore of the array area and across the proposed ECC**.** Scallop grounds (Cefas 2019) are located across the nearshore section of the ECC, partially overlapping the HVAC booster station search area. *Nephrops* spawning grounds (Coull et al. 1998) are located offshore and partially overlap with the far eastern corner of the array. There is limited information on lobster spawning grounds in the southern North Sea, however it is suggested that nearshore areas, close to the Humber Estuary may represent overwintering grounds (SMart Wind 2015a). Common whelk is not philopatric, and have a broad distribution along the coasts of Britain. Taking the locations of key shellfish species spawning grounds and their relatively broad distributions relative to the location of the HVAC

booster station search area and the array into consideration, and the temporary and localised nature of the impact, the magnitude of impact on these species is considered to be **minor** (adverse) from increases in SSC and smothering from deposition arising from construction activities.

3.11.1.26 All other VERs and their respective spawning grounds are distributed widely throughout the southern North Sea, and therefore taking the wider environment into context, the magnitude of impact on all other VERs is assessed as being **minor** (adverse) from impacts at the array, the HVAC booster station search area, and along the ECC.

Sensitivity of the receptor

3.11.1.27 Relatively high intensity spawning sites for herring occur in the vicinity of the HVAC booster station search area along the ECC, although this is to the south of the highest intensity spawning based on the IHLS data set. Nonetheless, it is likely that some proportion of the herring spawning habitat will be subject to indirect effects as a result of SSC plumes and sediment deposition.

3.11.1.28 However, it has been shown that herring eggs are tolerant of very high levels of SSC (Kiorboe et al. 1981). Adult herring are mobile and therefore may show avoidance behaviour to the impact whilst spawning herring may not show these avoidance behaviours. Given that any increases in SSC are expected to be short term and intermittent and, excluding within the immediate locality of the construction activity, within the natural range of SSC. Taking this into consideration, spawning herring are considered to be of medium - high vulnerability, with low recoverability to the impact, and of regional importance, and therefore the sensitivity of the receptor to increases in SSC and sediment deposition from construction activity is **high**.

3.11.1.29 Potential sandeel spawning grounds and 'preferred' habitats (**Figure 3.5**) are located across the offshore section of the ECC and the array area, although any impacts on this species are expected to be relatively small in the context of the spawning habitat available in the wider region. Furthermore, the secondary effects of increased concentrations of SSC in the water column and smothering (from deposition of particles), have been shown to be inconsequential to sandeel species (MarineSpace Ltd 2010). Sandeel eggs are also likely tolerant to increases in SSC and smothering from sediment deposition, due to the nature of resuspension and deposition within their natural high energy environment. Based on the species reduced sensitivity to increased SSC and deposition, sandeel are deemed to be of low vulnerability, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is **low**.

3.11.1.30 Brown crabs are considered to have a high tolerance to SSC and are reported to be insensitive to short term increases in turbidity; however, they may avoid areas of increased SSC as they rely on visual acuity during predation (Neal and Wilson 2008). Berried female brown crab exhibit a largely sedentary lifestyle during the overwintering period whilst brooding eggs. During this time, they are considered a stationary receptor, burying themselves into soft mud and sand, and are therefore unlikely to move away from disturbances. Berried females are considered more vulnerable to smothering from sediment deposition, due to their sedentary nature at this time, and as the eggs carried require regular aeration. Taking this into account, brown crab is considered to be of high

vulnerability during the overwintering period, high recoverability (Neal and Wilson 2008) and of regional importance, and therefore the sensitivity of the receptor is **medium**.

3.11.1.31 European lobster are considered a key species within the area (ecologically and commercially); however the species are not thought to exhibit a sedentary overwintering habit (as is observed in brown crab), being typically mobile and therefore considered able to move away from sources of disturbance. Berried females are likely to be more vulnerable to increased SSC and smothering impacts as the eggs carried require regular aeration. Lobster is therefore considered to be of medium vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **medium**.

3.11.1.32 Scallop can undertake limited swimming, although this is considered to be at a high energy cost and generally associated with predator avoidance, therefore this species is not expected to be able to travel large distances to avoid disturbance. Scallop are therefore considered to be of medium vulnerability, high recoverability (Marshall and Wilson 2008) and of regional importance, and therefore the sensitivity of the receptor is **medium**.

3.11.1.33 *Nephrops* were found in the east of the study area, with 13 berried females reported. This species constructs and inhabits complex burrows in environs characterised by stable mud. As with brown crab, berried females tend to be considered largely sedentary whilst brooding eggs, generally remaining within their burrows to overwinter, and are therefore unlikely to move away from disturbance. Berried females are considered more vulnerable to smothering from sediment deposition, as the eggs require regular aeration. However, since *Nephrops* are a burrowing species with the ability to excavate any sediment deposited within their burrows (Sabatini and Hill 2008), they are not considered particularly vulnerable to increased SSC and smothering. Impacts to *Nephrops* are largely dependent upon the density of the individuals in the area; given the relatively high abundances of this species in the east of the array area and the distribution of this species outside of the project area from historic literature (Cefas 2012), and taking into account the burrowing nature of the species *Nephrops* are considered to be of low vulnerability, high recoverability (Sabatini and Hill 2008) and of regional importance, and therefore the sensitivity of the receptor is **low**.

3.11.1.34 Common whelk (*Buccinum undatum*) is found across a range of habitats including muddy sand, gravel and rock, and are reportedly common off all British coasts. Common whelk typically burrow into mud to overwinter and emerge to feed when conditions improve. Taking into account their burrowing nature and their broad distribution around Britain, common whelk are therefore considered to be of low vulnerability, high recoverability and of local importance, and therefore the sensitivity of the receptor is **low**.

3.11.1.35 All other VERs and their respective spawning grounds are distributed widely throughout the Southern North Sea, exposure to naturally high variability in SSC within their natural range, and none of which exhibit substrate dependant spawning behaviours. As a result of this, all other VERs are considered to be of **low** sensitivity.

Significance of the effect

3.11.1.36 Increases in SSC and smothering of sedentary or spawning species from sediment deposition will represent a temporary and short-term intermittent impact, affecting a relatively small portion of the fish and shellfish habitats in the study area. Most receptors are predicted to have some tolerance to this impact since it mirrors the sedimentary processes that they experience regularly as a result of natural processes.

3.11.1.37 Overall, the magnitude of the impact has been assessed as **minor** (adverse) for herring at the array area, the HVAC booster station search area and along the ECC. The sensitivity of herring to increased SSC and smothering was assessed as **high**, resulting in either a slight (not significant) or moderate (significant) effect (as per the matrix in **Table 3.13**). The proposed cable corridor for Hornsea Four runs to the south of the core of the herring spawning area (based on the IHLS data showing the hotspot to be around Flamborough Head). Whilst the IHLS data from 2019/20 and 2020/21 show the hotspot overlapping with the ECC, this is due to the high densities of larvae recorded within these years and the fixed scale used for the presentation of the IHLS data (to show inter-annual variations), with the highest values found outside the ECC. The physical processes modelling identifies that the SSC from all works will be greatest within 10's to low 100's of metres from the release point and outwith this distance SSCs will be less than 100 mg/l and the sediment plume will be very spatially limited (reaching a maximum of 500 m at sediment loads of below 100 mg/l) (Appendix C of **Volume A5, Annex 1.1: Marine Processes Technical Report**). Impacts to herring eggs was only noted at SSCs above 250 mg/l and only where the eggs were exposed to high SSCs loads within the first two hours after fertilisation (Griffen et al. 2009). The nature of construction works is such that works (and therefore impacts) are both spatially and temporally intermittent and as such, the likelihood of a sediment plume from the works overlapping with very recently fertilised eggs or actively spawning herring is very low. Furthermore, the sediment plume is focused along the tidal axis which varies between tidal cycles and as such, any single area of herring spawning habitat is unlikely to be affected more than a few times consecutively, further reducing the likelihood of any interaction with spawning herring. Additionally, the majority of the ECC was identified as being of unsuitable habitat for herring spawning (as per the PSA data as presented in **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report** and **Figure 3.6**), with the centre of the IHLS hotspot data suggesting spawning primarily occurs within the sub-prime and suitable sediments to the north of the ECC (**Figure 3.6**) and therefore outwith any areas affected by high levels of SSC from construction works. Taking into account the short term, intermittent and localised nature of this impact and the relative tolerance of herring eggs to increased SSC and deposition (Kiorboe et al. 1981), the significance of effect is deemed **slight** rather than moderate for herring, which is not significant in EIA terms.

3.11.1.38 The sensitivity of sandeel is assessed as **low**. The **low** sensitivity and **minor** (adverse) magnitude of the impact on sandeel at the array area, the HVAC booster station search area and along the ECC could result in either a neutral or slights effect (as per the matrix in **Table 3.13**). Impacts on this species are expected to be relatively small in the context of the spawning habitat available in the wider region. In addition to this, sandeel and sandeel eggs are also considered relatively tolerant to this impact. Therefore, taking this into consideration, the significance of effect is deemed **neutral** for sandeel which is also not significant in EIA terms.

3.11.1.39 The magnitude of impact on shellfish receptors was assessed as being **minor adverse**, and the sensitivities of brown crab, scallop and European lobster were all assessed as **medium**. The **medium** sensitivities and **minor** (adverse) magnitude of the impact could result in either a slight or moderate effect (as per the matrix in **Table 3.13**). However, taking into account the extensive distribution of these species, and the relatively small degree of overlap of Hornsea Four with the identified shellfish resources and spawning grounds, it is concluded that the significance of the effect will be **slight**, which is not significant in EIA terms. *Nephrops* and common whelk were assessed as having **low** sensitivity from increased SSC and smothering, which could result in either a neutral or slight effect. Considering the extensive distribution of these species across the study area, the significance of effect is considered **neutral**, which is not significant in EIA terms.

3.11.1.40 The magnitude of impact on all other VERs has been assessed as **minor**, and their sensitivity as **low**. This could result in either a neutral or slight effect (as per the matrix in **Table 3.13**). Considering the extensive distribution of these species across the study area, and the small degree of impact in the context of the spawning grounds across the wider region, the significance of effect is deemed to be **neutral**, which is not significant in EIA terms.

Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-C-3)

3.11.1.41 As identified in **Table 3.10** and assessed in the above section (FSE-C-2), construction activities will re-suspend sediments. While in suspension, there is the potential for sediment bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on fish and shellfish receptors.

3.11.1.42 An assessment of subtidal sediment contamination within the array area was undertaken in **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** based on site-specific surveys within the Hornsea Four array and along the offshore ECC. That assessment is therefore used to inform the assessment below. The results reveal that hydrocarbon concentrations across most of the array were within the expected United Kingdom Offshore Operators Association (UKOOA) (2001) background concentrations, with some elevations in total hydrocarbon concentrations around existing oil and gas infrastructure as expected. All metal and hydrocarbon concentrations, when compared to Buchman (2008) Apparent Effects Threshold's (AETs), were below their respective AETs indicating that toxicological impacts on fauna were unlikely. Taking this into account, contaminant concentrations from across the array and ECC are considered unlikely to exert an effect on the marine environment.

Magnitude of impact

3.11.1.43 The potential volume of material disturbed will be up to 12,213,921 m^3, resulting in the potential release of sediment-bound contaminants which will be small and localised in extent. In addition, the nature of the subtidal sediments is predominantly medium to coarse sands (**Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**), typically with relatively low levels of fines adhering to them and therefore very low levels of sediment bound contaminants.

3.11.1.44 Following disturbance as a result of construction activities, the majority of re-suspended sediments are expected to be deposited in the immediate vicinity of the works (see **paragraphs 3.11.1.17** *et seq.*). The release of contaminants such as metals, hydrocarbons and organic pollutants from the small proportion of fine sediments is likely to be rapidly dispersed with the tide and/or currents and therefore increased bioavailability resulting in adverse eco-toxicological effects are not expected. The contaminants levels found are all comparable to the wider regional background and not considered to be recorded at a level that could result in a significant effect-receptor pathway if made bioavailable. The impacts to herring, sandeel, shellfish and all other VER receptors from construction in both the array area, the HVAC booster station search area and along the ECC, as a result of the release of sediment-bound contaminants are therefore considered to be of **negligible** (adverse) magnitude. Irrespective of the sensitivity of the receptor, the significance of the impact is **not significant** as defined in the assessment of significance matrix (**Table 3.13**) and is therefore not considered further in this assessment.

Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-C-4)

Introduction

3.11.1.45 The assessment below focuses on underwater noise from pile-driving (monopiles and pin piles) for the installation of foundations for offshore structures (i.e. WTGs and OSS), cable installation, vessel disturbance and UXO clearance.

3.11.1.46 To inform the assessment of potential impacts associated with underwater noise as a result of the installation of foundations, predictive underwater noise modelling has been undertaken for the relevant piling MDS, full details of which are presented in **Volume A4, Annex 4.5: Subsea Noise Technical Report**. To inform the assessment of the potential impacts associated with underwater noise as a result of UXO clearance, a high-level consideration has been provided of the potential effects arising from UXO clearance in **paragraph 3.11.1.145** *et seq.* It should be noted that UXO clearance will be consented under a separate Marine Licence and will therefore not be consented as part of the DCO, it is for this reason that assumptions have been made based on experience on previous projects, however, no project specifics are expressly considered.

3.11.1.47 As agreed during consultation with relevant stakeholders under the auspices of the Evidence Plan (see **B1.1.1: Evidence Plan Report**) the predictive subsea noise modelling for foundation installation has been undertaken at four locations (locations illustrated in **Figure 3.8** to **Figure 3.21**), with consideration of the key parameters associated with two MDSs, a spatial MDS (the scenario with the greatest potential spatial extent of impact) and a temporal MDS (the scenario with the longest potential duration), as set out below. Each MDS is assessed through reference to the predictive modelling, and the relevant metric and associated threshold criteria that have been agreed under the auspices of the Evidence Plan (OFF-ME&P-2.1).

Definition of Maximum Design Scenarios for underwater noise

3.11.1.48 The following provides further information on the definition of the MDS for underwater noise. As detailed in **Table 3.10**, several activities have the potential to introduce an effect receptor pathway for underwater noise. These can be broadly characterised as underwater noise associated with general seabed clearance, installation and vessel operations, underwater noise associated with foundation installation, and underwater noise associated with UXO specific seabed clearance.

3.11.1.49 General construction noise, arising from general vessel movements, dredging and seabed preparation works will generate low levels of continuous sounds (i.e. from the vessels themselves and/or the sounds from dredging tools). The Hornsea Four Order Limits are subject to high levels of shipping activity currently, and it is expected that the vessel activity would be no greater than the baseline during construction activities (due to construction exclusion zones reducing current shipping activity and the number of construction vessels expected to be much lower than that which currently transit the area). The underwater noise impacts from vessel noise is generally spatially limited to the immediate area around the vessel rather than having impacts over a wide area.

3.11.1.50 The spatial and temporal MDS are defined according to a maximum scenario, i.e. the maximum design parameters that may be utilised during the construction of the proposed development, and a most-likely scenario, i.e. the most realistic design parameter that may be utilised during the construction of the proposed development. In this context it is important to note that the maximum hammer energies assumed in the MDS are likely to be highly conservative and that in fact for many piling events, a lesser hammer energy will be required to complete the pile installation. **Table 3.15** below provides the MDS for each scenario, with further detail provided below.

Table 3.15 Spatial and Temporal MDS for underwater noise.

Parameter	Spatial MDS	Temporal MDS
Foundation type	Monopile	Pin pile
Hammer energy (maximum)	5,000 kJ	3,000 kJ
Hammer energy (most likely)	4,000 kJ	1,750 kJ
Maximum number of piles (HVAC Booster Station Search Area)	3	72
Maximum number of piles (Array)	190	756
Maximum piling duration (HVAC Booster Station Search Area)	13 hours	317 hours
Maximum piling duration (Array)	836 hours	3,326 hours

3.11.1.51 The spatial MDS equates to the greatest area of effect from subsea noise at any one time during piling which is considered to result from the concurrent installation of monopile foundations at the north west (NW) and eastern (E) corners of the array. The temporal MDS represents the longest duration of effects from subsea noise which is considered to result from the installation of up to 756 pin piles in the array.

3.11.1.52 With regards the seabed clearance works associated with UXO, as detailed in **Table 3.10**, as part of the site preparation activities for Hornsea Four, UXO clearance will be required. Whilst not always required, destructive UXO clearance through detonation of the UXO introduces a further underwater noise effect-receptor pathway that may result

in an effect on noise sensitive receptors. The UXO clearance is anticipated to be completed within the Hornsea Four array area and ECC, as part of the pre-construction site preparatory works. Until detailed pre-construction surveys are undertaken across the Hornsea Four array area and ECC, the exact number of potential UXO which will need to be cleared is unknown. However, given the potential for *in situ* detonation cannot be discounted, Hornsea Four has used its experience from other sites in the Southern North Sea to estimate the number of UXO that may require clearance. The MDS for UXO is therefore clearance of 86 UXO via detonation. The MDS assumes that each of these will be detonated, noting that in reality many of these may not be UXO or may be left *in situ* and avoided. Detonation of UXO would represent a short term (i.e. seconds) increase in underwater noise (i.e. sound pressure levels and particle motion) and while noise levels will be elevated such that this may result in injury or behavioural effects on fish and shellfish species, UXO detonations are considered to have a lower likelihood of triggering a population level effect than that associated from piling operations, due to the significant reduced temporal footprint that would arise from UXO operations. It is noted that Hornsea Four are not applying for a Marine Licence for UXO clearance as part of the DCO application and therefore no formal assessment has been made; however high-level consideration has been provided to the potential effects arising from UXO clearance in **paragraph 3.11.1.145** *et seq.* for completeness.

3.11.1.53 The following sections consider the potential sensitive receptors, and provide information regarding the agreed metrics and thresholds for assessment, followed by the assessment of the following effect-receptor pathways:

- Underwater noise associated with foundation installation;
    - Spatial MDS (maximum and most likely scenarios); and
    - Temporal MDS (maximum and most likely scenarios).
- Underwater noise associated with UXO clearance.

Receptor sensitivity and criteria for assessment.

3.11.1.54 Underwater noise can potentially have a negative impact on fish and shellfish species ranging from behavioural effects to physical injury/mortality. In general, biological damage as a result of sound energy is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration (i.e. UXO clearance or a single strike of a piling hammer). However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. Fish and shellfish are also considered to be sensitive to the particle motion element of underwater noise; an impact considered more important than sound pressure for many species, particularly invertebrates. However, research into this impact on fish populations is scarce, representing a source of uncertainty in the assessment process.

3.11.1.55 For the purposes of the assessment, **Volume A4, Annex 4.5: Subsea Noise Technical Report** presents the results of modelling for a range of noise levels, representing the MDS and the most likely scenarios (based on variable hammer energies as defined in **Table 3.15** above) for the installation of both monopiles and pin piles. The modelling results for cumulative sound exposure level (SEL_{cum}) provide outputs for both fleeing receptors (with

the receptors fleeing from the source at a consistent rate of 1.5 ms^{-1}), and stationary receptors to account for spawning activity for more static demersal spawners such as herring and sandeel.

Injury Criteria

3.11.1.56 The fish receptors within the Hornsea Four study area have been grouped into the Popper et al. (2014) categories (see Table 4 of **Volume A4, Annex 4.5: Subsea Noise Technical Report**) based on their hearing system, as outlined in **Table 3.16** below. The injury criteria for fish are also summarised in Table 4 of **Volume A4, Annex 4.5: Subsea Noise Technical Report**.

3.11.1.57 In the case of shellfish, there are no specific impact criteria; therefore, an assessment has been based on a review of peer-reviewed literature on the current understanding of the potential effects of underwater noise on shellfish species.

Table 3.16: Hearing Categories of Fish Receptors (Popper et al. 2014).

Category	Fish receptors relevant to Hornsea Four project
Group 1	Common sole, lemon sole, dab, plaice, sandeel, mackerel, elasmobranchs (thornback ray, spotted ray, blonde ray, starry smoothhound, lesser spotted dogfish and tope), river and sea lamprey.
Group 2	Atlantic salmon, sea trout.
Group 3	Herring, sprat, cod, whiting, European eel *.

(* denotes uncertainty or lack of current knowledge with regards to the potential role of the swim bladder in hearing)

3.11.1.58 The noise modelling for injury ranges for fleeing and stationary fish is presented in **Volume A4, Annex 4.5: Subsea Noise Technical Report** and referred to, as appropriate in the following assessments. **Table 3.17** summaries the results for each of the relevant criteria against each of the MDS under consideration – the values in **Table 3.17** provide the results for the E location which had the maximum ranges of all modelling location.

Table 3.17: Noise modelling results for injury ranges for fleeing and stationary receptors (single piling at E location).

Receptor	Criteria	Noise level (dB re 1 µPa Sound Pressure Level (SPL)/ dB re 1 µPa2 s Sound Exposure Level (SEL))	Spatial MDS range (maximum/ most likely) (m)	Temporal MDS range (maximum/ most likely) (m)
Mortality and potentially mortal injury				
Group 1 fish	SPL_{peak}	213	430 / 370	300 / 180
	SEL_{cum} (static)	219	760 / 300	530 / 150
Group 2 fish	SPL_{peak}	207	1,300 / 1100	890 / 550
	SEL_{cum} (fleeing)	210	< 100 / < 100 m	< 100 / < 100 m
Group 3 and 4 fish	SPL_{peak}	207	1,300 / 1,100	890 / 550
	SEL_{cum} (static)	207	5,400 / 2,400	4,000 / 1,300
	SEL_{cum} (fleeing)	207	< 100 / < 100 m	< 100 / < 100 m
Eggs and larvae	SPL_{peak}	207	1,300 / 1,100	890 / 550
	SEL_{cum} (static)	210	3,500 / 1,500	2,500 / 760
Recoverable injury				
Group 1 fish	SPL_{peak}	213	430 / 370	300 / 180
	SEL_{cum}(static)	216	1,300 / 520	910 / 260
Group 2 fish	SPL_{peak}	207	1,300 / 1,100	890 / 550
	SEL_{cum}(fleeing)	203	< 100 / < 100 m	< 100 / < 100 m
Group 3 and 4 fish	SPL_{peak}	207	1,300 / 1,100	890 / 550
	SEL_{cum} (static)	203	9,100 / 4,600	7,100 / 2,500
	SEL_{cum} (fleeing)	203	< 100 / < 100 m	< 100 / < 100 m
Temporary Threshold Shift				
Group 1 fish	SEL_{cum} (static)	186	38,000/28,000	34,000/21,000
Group 2 fish	SEL_{cum} (fleeing)	186	26,000/20,000	22,000/13,000
Group 3 and 4 fish	SEL_{cum} (static)	186	38,000/28,000	34,000/21,000
	SEL_{cum} (fleeing)	186	26,000/20,000	22,000/13,000

Mortality and potential mortal injury

3.11.1.59 The following paragraphs provide the assessment of potential impacts on each VER for the spatial MDS (maximum followed by most likely) and temporal MDS (maximum followed by most likely) for underwater noise associated with foundation installation. Initial consideration is given to the sensitivity of each VER to underwater noise, before characterising the scale and magnitude of effect before providing the overall conclusion.

Sandeel

3.11.1.60 Sandeel (Group 1 receptor, mortality onset at >219 dB SEL_{cum}) lack a swim bladder and are therefore considered less sensitive to underwater noise. Sandeel are considered stationary receptors, due to their burrowing nature, substrate dependence, and demersal spawning behaviours, and therefore may have limited capacity to flee the area compared to other Group 1 receptors. Group 1 receptors are thought to be affected by vibration through the seabed, particularly when buried in the seabed during hibernation. Taking this into account, sandeel are deemed to be of low vulnerability, medium recoverability and are of regional importance. The sensitivity of the receptor to underwater noise impacts is therefore considered to be **medium**.

3.11.1.61 With regards to the spatial MDS, the modelling results in **Table 3.17** indicate that the maximum predicted range for mortality and potential injury of spawning (stationary) sandeel is up to 760 m from the array piling location (NW location) and HVAC booster station search area (based on SEL_{cum} $^{(static)}$). The modelling results indicate that the most likely spatial MDS predicted range for mortality and potential mortal injury of spawning sandeel is up to 300 m from the array piling location (NW and E array modelling locations) and the HVAC booster station search area (based on SEL_{cum} $^{(static)}$). Noise impacts from monopile installation at the array and HVAC booster station on fleeing (non-spawning) sandeel are expected to be significantly less (< 100 m), and within the immediate vicinity of the piling activity.

3.11.1.62 With regards the temporal MDS, the results presented in **Table 3.17** indicates that the maximum predicted range for mortality and potential injury of spawning sandeel is up to 530 m from the array (NW and E array modelling locations) and the from the HVAC booster station search area (SEL_{cum} $^{(static)}$). The modelling results indicate that the most likely temporal MDS predicted range is up to 150 m from the array (NW and E array modelling locations) and from the HVAC booster station location, a significantly reduced impact when compared to the MDS scenario. Noise impacts from pin pile installation at the array and HVAC booster station on fleeing (non-spawning) sandeel are expected to be significantly less (< 100 m), and within the immediate vicinity of the piling activity.

3.11.1.63 Sandeel preferred habitats and spawning grounds are widely distributed across the southern North Sea (**Figure 3.3** and **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**), and therefore in the context of the wider environment, the impacts associated with the spatial MDS are considered to be of local to regional context. With regards the temporal MDS total piling time for three HVAC booster stations is 317 hours, whilst the total temporal MDS for the array is 3,326 hours over a six-year construction period. In the context of the annual sandeel spawning period (November to February (Ellis et al. 2010)) over six years (16,128 hours), this equates to 1.97% and 20.62% respectively of the spawning period potentially impacted by piling noise.

3.11.1.64 This assumes that all piling will occur within the sandeel spawning period and that the noise contours overlap the entire spawning ground. Given the broadscale nature of the sandeel spawning ground, against the likely spatial extent of the spatial MDS and the duration of the temporal MDS, the impact magnitude for mortality and potential mortal injury is considered to be **minor** (adverse) for both the spatial and temporal MDS.

3.11.1.65 Taking into account the sensitivity of the receptor to underwater noise, which is medium, and the magnitude of impact associated with which is considered to be of minor adverse, the significance of effect could be slight or moderate (in accordance with the matrix in **Table 3.13**). Sandeel are known to be present around a substantial proportion of the UK coast, not just in the North Sea and have spawning grounds that are correspondingly broad. Taking into account this broad distribution of suitable spawning habitats across the southern North Sea and more distant areas and the localised range of any injurious impacts, there are not considered to be any population level effects on the species, with rapid recovery from localised impacts supplied by the remaining population, and therefore, the overall effect on sandeel is predicted to be of **slight** significance which is not considered to be significant in EIA terms.

Herring

3.11.1.66 Herring (Group 3, mortality onset at 207 dB SEL_{cum}) have a swim bladder that is involved in hearing, and therefore are known to be sensitive to underwater noise. Key herring spawning and nursery habitats are located within the Hornsea Four study area, with areas of high larval abundance proximal to the proposed location of the HVAC booster station search area (**Figure 3.3**). Herring are demersal spawners and are therefore considered stationary receptors in the assessment during the spawning season, increasing their theoretical exposure to underwater noise from the construction phase of the development. Taking this into account, herring are considered to be of high vulnerability, with medium recoverability and of regional importance, therefore the sensitivity of herring to noise impacts is considered to be **high.**

3.11.1.67 Herring are a mobile species and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling, however herring are considered sensitive to sound pressure components of underwater noise, due to having a swim bladder involved in hearing. Due to the proximity of high density herring spawning grounds to the HVAC booster station search area (**Figure 3.3**) and the high degree of philopatric behaviour exhibited by spawning herring, and the consequential likelihood of herring not fleeing from piling noise when engaged in spawning activity, herring are considered stationary receptors for the purpose of this assessment.

3.11.1.68 Monopile installation (5,000 kJ hammer energy) in the array area or the HVAC booster station search area, represent the spatial MDS for noise impacts on herring. Modelling has been undertaken to represent both single piling scenarios at all three modelling locations (NW, E and S) in the array area and the HVAC booster station. Concurrent piling has also been modelled for two monopiles at the NW and E locations to provide the spatial MDS for concurrent piling. Concurrent piling does not alter the maximum impact ranges for injurious impacts for fish compared to those for single piling events.

3.11.1.69 With regard to the spatial MDS, the modelling results in **Table 3.17** and noise contours shown in relation to herring spawning grounds and larvae abundances (Coull et al. 1998 and IHLS data (2007 – 2021)) in **Figure 3.8** to **Figure 3.11** indicate that the maximum predicted range for mortality and potential mortal injury for spawning (stationary) herring is up to 5,400 m from the array area (E location), and up to 5,000 m from the HVAC booster station search area . However, there is no overlap between the noise contours for piling within the array and the main herring spawning grounds, or areas of high larval abundances (**Figure 3.9**). The maximum predicted range of mortality and potential mortal injury contour from monopile installation at the HVAC booster station search area, however, does occur within a moderate intensity part of the actively utilised herring spawning grounds (**Figure 3.11**). Whilst there will be no overlap with high intensity active spawning areas, Hornsea Four has committed (Co190) to a seasonal restriction for piling at the HVAC booster station search area during the peak spawning period of the Banks herring stock of the central North Sea (1st September to 16th October) as detailed in **Section 3.8.2**.

3.11.1.70 With regards the most likely spatial MDS (4,000 kJ hammer energy, concurrent piling) the results indicate that the most likely range for potential mortality and potential mortal injury is up to 2,400 m from the array (NW and E array modelling locations) (**Figure 3.13**) and from the HVAC booster station search area (**Figure 3.15**) on spawning herring, a significantly reduced impact than that predicted under the spatial MDS scenario.

3.11.1.71 With regards the temporal MDS the modelling indicates that the potential range for mortality and potential injury of spawning herring in this scenario may occur up to 4,000 m from the array (E location) (based on $SEL_{cum}^{(static)}$) (**Figure 3.16**).The result for the most likely temporal MDS impact range indicates a range for mortality and potential mortal injury of up to 1,300 m from the array (NW and E array modelling locations), and from the HVAC booster station search area.

3.11.1.72 Considering the maximum temporal impacts on herring, the impact of construction-related underwater noise is predicted to be of short to medium term duration. The total piling time for the HVAC booster station and array foundations equates to approximately 3.93% and 41.25 % respectively of the annual peak eight week spawning period (September to October) potentially impacted by piling noise within a six year construction period (as detailed in **paragraph 3.7.1.7**, this is considered to be the main spawning period for the Banks stock, consequently providing a more conservative assessment of temporal impacts). This assumes that piling of all pin piles will occur within the herring spawning period, with noise contours overlapping the entire spawning ground. As noted, noise contours from the array area have no overlap with high intensity herring spawning grounds (**Figure 3.16**) and therefore the temporal impacts from piling in the array on herring are predicted to be low. Noise contours from piling in the HVAC booster station location do however overlap with areas of moderate herring spawning intensity (**Figure 3.18**). With the implementation of a seasonal piling restriction for piling of the HVAC booster stations during peak herring spawning, the temporal impacts on herring are considered minimal.

3.11.1.73 Taking into consideration the locations of herring spawning grounds relative to the piling locations of Hornsea Four (**Figure 3.3**), the commitment (Co190) to no piling from 1st September – 16th October at the HVAC booster station search areas and the limited

temporal impacts, the magnitude of effect on herring from piling within the array area and the HVAC booster station search area are both assessed as being **minor** (adverse) for both the spatial and temporal MDS, maximum and most likely scenarios.

3.11.1.74 Taking into account the sensitivity of the receptor to underwater noise, which is **high**, and the magnitude of impact associated with which is considered to be of **minor**, the significance of effect could be slight or moderate (in accordance with the matrix in **Table 3.13**). Taking into account the local to regional spatial impacts on the species, the implementation of the seasonal restriction on piling at the HVAC booster station search area during the main herring spawning period for the Banks stock, and the minimal overlap from underwater noise with the active spawning grounds from piling at the array, it is considered unlikely that there will be any population level effects, and therefore the overall effect on herring is predicted to be of **slight** significance which is not significant in EIA terms.

Eggs and larvae

3.11.1.75 Sandeel, herring, cod and whiting all have spawning grounds within the vicinity of Hornsea Four (**Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**). Eggs and larvae are considered organisms of concern by Popper et al. (2014), due to their vulnerability, reduced mobility and small size. As a result of this, the sensitivity of eggs and larvae to noise impacts is therefore considered to be **high**. Thresholds of effects for eggs and larvae have been defined separately within the Popper et al. (2014) guidance, with damage expected to occur at 210 dB SEL_{cum} or >207 dB SPL_{peak}.

3.11.1.76 With regards the spatial MDS the modelling results indicate that the maximum potential range for mortality and potentially mortal injury of eggs and larvae is up to 3,500 m from the array area (E location) (based on $SEL_{cum}^{(static)}$). The results for the most likely spatial MDS indicate the potential range for mortality and potential mortal injury of eggs and larvae is up to 1,500 m from the array (NW and E array modelling locations) and from the HVAC booster station search area (based on $SEL_{cum}^{(static)}$).

3.11.1.77 With regards the temporal MDS the maximum predicted range for mortality and potentially mortal injury effects is up to 1,750 m from the array (based on $SEL_{cum}^{(static)}$). The results for the most likely temporal MDS indicate the potential range for mortality and potential mortal injury of eggs and larvae is up to 760 m from the array, and from the HVAC booster station search area, a significantly reduced impact than that proposed in from the MDS (based on $SEL_{cum}^{(static)}$).

3.11.1.78 Taking into consideration the proximity of sandeel and herring spawning grounds to Hornsea Four (**Figure 3.3**), the broad distribution of whiting, cod and sandeel spawning grounds within UK waters (**Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**), and the implementation of the commitment (Co190) to no piling at the HVAC booster station search area over the peak spawning period for herring, the magnitude of effect on eggs and larvae from piling within the array area and the HVAC booster station search area is assessed as being **minor** (adverse).

3.11.1.79 Taking into account the sensitivity of eggs and larvae to underwater noise, which is **high**, and the magnitude of impact associated with which is considered to be of **minor**, the significance of effect could be slight or moderate (in accordance with the matrix in **Table**

3.13). Taking into account the broad distribution of the spawning grounds within UK waters, and the implementation of the seasonal restriction on piling at the HVAC booster station search area during the main herring spawning period for the Banks stock, it is considered unlikely that there will be any population level effects, and therefore the overall effect on eggs and larvae is predicted to be of **slight** significance which is not significant in EIA terms.

Shellfish

3.11.1.80 On the basis that shellfish do not possess swim bladders or other gas filled organs, it is considered that shellfish are primarily sensitive to particle motion rather than sound pressure (e.g. Popper and Hawkins 2018). As there are currently no criteria for assessing particle motion, it is not possible to undertake a threshold-based assessment of the potential for injury to shellfish in the same way as can be done for fish. As such, a qualitative assessment of the potential for mortality or mortal injury has been made based on peer-reviewed literature.

3.11.1.81 Pile driving is recognised as a source particle motion, generating high levels of particle motion in the nearfield (Hazelwood and Macey 2016) which could potentially result in injury or mortality to sensitive shellfish receptors. Impacts from particle motion are also likely to occur local to the source, with studies having demonstrated the rapid attenuation of particle motion with distance (Mueller-Blenkle et al. 2010). Studies on lobsters have shown no mortality effect on the species (>220 dB) (Payne et al. 2007). Similarly, studies of molluscs (e.g. mussels *Mytilus edulis* and periwinkles *Littorina* spp) exposed to a single airgun at a distance of 0.5 m have shown no effects after exposure (Kosheleva 1992). Taking this into consideration, shellfish VERs within the study area are deemed to be of local to international importance, medium vulnerability, and high recoverability. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.1.82 Brown crab spawning grounds (Eaton et al. 2003) are located to the west of the HVAC booster station, clipping the far western edge of the proposed location of the booster station, and inshore of the array area, however in a broader context the grounds are also located across the English Channel and Western Approaches, with spawning areas also apparent in the Bay of Biscay and the Celtic Sea (Thompson et al. 1995; Pawson 1995). There is evidence that overwintering grounds for lobster may be located nearshore, close to the Humber Estuary (SMart Wind 2015a), however there is no direct overlap with the Hornsea Four study area. Lobster also has a wide distribution in northeast Atlantic waters, from Northern Norway south to the Atlantic coast of Morocco (Prodöhl et al. 2007). *Nephrops* spawning grounds (Coull et al. 1998) overlap the proposed array area and also extend further offshore across the central North Sea. The nearshore section of the Hornsea Four ECC, and the HVAC booster station search area would also cross a large scallop ground, located along the Hornsea coast (Cefas 2019),), although it should be noted that key scallop grounds are also located across the English Channel, the Irish Sea and off the coasts of Scotland (Cappell 2018). Due to the commercial value and importance of scallop, brown crab, European lobster, *Nephrops* and common whelk to the region, and proximity of key shellfish beds, spawning grounds and overwintering areas to the project, due consideration is given to the potential for impacts on these species from noise impacts during construction. Taking the widespread presence across UK waters into account, and the proportionately small numbers of individuals that

would be affected (relative to the wider population), the magnitude of effect on shellfish receptors is assessed as **minor** (adverse).

3.11.1.83 Taking into account the sensitivity of the receptor to underwater noise, which is **medium**, and the magnitude of impact associated with which is considered to be **minor**, this could result in either a slight or moderate significance of effect. Taking into account the broad distribution of these receptors across the study area, the available literature suggesting a low risk of mortality or significant injury, and the relatively short-term nature of the impact, it is considered unlikely that there will be any more than a highly localised effect, with rapid recovery of the remaining stock avoiding a population level effect. Therefore, the overall effects of noise impacts on shellfish are predicted to be of **slight** significance which is not considered to be significant in EIA terms.

Recoverable Injury

3.11.1.84 Recoverable injury is a survivable injury with full recovery occurring after exposure, although decreased fitness during this recovery period may result in increased susceptibility to predation or disease (Popper et al. 2014). The impact ranges for recoverable injury and mortality/potential mortal injury are more or less the same due to the thresholds used, the potential for mortality or mortal injury is likely to only occur in extreme proximity to the pile, although the risk of this occurring will be reduced by use of soft start techniques at the start of the piling sequence. This means that fish in close proximity to piling operations will move outside of the impact range, before noise levels reach a level likely to cause irreversible injury.

Sandeel

3.11.1.85 As noted previously in **paragraph 3.11.1.60**, sandeel are a Group 1 receptor (recoverable injury onset at 216 dB SEL_{cum}), considered to be of **medium** sensitivity to underwater noise, with spawning grounds located across the Southern North Sea.

3.11.1.86 The concurrent piling of monopiles (hammer energy 5,000 kJ) in the array and piling in the HVAC booster station search area, represents the spatial MDS for noise impact on spawning sandeel. Noise modelling suggests that the potential for recoverable injury of spawning sandeel in this maximum scenario may occur up to 1,300 m from the array (NW and E array modelling locations) and HVAC booster station search area (based on $SEL_{cum}^{(static)}$). Modelling of the most likely spatial MDS impacts from monopile installation (4,000 kJ) showed the potential for mortality and potential mortal injury of spawning (stationary) sandeel may occur up to 520 m from the array (NE location), and up to 510 m from the HVAC booster station search area (based on $SEL_{cum}^{(static)}$).

3.11.1.87 The piling of pin piles (hammer energy 3,000 kJ) represents the temporal MDS for noise impacts on spawning sandeel. Noise modelling suggests that the potential for recoverable injury of spawning sandeel in this maximum scenario may occur up to 910 m from the array (NW location) and 900 m from the HVAC booster station search area (based on SEL_{cum}). Modelling for the most likely impacts from pin pile installation (1,750 kJ hammer energy) showed the potential for recoverable injury may occur up to 260 m from the array, and from the HVAC booster station search area, a significantly reduced impact than that proposed in from the temporal MDS.

3.11.1.88 As noted in paragraph 3.11.1.63, sandeel preferred habitats and spawning grounds are widely distributed across the Southern North Sea, and therefore the spatial MDS is considered to be of local to regional extent in the context of the wider environment. The temporal MDS equates to a maximum of 20.62% of the annual peak sandeel spawning periods over a six-year construction period, potentially impacted by the piling noise. It should be noted that this makes the assumption that all piling will occur within the sandeel spawning period and that the noise contours overlap the entire spawning ground. Given the broadscale nature of the sandeel spawning ground against the likely spatial extent of the spatial MDS and the duration of the temporal MDS, the impact magnitude for recoverable injury is considered to be **minor** (adverse).

3.11.1.89 Taking into account the sensitivity of the receptor to underwater noise, which is **medium**, and the **minor** magnitude of impact, this could lead to a slight or moderate significance of effect. Sandeel are known to be present around a substantial proportion of the UK coast and have spawning grounds that are correspondingly broad. Considering this broad distribution of suitable spawning habitats across the Southern North Sea and more distant areas and the localised range of any injurious impacts, there are not considered to be any population level effects on the species, and therefore, the overall effect on sandeel is predicted to be of **slight** significance which is not considered to be significant in EIA terms.

Herring

3.11.1.90 As noted above in paragraph 3.11.1.66, herring (Group 3 receptor, recoverable injury onset at 203 dB SEL_{cum}) are considered to be of **high** sensitivity to underwater noise, with spawning grounds located within the study area, with areas of high larval abundance proximal to the proposed HVAC booster station search area.

3.11.1.91 The piling of monopiles in the array area (NW, E and S array modelling locations) and in the HVAC booster station search area (5,000 kJ hammer energy) represent the spatial MDS for noise impacts on herring; the noise contours are shown in relation to herring spawning grounds and larvae abundances (IHLS data) in Figure 3.8 to Figure 3.21. Concurrent piling within the array area does not result in any larger impact ranges than for single piling events.

3.11.1.92 With regards the spatial MDS, the modelling results in Table 3.17 and noise contours shown in relation to herring spawning grounds and larval abundances (Coull et al. 1998 and IHLS data (2007 – 2021)) in Figure 3.8 to Figure 3.11, indicate that the maximum predicted range for recoverable injury for herring is up to 9,100 m from the array area for stationary receptors (E location) (Figure 3.9), and up to 8,100 m from the HVAC booster station search area (based on $SEL_{cum}^{(static)}$) (Figure 3.11). However, there is no overlap from the array modelling locations with main herring spawning grounds (Coull et al. 1998), or areas of high larval abundances (IHLS data) (Figure 3.9). The maximum predicted range of recoverable injury contour from monopile installation at the HVAC booster station search area however, does occur within moderate intensity herring spawning grounds and spawning activity (Figure 3.11). The implementation of a seasonal restriction (Co190) for piling at the HVAC booster station search area during the peak spawning period of the Banks herring stock of the central North Sea (1st September to

16th October) will mitigate against these impacts, and therefore reduce the magnitude of impact on spawning herring.

3.11.1.93 With regards to the most likely spatial MDS impacts from concurrent monopile installation in the array, and sequential piling of the HVAC booster station search area (4,000 kJ hammer energy) the results indicate that the potential for recoverable injury in this scenario may occur up to 4,600 m from the array area (E location) on stationary (spawning) herring (**Figure 3.13**), and up to 4,300 m from the HVAC booster station location (**Figure 3.15**). There is no overlap from the array modelling locations with herring spawning grounds (Coull et al. 1998) (**Figure 3.13**). The HVAC booster station search area noise contour does however overlap a small portion of moderately high intensity herring spawning grounds and spawning activity (**Figure 3.15**).

3.11.1.94 With regards to the temporal MDS (piling of pin piles, hammer energy 3,000 kJ), the modelling indicates the maximum ranges for recoverable injury of spawning herring in this scenario may occur up to 7,100 m from the array (E location) (**Figure 3.16**) and 6,400 m from the HVAC booster station search area (based on $SEL_{cum}^{(static)}$) (**Figure 3.18**). The results for the most likely impact range associated with the temporal MDS indicates a range for recoverable injury of up to 2,500 m from the array area (NW location), and 2,500 m from the HVAC booster station search area, on stationary (spawning) herring.

3.11.1.95 Considering the maximum temporal impacts on herring, the impact of construction related underwater noise is predicted to be of short to medium term duration. As noted previously the total piling time for the HVAC booster station search area and array foundations equates to approximately 3.93% and 41.25% respectively, of the annual six-week spawning period (over a six-year construction period) potentially impacted by piling noise. As noted, this assumes that piling will occur within the herring spawning period, with noise contours overlapping the entire spawning ground. As there is no overlap of the array noise contours from the piling of pin piles with areas of high intensity spawning activity (**Figure 3.16**), the temporal impacts from piling in the array are predicted to be low. Noise contours from piling in the HVAC booster station location do however overlap with areas of moderate herring spawning intensity (**Figure 3.18**). With the implementation of a seasonal piling restriction for piling of the HVAC booster stations during peak herring spawning, the temporal impacts on herring are considered minimal.

3.11.1.96 Taking into consideration the locations of herring spawning grounds relative to the piling locations of Hornsea Four (**Figure 3.3**), the commitment to no piling from 1st September – 16th October at the HVAC booster station search areas (Co190) and the limited temporal impacts, the magnitude of effect on herring from piling within the array area and the HVAC booster station search area is assessed as being **minor** (adverse) for both the spatial and temporal MDS and most likely spatial and temporal scenarios.

3.11.1.97 Considering herring as a **high** sensitivity receptor, to an impact of **minor** magnitude, the significance of effect could be either slight or moderate. Taking into consideration the local to regional spatial impacts on the species and the implementation of the seasonal restriction on piling at the HVAC booster station search area and the minimal overlap from underwater noise with the active spawning grounds from piling at the array, it is considered unlikely that there will be any population level effects, and therefore the

overall effect on herring is predicted to be of **slight** significance which is not significant in EIA terms.

Eggs and larvae

3.11.1.98 Eggs and larvae close to the substrate are considered vulnerable to particle motion generated by pile driving (Popper et al. 2014), and as a result of this are considered to be of **high** sensitivity to impacts from underwater noise. Sandeel and herring are both demersal spawners, with both species have spawning grounds within the vicinity of Hornsea Four, and therefore risks to eggs and larvae are considered in this assessment. Key spawning grounds for both sandeel and herring are located in close proximity to Hornsea Four (Figure 3.3), and therefore in accordance with the Popper et al. (2014) criteria, the extent of noise disturbance potentially causing recoverable injury in herring and sandeel eggs and larvae would result in a moderate degree of disturbance at a near field distance from the source. Both whiting and cod have spawning grounds and nursery grounds across the array area and offshore section of the ECC.

3.11.1.99 Considering the locality of sandeel and herring spawning grounds to Hornsea Four (Figure 3.3), the broad distribution of whiting, cod, herring and sandeel spawning grounds within UK waters, and the implementation of the seasonal piling restriction at the HVAC booster station search area, the magnitude of effect on eggs and larvae from piling within the array area and the HVAC booster station search area is assessed as being **minor** (adverse).

3.11.1.100 Taking into consideration the **high** sensitivity of eggs and larvae to underwater noise, and the **minor** magnitude of impact, the significance of effect could be slight or moderate (in accordance to the matrix in Table 3.13). Taking into account the broad distribution of the spawning grounds within UK waters, and the implementation of the seasonal restriction on piling at the HVAC booster station search area during the main herring spawning period for the Banks stock, it is considered unlikely that there will be any population level effects, and therefore the overall effect on eggs and larvae is predicted to be of **slight** significance which is not significant in EIA terms.

Shellfish

3.11.1.101 As stated above in **paragraph 3.11.1.80** *et seq.,* there are no criteria for shellfish sensitivity to noise, and therefore a qualitative assessment has been undertaken using peer-reviewed literature. On the basis that shellfish do not possess swim bladders or other gas filled organs, it is considered that shellfish are primarily sensitive to particle motion rather than sound pressure (e.g. Popper and Hawkins 2018). Pile driving is recognised as a source particle motion, generating high levels of particle motion in the nearfield (Hazelwood and Macey 2016), and as a result shellfish are considered to be of **medium** sensitivity to underwater noise impacts.

3.11.1.102 As detailed in **paragraph 3.11.1.80** *et seq.,* it is understood that particle motion attenuates rapidly, and therefore impacts on shellfish from particle motion are likely to occur local to the source. Taking this into account, and the broad distribution of these species along the UK coasts, and across the English Channel (as discussed previously in

paragraph 3.11.1.82), the magnitude of effect on shellfish receptors is considered to be **minor** (adverse).

3.11.1.103 A **minor** magnitude and **medium** sensitivity could result in either a slight or moderate significance of effect (in accordance with the significance matrix in Table 3.13). Taking into account the broad distribution of these receptors across the study area, the available literature suggesting a low risk of recoverable injury (as detailed in paragraph 3.11.1.81) and the relatively short term nature of the impact, it is considered unlikely that there will be any more than a highly localised effect, with rapid recovery from remaining stock. Therefore, the effects of noise impacts on shellfish are predicted to be of **slight** significance which is not significant in EIA terms.

Temporary Threshold Shift (TTS)/ Hearing Damage

3.11.1.104 Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS has been demonstrated in some fishes, resulting from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves. However, sensory hair cells are constantly added to fishes and are replaced when damaged and therefore the extent of TTS is of variable duration and magnitude. Normal hearing ability returns following cessation of the noise causing TTS, though this period is variable. When experiencing TTS, fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment. Volume A4, Annex 4.5 Subsea Noise Technical Report presents the ranges at which TTS in fish may occur as a result of piling operations during the Hornsea Four construction phase and these are drawn upon in the following assessment.

Sandeel

3.11.1.105 As noted above in paragraph 3.11.1.60, sandeel (Group 1 receptor, TTS onset at 186 dB SEL_{cum}) lack a swim bladder, and are therefore considered less sensitive to noise, they are however considered sensitive to vibration through the seabed. On account of this, sandeel are therefore considered to be of **medium** sensitivity to underwater noise impacts.

3.11.1.106 The piling of monopiles in the NW, S and E locations of the array, and sequential piling in the HVAC booster station search area (hammer energy 5,000 kJ), represent the spatial MDS for noise impacts on spawning sandeel from a single piling event. Concurrent piling at the NW and E locations results in a negligible change in the maximum impact ranges (as presented below); rather, concurrent piling results in a larger area of effect between the piling locations where the combined noise from the two piling events interacts rather than increasing the maximum impact range (Figure 3.8).

3.11.1.107 With regards to the spatial MDS, the modelling results in Table 3.17 indicate that the maximum predicted range for TTS of spawning sandeel is 38,000 m from the piling location (E location) (based on $SEL_{cum}^{(static)}$), and up to 31,000 m from the HVAC booster station search area. Noise modelling of the most likely spatial MDS impacts showed the potential of TTS of spawning sandeel may occur up to 28,000 m from the array (E location), and up to 23,000 m from the HVAC booster station location.

3.11.1.108 The piling of pin piles (hammer energy 3,000 kJ) represents the temporal MDS for noise impacts on spawning sandeel. Noise modelling suggests that the potential for TTS of spawning sandeel in this scenario may occur up to 34,000 m from the array (E location) (based on $SEL_{cum}^{(static)}$), and up to 28,000 m from the HVAC booster station search area. The modelling results indicate that the most likely predicted range for the temporal MDS is up to 21,000 m from the array (E location), and up to 17,000 m from the HVAC booster station search area.

3.11.1.109 As noted above in **paragraph 3.11.1.63**, sandeel habitats are broadly distributed across the study area and Southern North Sea. Therefore, the impacts associated with the maximum and most likely spatial MDS are considered to be of local to regional context in the context of the wider environment.

3.11.1.110 As detailed in **paragraph 3.11.1.88**, with regards the maximum and most likely temporal MDS the total piling time equates to a maximum of 20.62% of the sandeel spawning periods (for piling in the array) over the six-year construction period. It should be noted however, that this assumes that all piling will occur within the spawning period, and that the noise contours overlap the entire spawning ground.

3.11.1.111 Taking into account the broadscale nature of the sandeel spawning ground, against the spatial extent of the spatial MDS and the duration of the temporal MDS, the impact magnitude for TTS is considered to be **minor** (adverse).

3.11.1.112 Considering the sensitivity of the receptor to underwater noise, which is **medium**, and the **minor** magnitude of impact, this could lead to a slight or moderate significance of effect. Taking into account the broad distribution of suitable spawning habitats across the Southern North Sea, there are not considered to be any population level effects on the species, and therefore, the overall effect on sandeel is predicted to be of **slight** significance which is not considered to be significant in EIA terms.

Herring

3.11.1.113 As noted above in **paragraph 3.11.1.66**, herring (Group 3 receptor, TTS onset at 186 dB SEL_{cum}) are considered to be of **high** sensitivity to underwater noise. Due to their demersal spawning nature, herring are considered a stationary receptor in this assessment.

3.11.1.114 Monopile installation (5,000 kJ hammer energy) in the array area (NW, S and E array modelling locations) and sequential piling in the HVAC booster station search area, represents the spatial MDS for noise impacts on herring from a single piling event. Concurrent piling at the NW and E locations results in a negligible change in the maximum impact ranges (as presented below); rather, concurrent piling results in a larger area of effect between the piling locations where the combined noise from the two piling events interacts rather than increasing the maximum impact range (**Figure 3.8**).

3.11.1.115 The spatial MDS noise contours are shown in relation to herring spawning grounds (Coull et al. 1998) and larval abundances (IHLS data) in (**Figure 3.9** and **Figure 3.11**). The potential for TTS in herring (186 dB $SEL_{cum}^{(static)}$) during the spawning season (September to October) may occur up to 38,000 m from the array area (E location) under the spatial MDS scenario (**Figure 3.9**). Noise modelling of the most likely spatial impacts for

monopiles (4.000 kJ) show that TTS may occur in herring up to 28,000 m from the array (E location) (Figure 3.13).

3.11.1.116 The piling of pin piles (hammer energy 3,000 kJ) represents the temporal MDS for noise impacts on spawning herring. Noise modelling suggests that the potential for TTS of spawning sandeel in this maximum scenario may occur up to 34,000 m from the array (NW location) (based on $SEL_{cum}^{(static)}$) (Figure 3.17). Noise modelling for the most likely impacts from pin pile installation (1,750 kJ hammer energy) showed the potential for TTS of spawning herring may occur up to 21,000 m from the array (NW location) and from the HVAC booster station location.

3.11.1.117 With reference to Figure 3.9, the spatial MDS noise contours from the array overlap an area of low intensity herring spawning grounds. The spatial MDS noise contour from piling at the HVAC booster station search area (Figure 3.11) overlaps an area of peak intensity herring spawning grounds ($SEL_{cum}^{(static)}$). Whilst piling at the HVAC booster station search area will have a significant spatial impact on spawning herring, the commitment to a seasonal restriction (Co190) for piling at the HVAC booster station search area during the peak spawning period of the Banks herring stock of the central North Sea (1st September to 16th October) will mitigate against these impacts, and therefore reduce the magnitude of impact on spawning herring.

3.11.1.118 Considering the temporal MDS impacts on herring, as in paragraph 3.11.1.95, the total piling time of the array and HVAC booster station foundations equates to approximately 41.25% and 3.93% of the annual six-week spawning period respectively (over the six-year construction period). This makes the assumption that all piling will occur within the herring spawning period, with noise contours overlapping the entire spawning ground.

3.11.1.119 Taking into consideration the locations of herring spawning grounds relative to the piling locations of Hornsea Four (Figure 3.3), the commitment (Co190) to no piling from 1st September – 16th October at the HVAC booster station search area and the limited temporal impacts, the magnitude of effect on herring from piling within the array area and the HVAC booster station search area are both assessed as being **minor** (adverse) for both the spatial and temporal MDS maximum and most likely scenarios.

3.11.1.120 A **minor** magnitude and **high** sensitivity can result in either a slight or moderate significance of effect. Taking into consideration the reduced temporal impacts, and the implementation of a seasonal piling restriction at the HVAC booster station search areas, it is considered unlikely that there will be any population level effects, and therefore the overall effect on herring is predicted to be of **slight** significance which is not significant in EIA terms.

Eggs and larvae

3.11.1.121 Impacts on eggs and larvae were assessed using the Popper et al. (2014) criteria, in terms of risk of recoverable injury in paragraph 3.11.1.98 *et seq.* The Popper et al. (2014) criteria for TTS are the same, and therefore the impact assessment for eggs and larvae replicates that undertaken for recoverable injury in paragraph 3.11.1.98 *et seq.*

3.11.1.122 Eggs and larvae were assessed as having **high** sensitivity to underwater noise impacts, with a moderate degree of disturbance at a near field distance from the source predicted

on the receptors. The magnitude of effect was considered to be **minor** (adverse). The significance of effect was assessed as **slight** after taking into consideration the broad distribution of spawning grounds in UK waters, and the commitment to a seasonal piling restriction at the HVAC booster station search area during peak herring spawning times (Co190).

Shellfish

3.11.1.123 As stated above in **paragraph 3.11.1.80** *et seq.,* there are no criteria for shellfish sensitivity to noise, and therefore a qualitative assessment has been undertaken using peer reviewed literature. On the basis that shellfish do not possess swim bladders or other gas filled organs, it is considered that shellfish are primarily sensitive to particle motion rather than sound pressure (e.g. Popper and Hawkins 2018). As the understanding of marine invertebrate sensitivity to particle motion is in its infancy (Lewandowski et al. 2016), there is limited information available on the potential for hearing damage on shellfish from particle motion. However, a study by Zhang et al. (2015) did suggest that severe particle motion could irreparably damage the statocysts of cephalopods at short range, causing hearing impairment. This was considered likely to occur as a result of pile driving, although thought to only occur at short range. Taking this into account, shellfish are considered to be of **medium** sensitivity to underwater noise impacts.

3.11.1.124 As detailed in **paragraph 3.11.1.80** *et seq.* it is understood that particle motion attenuates rapidly, therefore any impacts on shellfish are likely to be localised. Taking this into account, and the broad distribution of these species along the UK coasts, and across the English Channel (as discussed previously in **paragraph 3.11.1.82**), the magnitude of magnitude of effect on shellfish receptors is assessed as **minor** (adverse).

3.11.1.125 A **minor** magnitude and **medium** sensitivity could result in either a slight or moderate significance of effect (in accordance with the significance matrix in **Table 3.13**). Taking into account the broad distribution of these receptors across the study area, the localised nature of the effects, it is considered unlikely that there will be a population level effect on shellfish. Therefore, the effects of noise impacts on shellfish are predicted to be of **slight** significance which is not significant in EIA terms.

Behavioural Impacts

3.11.1.126 Different fish and shellfish have varying sensitivities to piling noise, depending on how these species perceive sound in the environment. Behavioural effects in response to construction related underwater noise include a wide variety of responses including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column (e.g. Hawkins et al. 2014). Depending on the strength of the response and the duration of the impact, there is the potential for some of these responses to lead to significant effects at an individual level (e.g. reduced fitness, increased susceptibility to predation) or at a population level (e.g. avoidance or delayed migration to key spawning grounds), although these may also result in short-term, intermittent changes in behaviour that have no wider effect, particularly once acclimatisation to the noise source is taken into account. Popper et al. (2014) provide qualitative behavioural criteria for fish from a range of sources. These categorise the risks of effects in relative terms as 'high, moderate or low' at three distances from the source: near (10s of metres), intermediate (100s of metres), and far

(1000s of metres), respectively. The behavioural criteria are summarised in Table 7 of **Volume A4, Annex 4.5: Subsea Noise Technical Report**.

3.11.1.127 Information on the impact of underwater noise on marine invertebrates is scarce, and no attempt has been made to set exposure criteria (Hawkins et al. 2014b). Studies on marine invertebrates have shown sensitivity of marine invertebrates to substrate borne vibration (Roberts et al. 2016). It is generally their hairs which provide the sensitivity, although these animals also have other sensor systems which could be capable of detecting vibration. It has also been reported that slow, rolling interface waves that move out from a source like a pile driver can produce large particle motion amplitudes travelling considerable distances (Hawkins and Popper 2016), with implications for demersal and sediment dwelling shellfish (e.g. *Nephrops*) in close proximity to piling operations.

Herring

3.11.1.128 Group 3 fish are more sensitive to the sound pressure components of underwater noise and therefore the risks of behavioural effects in the intermediate and far fields are greater for these species. Herring have a swim bladder which is involved with hearing, and therefore behavioural effects are expected to be greater, potentially occurring over the range of tens of kilometres, although as detailed above, this may not result in a strong avoidance reaction. Taking this into account, herring are considered to be of **high** sensitivity to underwater noise impacts.

3.11.1.129 Key spawning habitats for herring are located in close proximity to the Hornsea Four HVAC booster station search area in particular, and therefore adult spawning herring within these habitats would be expected to show a behavioural response as a result of construction-related underwater noise from piling operations at the HVAC booster station. Therefore, considering the Popper et al. (2014) criteria, any risk of behavioural effects in herring from piling are expected to be Moderate in the far field, and High within the intermediate field. However, with the implementation of a seasonal piling restriction (Co190) for piling of the HVAC booster stations during peak herring spawning, behavioural impacts on herring are expected to be reduced.

3.11.1.130 Taking into consideration the locations of herring spawning grounds relative to the piling locations of Hornsea Four (**Figure 3.4**), and the commitment to no piling from 1st September – 16th October at the HVAC booster station search area (Co190), the magnitude of effect on herring from piling in the array and HVAC booster station search area are both assessed as being **minor** (adverse).

3.11.1.131 A **minor** magnitude and **high** sensitivity can result in either a slight or moderate significance of effect. Considering the implementation of a seasonal piling restriction at the HVAC booster station search area during the peak herring spawning period, it is considered unlikely that there will be any population level effects, and therefore the overall effect on herring is predicted to be of **slight** significance which is not significant in EIA terms.

Sandeel

3.11.1.132 Sandeel (Group 1 receptor) lack a swim bladder, are assessed as having **medium** sensitivity to impacts from sound pressure in **paragraph 3.11.1.60** due to their reduced mobility, and therefore inability to flee from noise impacts. As a result of their reduced sensitivity to sounds pressure, the behavioural effects on this species are expected to be low.

3.11.1.133 Sandeel spawning and nursery habitats are present within the Hornsea Four study area, these tend to extend over a wide area, and the relative proportion of these habitats affected by piling operations at any one time will therefore be small in the context of the wider habitat available. Therefore, considering the Popper et al. (2014) criteria, any risk of behavioural effects or auditory masking in sandeel from piling are expected to be Low in the intermediate field. Taking this into consideration, the magnitude of impact on sandeel is considered to be **minor** (adverse).

3.11.1.134 Taking into account the sensitivity of the receptor to underwater noise, which is **medium**, and the **minor** magnitude of impact, this could lead to a slight or moderate significance of effect. Considering the broad distribution of suitable spawning habitats across the Southern North Sea, there are not considered to be any population level effects on the species, and therefore, the overall effect on sandeel is predicted to be of **slight** significance which is not considered to be significant with in EIA terms.

Eggs and larvae

3.11.1.135 Impacts on herring eggs and larvae were assessed using the Popper et al. (2014) criteria, in terms of risk of recoverable injury and TTS in **paragraph 3.11.1.98** *et seq*. The Popper et al. (2014) criteria for behavioural impacts are the same, and therefore the impact assessment for eggs and larvae replicates that undertaken for recoverable injury and TTS.

3.11.1.136 Eggs and larvae were assessed as having **high** sensitivity to underwater noise impacts, with a moderate degree of disturbance at a near field distance from the source predicted on the receptors. The magnitude of effect was considered to be **minor** (adverse). The significance of effect was assessed as **slight** after taking into consideration the broad distribution of spawning grounds in UK waters, and the implementation of a seasonal piling restriction at the HVAC booster station search area during peak herring spawning times.

Shellfish

3.11.1.137 As stated above in **paragraph 3.11.1.80** *et seq.,* there are no criteria for shellfish sensitivity to noise, and therefore a qualitative assessment has been undertaken using peer reviewed literature. Shellfish are considered a potential sensitive receptor to particle motion from piling, due to typically having low motility, and therefore are considered unlikely to be able to vacate the area at the onset of 'soft-start piling'; Roberts (2015) suggested that vibroacoustic stimuli may elicit and affect anti-predator responses, such as startle response in crabs and valve closure in mussels. Such responses would effectively be distractions from routine activities such as feeding. Behavioural

changes in mussels have also been observed in response to simulated pile-driving, with increased filtration rates observed in blue mussels (Spiga et al. 2016). In addition to this, Samson et al. (2016) recorded a range of behavioural responses to underwater noise in cephalopods, including inking, colour changes and startle responses. Taking the above into consideration, shellfish were considered to be of **medium** sensitivity to underwater noise impacts.

3.11.1.138 As detailed in **paragraph 3.11.1.80** *et seq.*, it is understood that particle motion attenuates rapidly, therefore any impacts on shellfish are likely to be localised. Taking this into account, and the broad distribution of these species along the UK coasts, and across the English Channel (as discussed previously in **paragraph 3.11.1.82**), the magnitude of effect on shellfish receptors is assessed as **minor** (adverse).

3.11.1.139 A **minor** magnitude and **medium** sensitivity could result in either a slight or moderate significance of effect (in accordance with the significance matrix in **Table 3.13**). Taking into account the broad distribution of these receptors across the study area, the localised nature of the effects, it is considered unlikely that there will be a population level effect on shellfish. Therefore, the effects of noise impacts on shellfish are predicted to be of **slight** significance which is not significant in EIA terms.

Hornsea Four

Figure 3.8

MDS single piling at all locations and concurrent piling at NW and E of the array area (fleeing receptor; monopile; 5,000kJ)

300000
350000
400000
450000
6050000
6000000
5950000

N
GRID NORTH

207
203
186
186
186

Scale@A3: 1:7,500
0 0.1 0.2 Kilometres
0 0.05 0.1 Nautical Miles

203 207

Scale@A3: 1:7,500
0 0.1 0.2 Kilometres
0 0.05 0.1 Nautical Miles

203 207

Scale@A3: 1:7,500
0 0.1 0.2 Kilometres
0 0.05 0.1 Nautical Miles

- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- Monopile Contours (dB SELcum) - Fleeing Receptors
- NW and E Concurrent Monopile 186 dB SELcum Contour - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
...	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	10/08/2021

NW Monopile Noise Contour
Fleeing Receptors
Document no: HOW04GB0135
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

Date: 10/08/2021 Author: BenBlakeman
Name: HOW04GB0135_FSF_IHLS_Noise_Contours_NW_E_S_Monopile_Fleeing_WC

Hornsea Four

Figure 3.9

MDS single piling at all locations and concurrent piling at NW and E of the array area (stationary receptor; monopile; 5,000kJ)

300000 350000 400000 450000

6050000

6000000

5950000

N

GRID NORTH

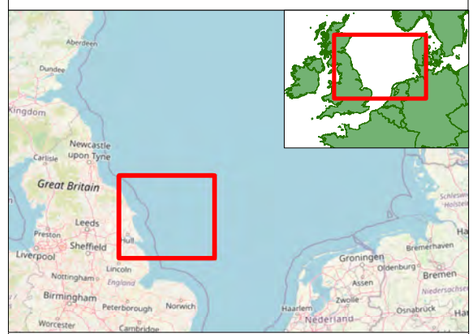
Scale@A3: 1:250,000
0 3 6 Kilometres
0 2 4 Nautical Miles

207
203
186

- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- Monopile Contours (dB SELcum) - Stationary Receptors
- NW and E Concurrent Monopile 186 dB SELcum Contour - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
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NW Monopile Noise Contour
Stationary Receptors
Document no: HOW04GB0134
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

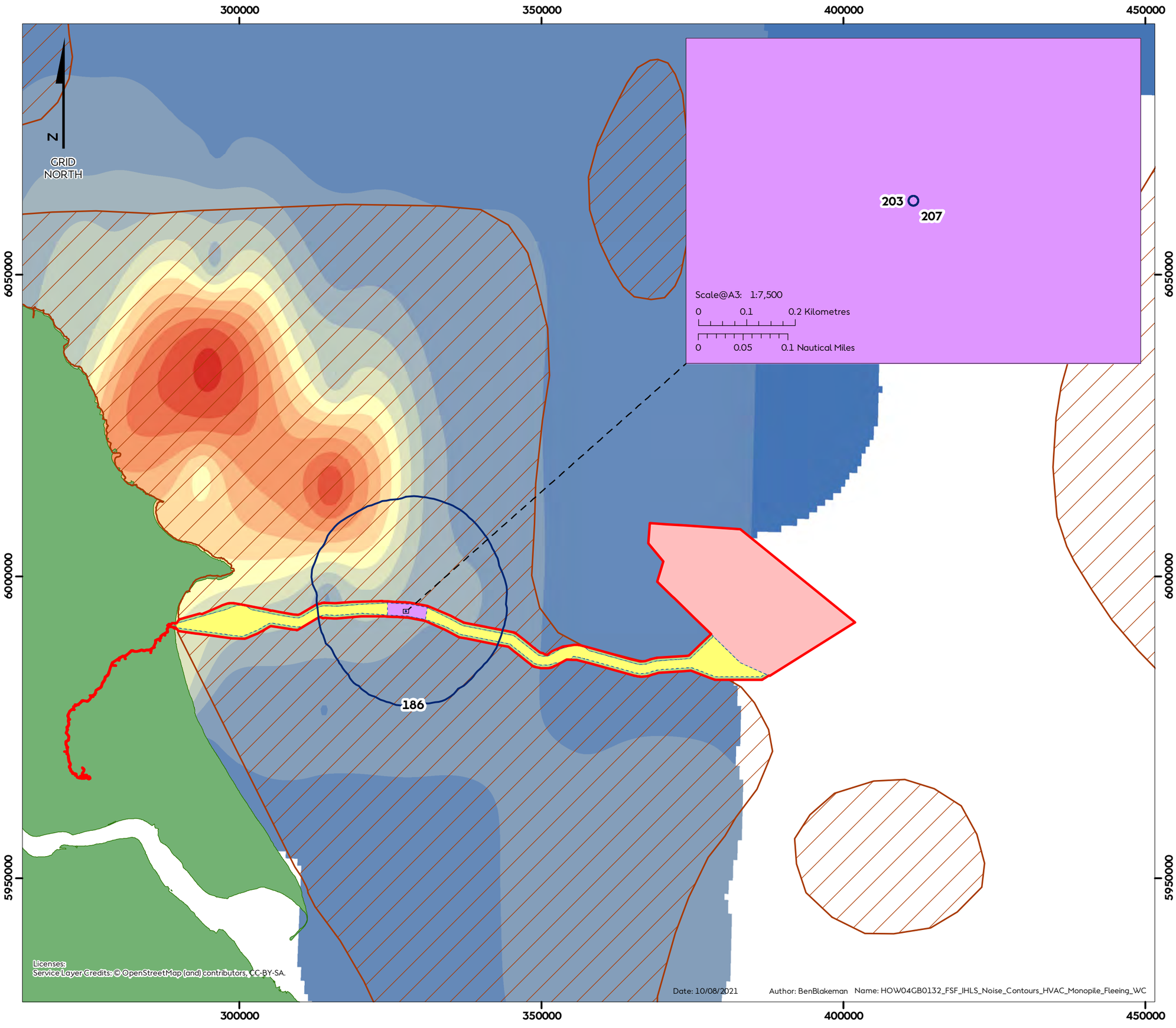
Date: 10/08/2021 Author: BenBlakeman

Name: HOW04GB0134_FSF_IHLS_Noise_Contours_NW_E_S_Monopile_Stationary_WC

Hornsea Four

Figure 3.10

MDS single piling at
HVAC booster station
(fleeing receptor; monopile; 5,000kJ)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- HVAC Monopile Contours (dB SELcum) - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000

0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	10/08/2021

NVAC Monopile Noise Contour
Fleeing Receptors
Document no: HOW04GB0132
Created by: BPHB
Checked by: AL
Approved by: LK

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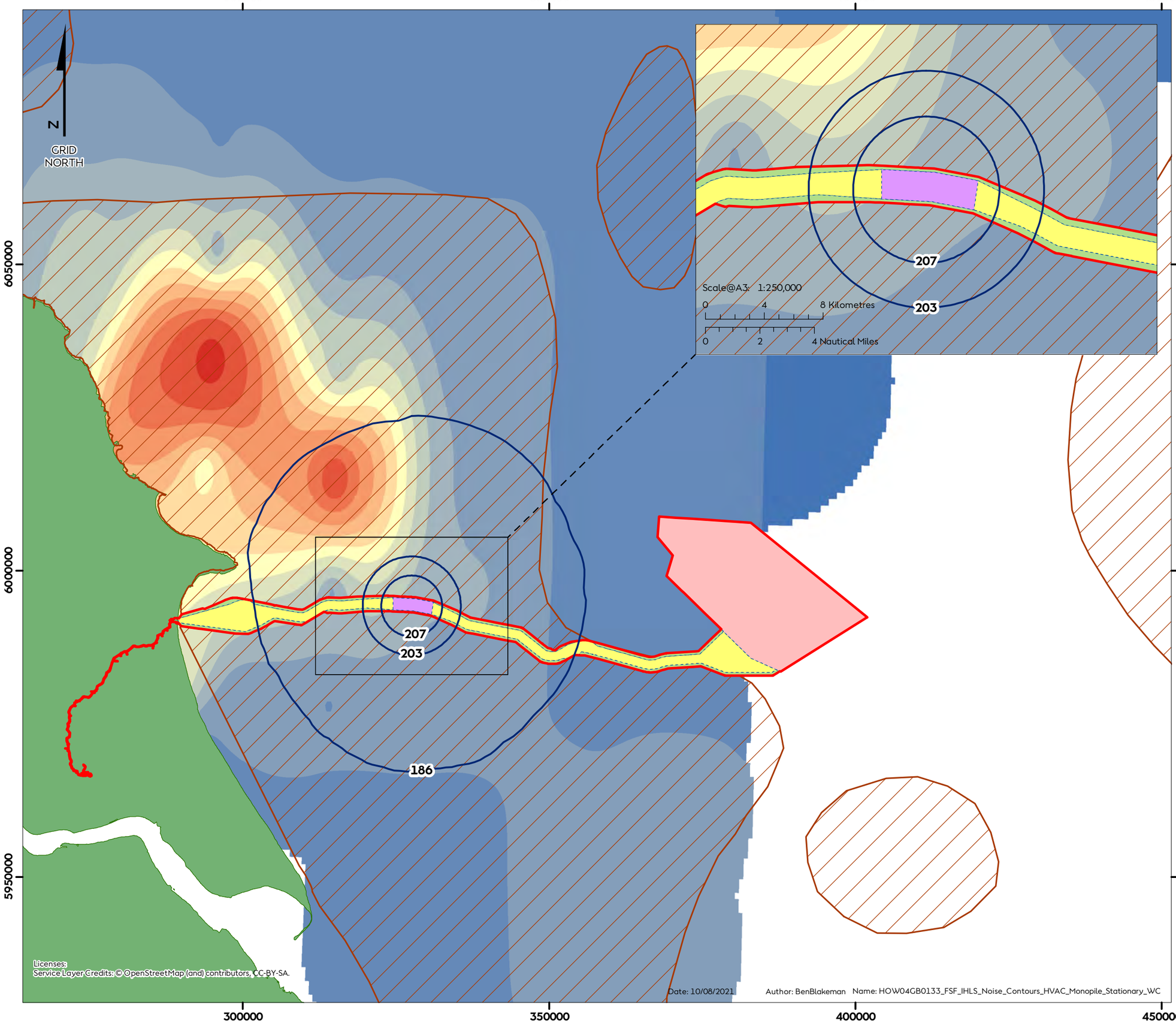
Figure 3.11

MDS single piling at HVAC booster station (stationary receptor; monopile; 5,000kJ)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- HVAC Monopile Contours (dB SELcum) - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	10/08/2021

NVAC Monopile Noise Contour
Stationary Receptors
Document no: HOW04GB0133
Created by: BPHB
Checked by: AL
Approved by: LK

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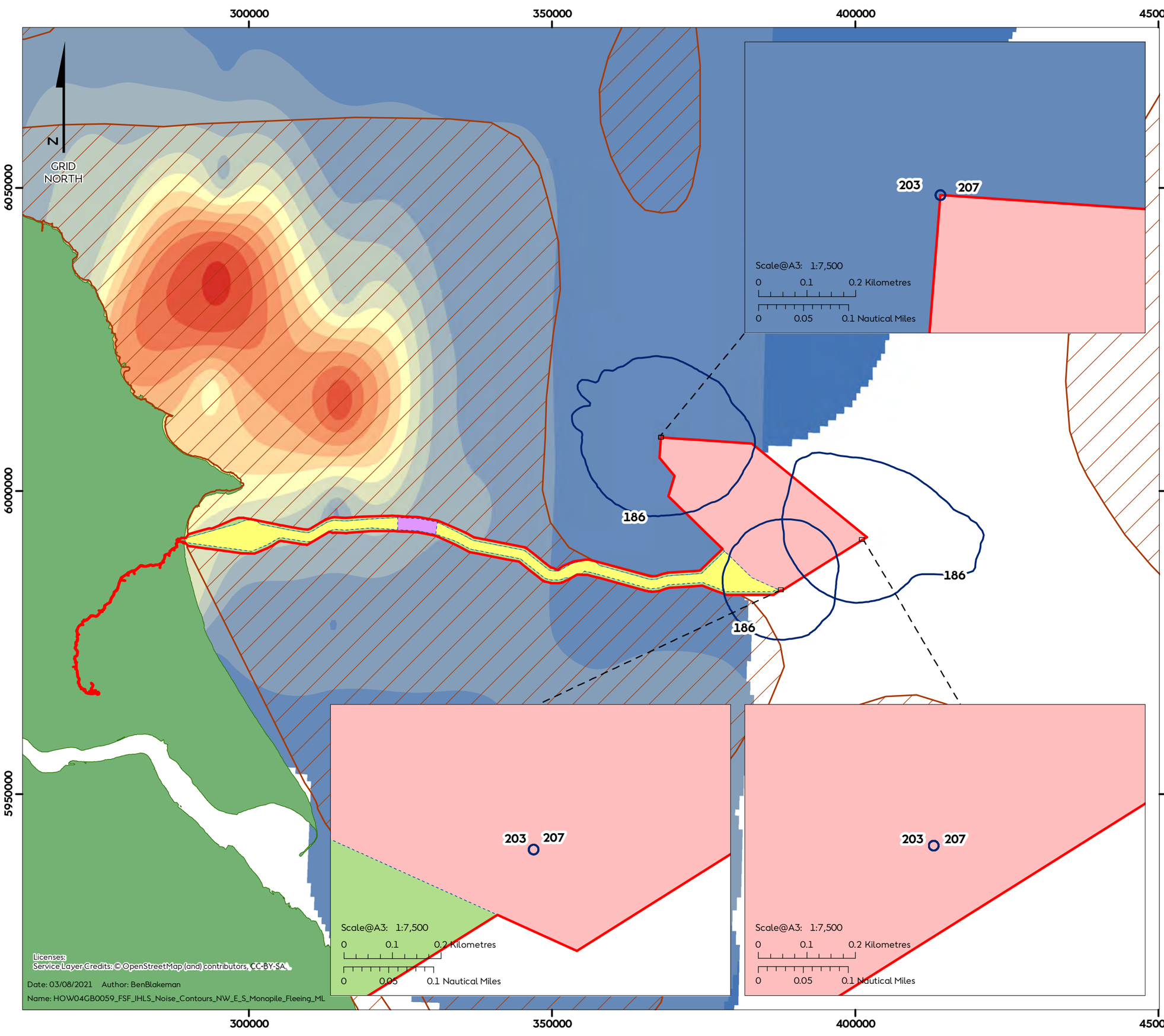
Figure 3.12

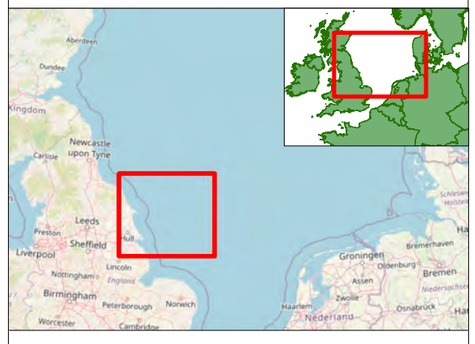
Most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the Northwest, East and South modelling locations of the array area (fleeing receptors at a rate of 1.5 ms-1)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- Monopile Contours (dB SELcum) - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000

0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
---	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	03/08/2021

NW Monopile Noise Contour
Fleeing Receptors ML
Document no: HOW04GB0059
Created by: BPHB
Checked by: AL
Approved by: LK

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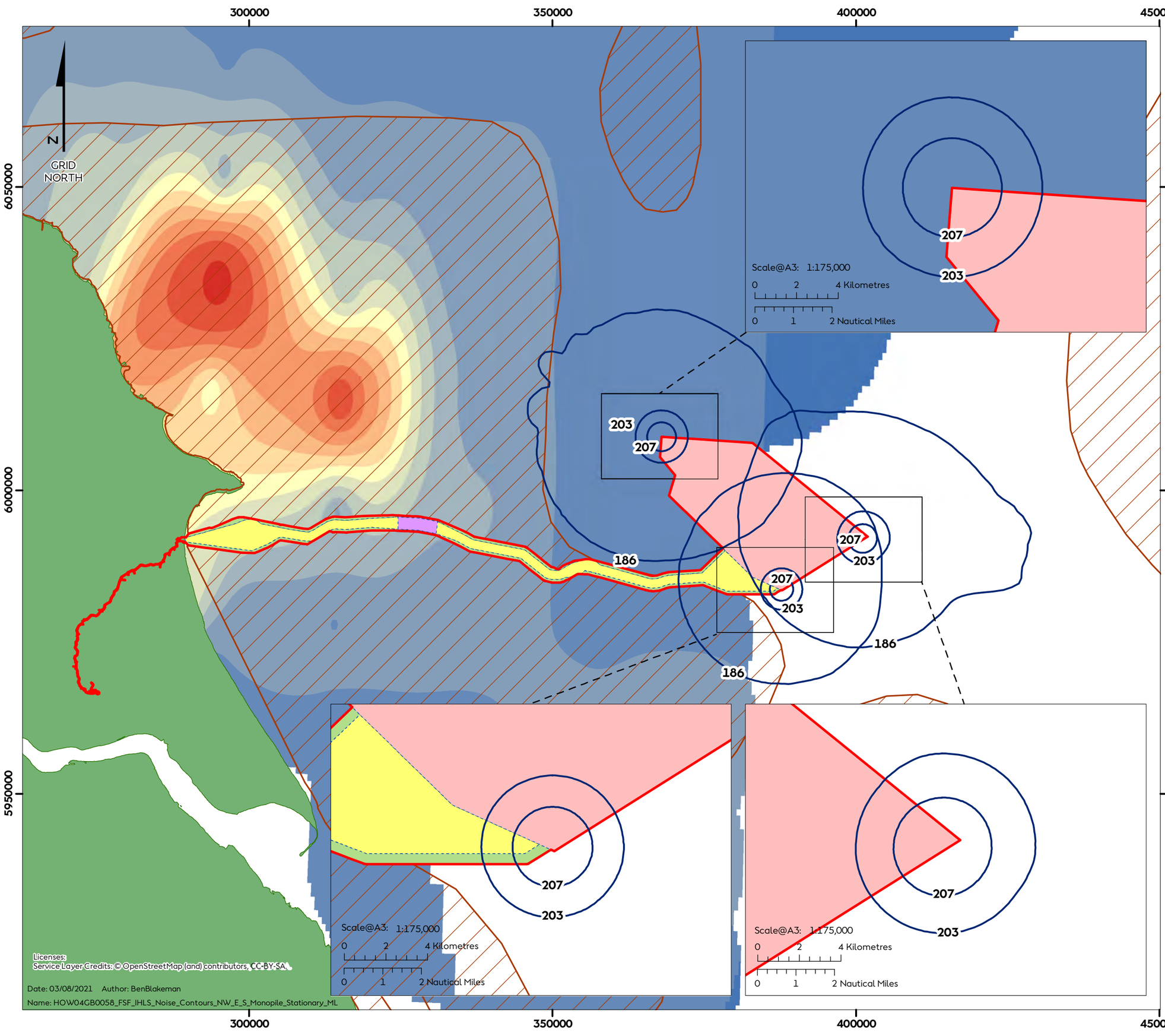
Figure 3.13

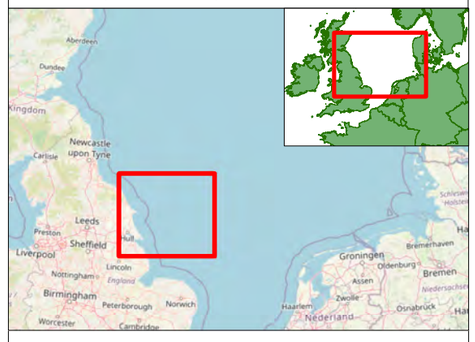
Most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the Northwest, East and South modelling locations of the array area (stationary receptors)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- Monopile Contours (dB SELcum) - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	03/08/2021

NW Monopole Noise Contour
Stationary Receptors ML
Document no: HOW04GB0058
Created by: BPHB
Checked by: AL
Approved by: LK

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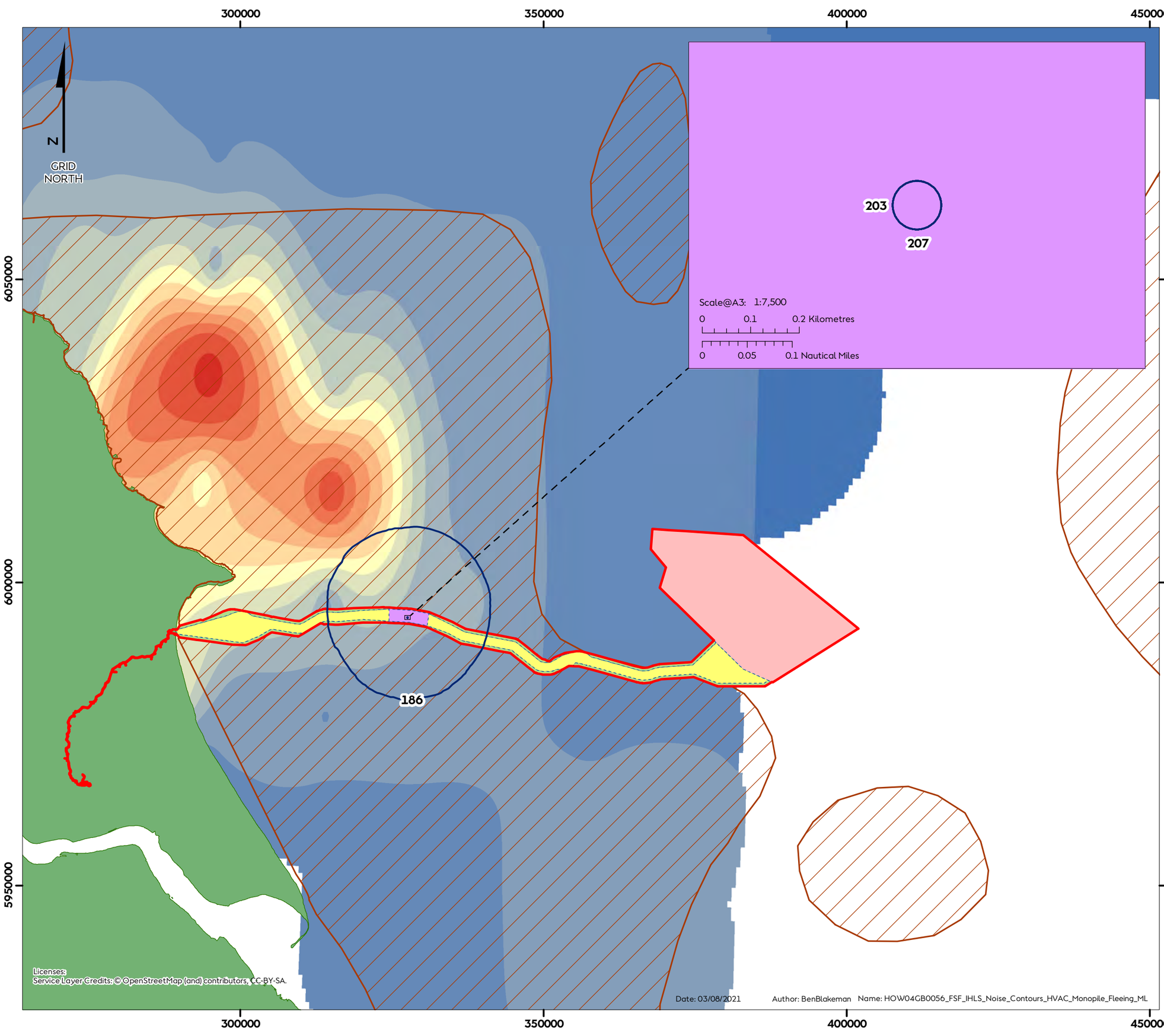
Figure 3.14

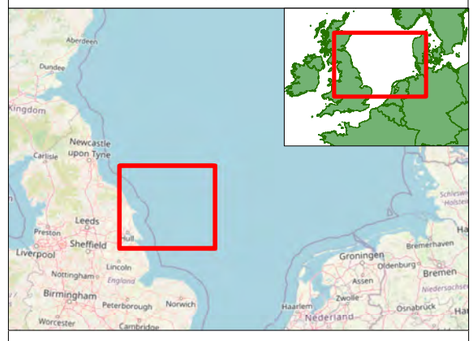
Most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the HVAC booster station modelling location (fleeing receptors at a rate of 1.5 ms-1)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- HVAC Monopile Contours (dB SELcum) - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	03/08/2021

NVAC Monopile Noise Contour
Fleeing Receptors ML
Document no: HOW04GB0056
Created by: BPHB
Checked by: AL
Approved by: LK

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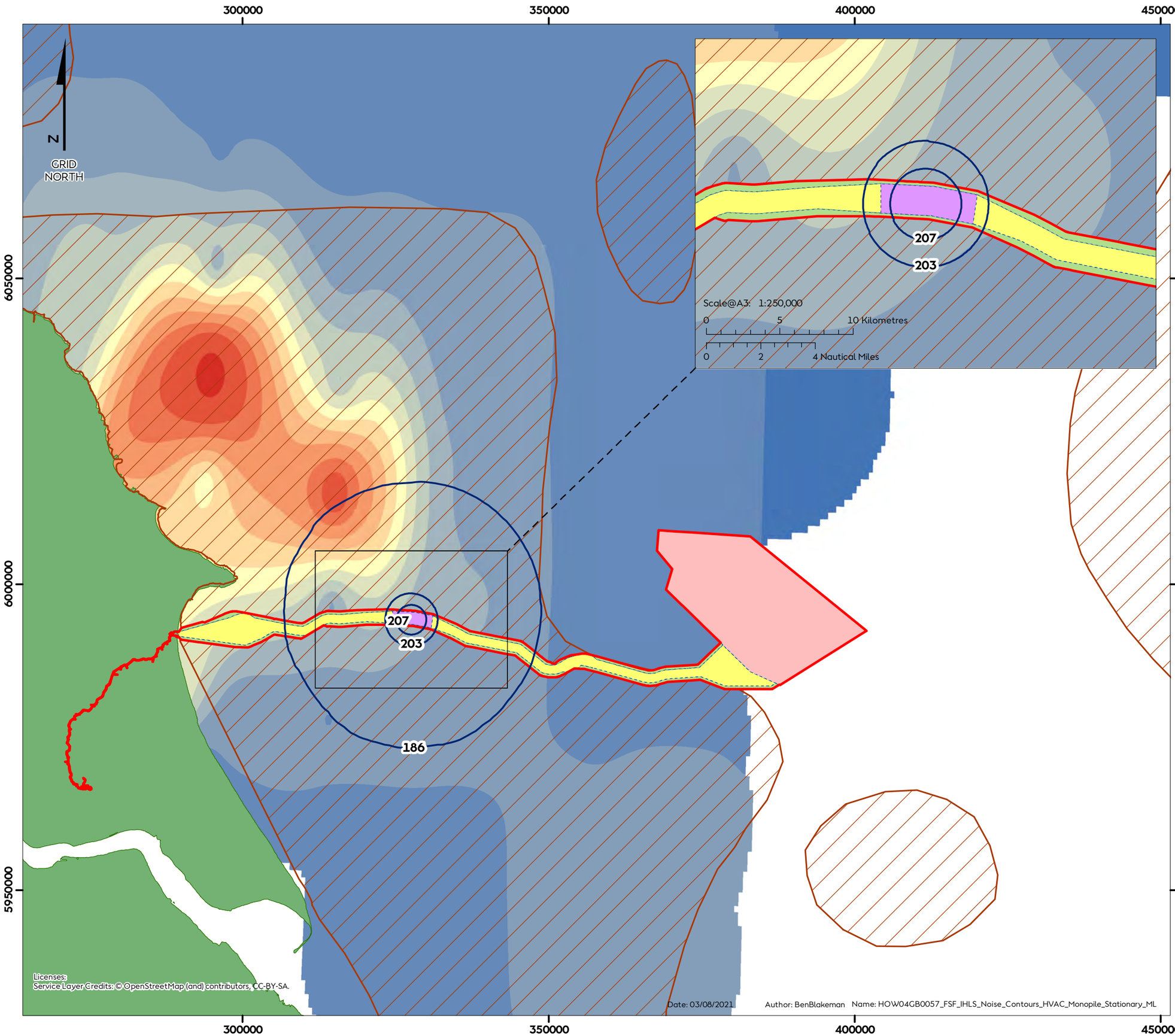
Figure 3.15

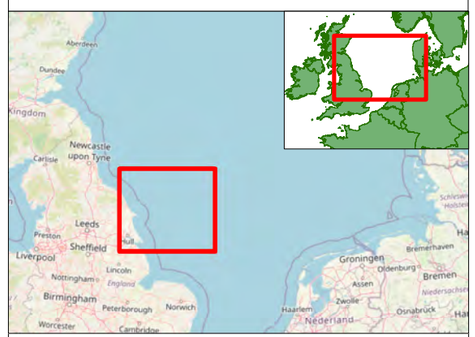
Most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the HVAC booster station modelling location (stationary receptors)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- HVAC Monopile Contours (dB SELcum) - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
---	First Issue	29/05/2019
A	Updated following PEIR consultation, for DCO	03/08/2021

NVAC Monopile Noise Contour
Stationary Receptors ML
Document no: HOW04GB0057
Created by: BPHB
Checked by: AL
Approved by: LK

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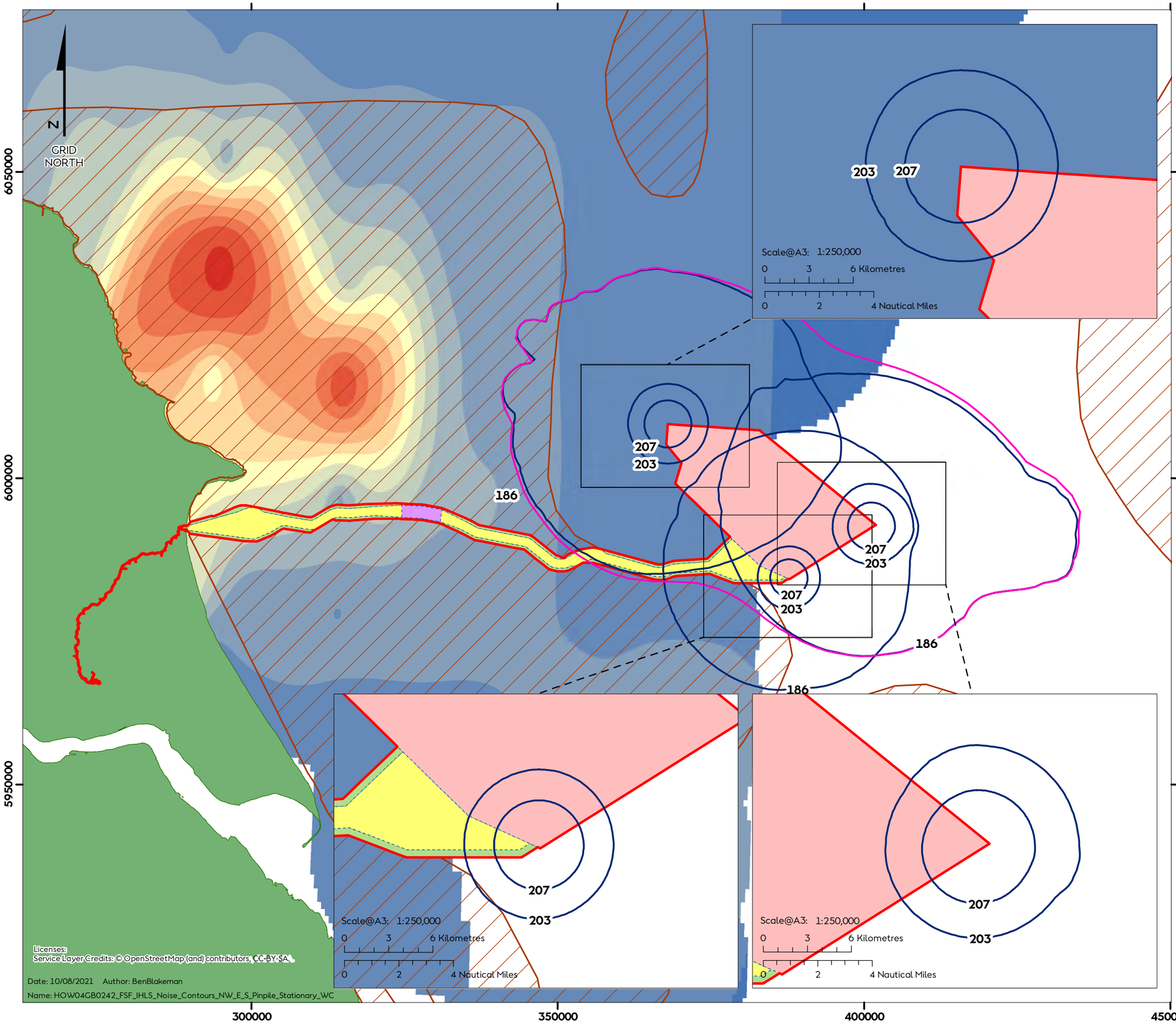
Figure 3.16

MDS single piling at all locations and concurrent piling at NW and E of the array area (stationary receptor; pin pile; 3,000kJ)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- Pinpile Contours (dB SELcum) - Stationary Receptors
- NW and E Concurrent Pinpile 186 dBht Contour - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	10/08/2021

Pinpile Noise Contour
Stationary Receptors
Document no: HOW04GB0242
Created by: BPHB
Checked by: AL
Approved by: LK

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Hornsea Four

Figure 3.17

MDS single piling at all locations and concurrent piling at NW and E of the array area (fleeing receptor; pin pile, 3,000kJ)

300000 350000 400000 450000

6050000

6000000

5950000

N

GRID NORTH

203 207 186

Scale@A3: 1:7,500
0 0.1 0.2 Kilometres
0 0.05 0.1 Nautical Miles

- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- Pinpile Contours (dB SELcum) - Fleeing Receptors
- NW and E Concurrent Pinpile 186 dBht Contour - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	10/08/2021

Pinpile Noise Contour
Fleeing Receptors
Document no: HOW04GB0243
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

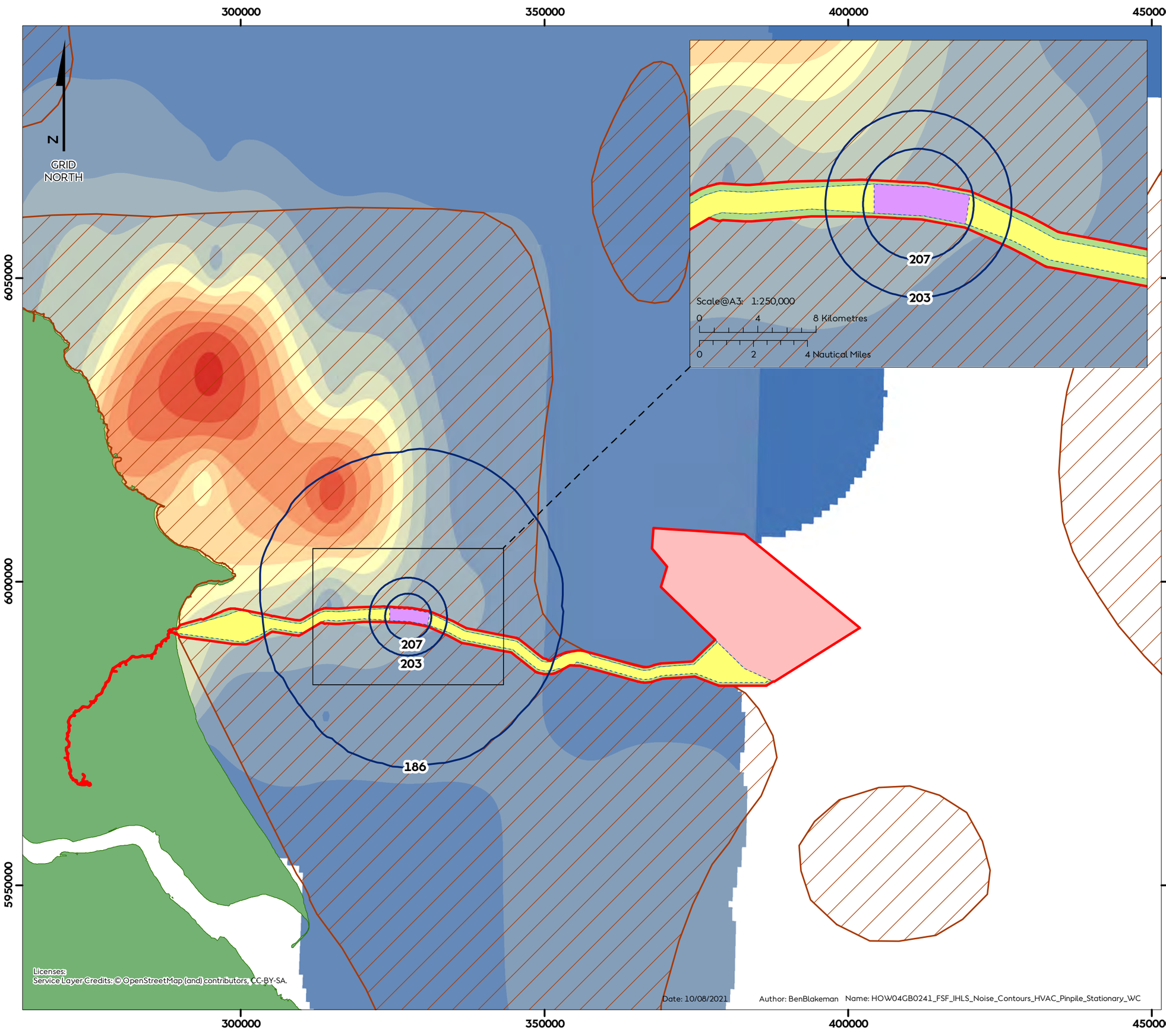
Date: 10/08/2021 Author: BenBlakeman

Name: HOW04GB0243_FSF_IHLS_Noise_Contours_NW_E_S_Pinpile_Fleeing_WC

Hornsea Four

Figure 3.18

MDS single piling at HVAC booster station (stationary receptor; pin pile; 3,000kJ)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- HVAC Pinpile Contours (dB SELcum) - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:600,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	10/08/2021

NVAC Pinpile Noise Contour
Stationary Receptors
Document no: HOW04GB0241
Created by: BPHB
Checked by: AL
Approved by: LK

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Hornsea Four

Figure 3.19

MDS single piling at
HVAC booster station
(fleeing receptor; pin pile; 3,000kJ)

300000 350000 400000 450000

6050000 6000000 5950000

N
GRID NORTH

203
207
186

Scale@A3: 1:7,500
0 0.1 0.2 Kilometres
0 0.05 0.1 Nautical Miles

- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- HVAC Pinpile Contours (dB SELcum) - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
...	First Issue	10/08/2021

NVAC Pinpile Noise Contour
Fleeing Receptors
Document no: HOW04GB0240
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe
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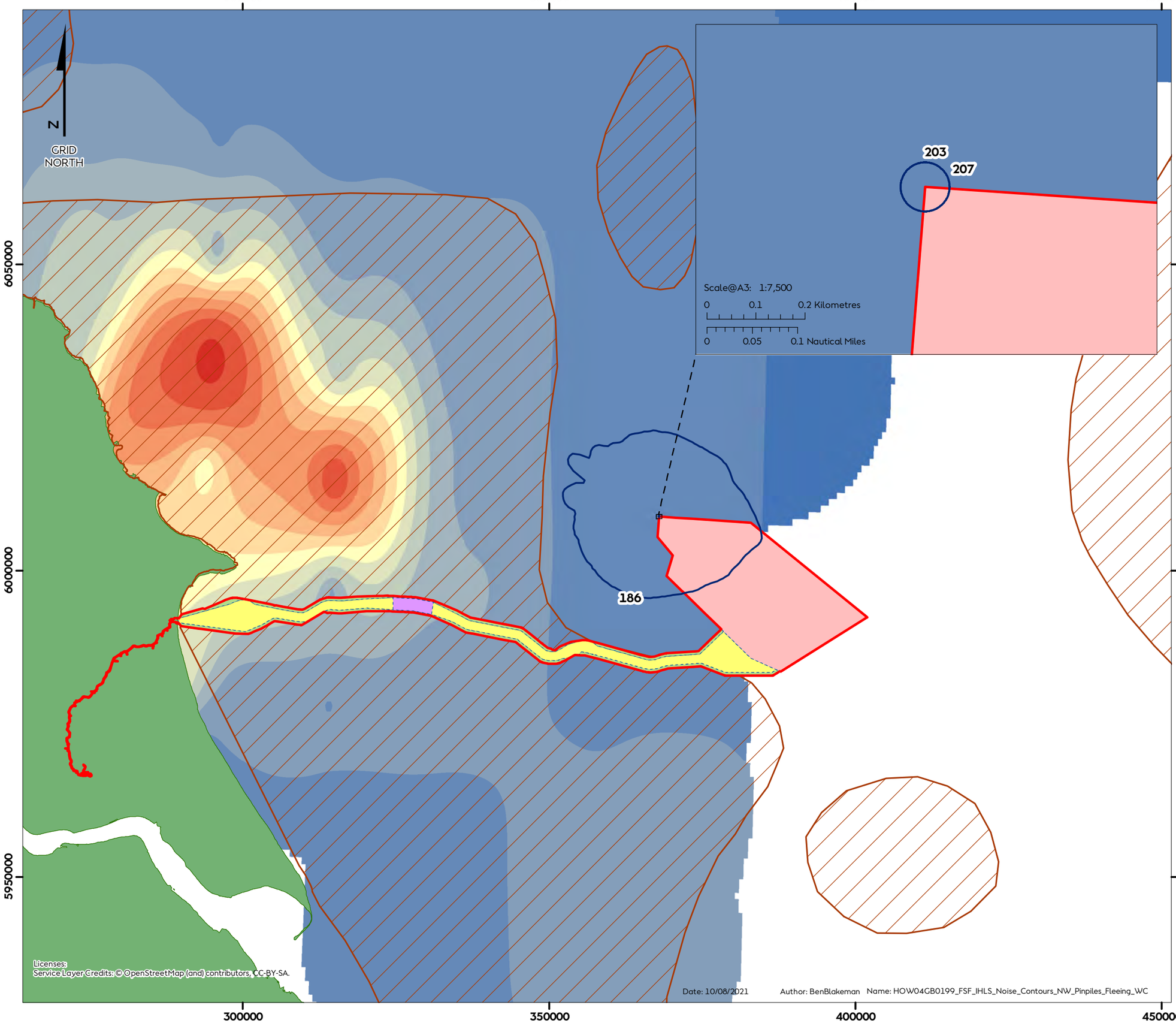
Date: 10/08/2021 Author: BenBlakeman Name: HOW04GB0240_FSF_IHLS_Noise_Contours_HVAC_Pinpile_Fleeing_WC

Hornsea Four

Figure 3.20

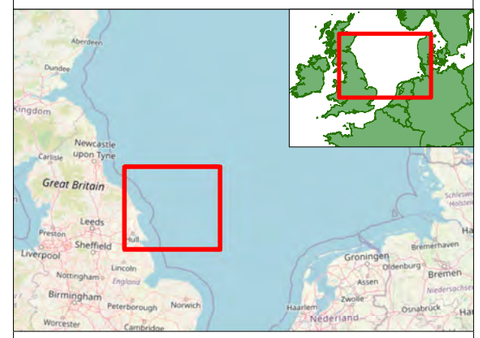
MDS multiple pile installation at NW location in array (fleeing receptor; pin piles; 3,000kJ)



- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- NW 3x Pin Pile Contours (dB SELcum) - Fleeing Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000



Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:600,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	10/08/2021

NW Pinpiles Noise Contour
Fleeing Receptors
Document no: HOW04GB0199
Created by: BPHB
Checked by: AL
Approved by: LK

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Hornsea Four

Figure 3.21

MDS multiple pile installation at NW location in array (stationary receptor; pin piles; 3,000kJ)

300000 350000 400000 450000

6050000 6000000 5950000

N
GRID NORTH

Scale@A3: 1:300,000
0 4 8 Kilometres
0 2 4 Nautical Miles

207
203
207
203
186

- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Offshore Temporary Works Area
- NW 3x Pin Pile Contours (dB SELcum) - Stationary Receptors
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2008-2020/2021 Banks Data - Total Larval Abundance Per m²

- 0
- 0.1 - 1,500
- 1,500.1 - 6,000
- 6,000.1 - 12,750
- 12,750.1 - 20,500
- 20,500.1 - 28,500
- 28,500.1 - 36,500
- 36,500.1 - 45,500
- 45,500.1 - 55,000
- 55,000.1 - 66,000
- 66,000.1 - 77,250
- 77,250.1 - 100,000
- 100,000.1 - 120,000

Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:600,000
0 10 20 Kilometres
0 5 10 Nautical Miles

REV	REMARK	DATE
....	First Issue	10/08/2021

NW Pin Piles Noise Contour
Stationary Receptors
Document no: HOW04GB0198
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe Ørsted

Date: 10/08/2021 Author: BenBlakeman Name: HOW04GB0198_FSF_IHLS_Noise_Contours_NW_Pinpiles_Stationary_WC

Noise and vibration arising from the simultaneous piling of pin piles

3.11.1.140 In response to consultee comments from the MMO and Natural England (Section 42 consultation, 23 September 2019), noise modelling for multiple pin piles (3,000 kJ hammer energy) at the NW location of the array over a 24-hour period (3 piles) was undertaken. The noise contours for this scenario are shown in relation to herring spawning grounds and larvae abundances (Coull et al. 1998 and IHLS (2007 – 2021) data sources) in **Figure 3.20** and **Figure 3.21**.

3.11.1.141 The modelling showed that the potential for mortality and potential mortal injury in this scenario may occur up to 1,300 m from the array on (spawning) sandeel, and up to 7,300 m from the array on (spawning) herring (based on SEL_{cum}).

3.11.1.142 For recoverable injury, the noise modelling indicates that there is the potential for recoverable injury in sandeel up to 2,100 m from the array, with the potential for the same effects on herring 11,000 m from the array (based on SEL_{cum}).

3.11.1.143 As indicated by the noise modelling, TTS is predicted to occur up to 38,000 m from the array on (spawning) herring (based on SEL_{cum}).

3.11.1.144 The noise contours for mortality or potential mortal injury, and recoverable injury of herring both lie outside of any herring spawning grounds (Coull et al. 1998), and areas of high herring larvae abundance (**Figure 3.20** and **Figure 3.21**). The noise contour for TTS overlaps a herring spawning ground and clips an area of low to moderate herring larvae abundance but has no interaction with any areas of high larvae abundance. While the individual ranges for the simultaneous piling for pin piles results in larger ranges than a single monopile, the concurrent installation of monopiles still represents the spatial MDS and is assessed in **paragraph 3.11.1.45** *et seq* of this report.

Noise and vibration arising from UXO clearance

3.11.1.145 Prior to the start of construction UXO investigation works will be required which may require the clearance of UXO in situ, resulting in emission of underwater noise.

3.11.1.146 The Applicant is not applying for consent for UXO clearance works as part of this DCO application; however, it is acknowledged that UXO clearance is likely to comprise part of the project, albeit under a separate Marine Licence application, and as such, it is appropriate to consider the potential impacts of this additional source of underwater noise on fish and shellfish species.

3.11.1.147 UXO clearance activities are one of the loudest anthropogenic noise sources that occur underwater, with typically much higher source levels than those from piling. UXO clearance is expected to result in mortality, mortal injury, recoverable injury, TTS and disturbance to fish and shellfish species, depending on the proximity of the individuals to the UXO location and the size of the UXO. Small scale mortality of fish as a result of UXO detonation are frequently recorded, with dead fish recorded floating at the surface following the detonation as an "other observations" recording by Marine Mammal Observers. The recordings for dead fish are typically made within the immediate vicinity of the detonation and as such this is expected to be a small-scale impact.

3.11.1.148 Injury and disturbance effects will impact a progressively larger area, with TTS and disturbance effects potentially reaching 10's of kilometres from the UXO location.

3.11.1.149 Due to the potential impacts from underwater noise from UXO clearance, bubble curtains have in some cases been used for UXO clearance works to reduce the sound level received by marine animals from the detonation. While the primary driver for the deployment of bubble curtains is legislation protecting marine mammals, where bubble curtains are used, they will also result in a reduction of the impacts to fish and shellfish receptors as well. Recently, a new technique to the commercial sector for UXO clearance has been promoted: deflagration or "low order" detonation. This method, while currently untested in the commercial offshore wind sector, is being explored at an industry level and by government regulators as an alternative to standard techniques; evidence to date suggests a quieter source level which is anticipated to result in reduced impacts on the marine environment.

3.11.1.150 It is possible that UXO operations will be planned to take place year-round during the UXO clearance campaign pre-construction and therefore has the potential to interact with the spawning period for different fish and shellfish species. However, each UXO clearance is a discrete event and while this may result in some temporary disturbance to spawning fish, it is less likely to result in the displacement of fish from specific spawning grounds, compared to more continuous noise sources such as piling.

3.11.1.151 While individual UXO detonations have the potential to result in greater impact ranges than a piling event, the discrete nature of a UXO detonation is considered to result in a lesser overall effect on fish and shellfish species populations. A full assessment of the potential impacts from UXO clearance works will be submitted to support a separate Marine Licence application prior to undertaking UXO clearance works at Hornsea Four, once the full number of potential UXO and the likely sizes of these UXO are known, following further surveys which will only be undertaken once consent for the project is granted.

3.11.2 Operation and Maintenance

3.11.2.1 The potential impacts of the offshore operation and maintenance of Hornsea Four have been assessed on fish and shellfish ecology. The environmental impacts arising from the operation and maintenance of Hornsea Four are listed in **Table 3.10** along with the MDS against which each operation and maintenance phase impact has been assessed.

Temporary localised increases in SSC and smothering (FSE-O-18)

3.11.2.2 Temporary localised increases in suspended sediment concentration (SSC) and associated sediment deposition are expected from cable remedial burial and cable repairs. **Chapter 1: Marine Geology, Oceanography and Physical Process** and **Volume A5, Annex 1.1: Marine Processes Technical Report** provides a full description of the offshore physical environment assessment, with a summary of the MDSs associated with the impact, as detailed in **Table 3.10** of this ES chapter.

Magnitude of impact

3.11.2.3 **Table 3.10** presents the MDS associated with increases in SSC and deposition. The MDS for SSC and deposition during the operation and maintenance phase of Hornsea Four is predicted to be the total release of 692,916 m^3 of sediment in the array area and offshore ECC. **Table 3.14** presents the maximum distance the sediment plume will travel, and the maximum sediment deposition depths from site-specific modelling undertaken to inform the ES.

3.11.2.4 Cable remedial burial and cable repairs are both predicted to cause sediment plumes. Plumes are expected restricted to be within the tidal excursion, with plumes expected to occur over a maximum distance of 14 km from the source. Sediment plumes are expected to quickly dissipate after cessation of the activities, due to settling and wider dispersion with the concentrations reducing quickly over time to background levels. Sediment deposition will consist primarily of coarser sediments deposited close to the source, with a small proportion of silt deposition (reducing exponentially from source).

3.11.2.5 It should be noted that any sediment released from cable protection replenishment will be of a substantially smaller scale than that for cable reburial works as the only sediment released from this activity will be that which arises when the cable protection is placed on the seabed. This is in comparison with sediment released from cable burial works for which it is assumed that the full volume of sediment from the trench is suspended and entrained in the water column.

3.11.2.6 Each event will be discrete, short term, and of localised extent (within one tidal excursion), and therefore taking into consideration the localised nature of herring spawning grounds to Hornsea Four, the magnitude of impact on herring from an increase in SSC from cable maintenance within the array area and along the ECC is assessed as **minor** (adverse).

3.11.2.7 Due to the presence of sandeel habitats across the southern North Sea, the magnitude of impact from increased SSC from cable maintenance activities within the array area and along the ECC are also considered to be **minor** (adverse)**.**

3.11.2.8 Due to the proximity of shellfish spawning grounds to the array area (brown crab, and *Nephrops* spawning grounds overlap with the array (Eaton et al. 2003; Coull et al. 1998) and the ECC (partial overlap with scallop resources, and brown crab spawning grounds (Cefas 2019; Eaton et al. 2003), the magnitude of impact from increased SSC from cable maintenance activities within the array area and along the ECC on these species are considered to be **minor** (adverse).

3.11.2.9 All other VERs and their respective spawning grounds are distributed widely throughout the Southern North Sea, and therefore taking the wider environment into context, the magnitude of impact on all other VERs is assessed as being **minor** (adverse) at array area and along the ECC.

Sensitivity of the receptor

3.11.2.10 High intensity spawning sites for herring occur in the vicinity of the ECC, and therefore the spawning sites are likely to be indirectly impacted by cable replacement and cable protection replenishment. However, it has been shown that herring eggs are tolerant of very high levels of SSC (Kiorboe et al. 1981). Adult herring are mobile and therefore may show avoidance behaviour to the impact. Spawning herring may not show these avoidance behaviours, however as any increases in SSC are expected to be short term and within the natural range of SSC, herring are expected to be largely unaffected by this impact. Taking this into consideration, herring are deemed to be of high vulnerability, with low recoverability and of regional importance, and therefore the sensitivity of the receptor is **high**.

3.11.2.11 Sandeel spawning grounds and preferred habitats (**Figure 3.5**) are located across the offshore section of the ECC and the array area, however any impacts on this species are expected to be relatively small in the context of the spawning habitat available in the wider region. Sandeel species, and eggs are considered tolerant to increases in SSC and deposition, due to the nature of resuspension and deposition within their natural high energy environment. Based on the species reduced sensitivity to increased SSC and deposition, sandeel are deemed to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **low**.

3.11.2.12 More sedentary species (such as shellfish) are likely to be more vulnerable to increases in SSCs and subsequent deposition. Berried crustaceans (e.g. brown crab, European lobster and *Nephrops*) are likely to be more vulnerable to increased SSC and deposition as the eggs carried by these species require more regular aeration and as they are considered to have limited mobility, remaining sedentary during the overwintering period, whilst brooding eggs. In the construction phase assessment (see **paragraph 3.11.1.17** *et seq.*) shellfish receptors were considered to be of **medium** sensitivity to increased SSC and deposition, with the exception of *Nephrops* and common whelk which were assessed as **low** sensitivity due to their burrowing nature.

3.11.2.13 All other VERs and their respective spawning grounds are distributed widely throughout the southern North Sea, and none of which exhibit substrate dependant spawning behaviours which could be impacted by increased SSC and associated sediment deposition. Therefore, all other VERs are considered to be of **low** sensitivity to this impact in the operation and maintenance phase of this project.

Significance of the effect

3.11.2.14 Increases in SSC and associated sediment deposition from cable maintenance activities are expected to be discrete events, representing a temporary and short-term impact, affecting a relatively small and localised portion of the fish and shellfish habitats in the study area. Most receptors are predicted to have some tolerance to this impact. Overall, the magnitude of the impact has been assessed as **minor** for all receptors within both the array area and along the ECC.

3.11.2.15 The sensitivity of herring has been assessed as **high**. A **minor** magnitude and a sensitivity of **high** can result in either a slight of moderate significance of impact (as per the significance matrix in **Table 3.13**), however, taking into consideration the relative

tolerance of herring eggs to increased SSC and sediment deposition, and the short term and localised nature of the impact with SSCs over the core spawning areas below low and spatially very limited (as detailed in the construction phase assessment in paragraph 3.11.1.37) the significance of effect is deemed **slight** for herring, which is not significant in EIA terms.

3.11.2.16 The sensitivity of sandeel is considered to be **low** and could therefore also have a significance of either neutral or slight (as per the significance matrix in Table 3.13. Impacts on this species are expected to be relatively small in the context of the spawning habitat available in the wider region. Therefore, taking this into consideration alongside the relative tolerance of sandeel to increased SSC and sediment deposition, the significance of effect is deemed **neutral** for sandeel which is also not significant in EIA terms.

3.11.2.17 The sensitivity for brown crab, scallop and European lobster have all been assessed as **medium** and therefore the significance of effect could either be slight or moderate (in accordance with the significance matrix in Table 3.13). Taking into account the extensive distribution of these species along the coasts of the UK, and the small degree of overlap of Hornsea Four with identified shellfish resources and spawning grounds, it is concluded that the effect will be of **slight** significance, which is not significant in EIA terms.

3.11.2.18 *Nephrops* and common whelk were considered to have **low** sensitivity to the potential of increased SSC and smothering. This could result in either a neutral or slight significant of effect impact (as per the significance matrix in Table 3.13), however taking into account the extensive distribution of these species across the study area, the significance of effect is deemed to be **neutral**, which is not significant in EIA terms.

3.11.2.19 The magnitude of the impact on all other VERs has been assessed as **minor**, and their sensitivity as **low**. This could result in either a neutral or slight significant of effect impact (as per the significance matrix in Table 3.13), however taking into account the extensive distribution of these species across the study area, and the small degree of impact in the context of the spawning grounds across the wider region, the significance of effect is deemed to be **neutral**, which is not significant in EIA terms.

Long term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (FSE-O-6)

3.11.2.20 The presence of infrastructure such as foundations and cable protection at crossings have the potential to impact on fish and shellfish ecology by the removal of essential habitats for survival (e.g. spawning, nursery and feeding habitats).

Magnitude of impact

3.11.2.21 The long-term habitat loss due to the presence of foundations, scour protection and cable protection is expected to be up to a maximum of 3,730,671 m^2, which represents 0.09% of the fish and shellfish study area. Comparable habitats are present and widespread within the wider area.

3.11.2.22 The impact is predicted to be of local spatial extent (i.e. within the Hornsea Four Order Limits), of long-term duration, continuous and irreversible (within the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly.

3.11.2.23 The Hornsea Four nearshore section of the ECC is located proximal to main high intensity herring spawning grounds (**Figure 3.3**). The ECC and the proposed location of the HVAC booster station search area directly overlap with areas of low intensity spawning activity. Due to the localised nature of the impact (within the Hornsea Four Order Limits), and the small overlap with low intensity herring spawning grounds, any impacts on spawning grounds from habitat loss are expected to be minor.

3.11.2.24 The Hornsea Four offshore section of the ECC and the array area are also located within preferred sandeel spawning and nursery habitat (**Figure 3.6**), however the proportion of habitat affected within Hornsea Four is small in the context of known wider sandeel habitats in the area.

3.11.2.25 Taking into consideration the reduced relative importance of the herring spawning grounds which overlap Hornsea Four, and the localised nature of the impact, the magnitude of impact from long term habitat loss, associated with construction within the array area, the HVAC booster station search area and along the ECC on herring is considered to be **minor** (adverse). Due to the wide distribution of sandeel habitats across the southern North Sea, the magnitude of impact of habitat loss from construction within the array area, the HVAC booster station search area and along the ECC is also considered to be **minor** (adverse).

3.11.2.26 Brown crab and *Nephrops* spawning grounds (Eaton et al. 2003; Coull et al. 1998), and scallop grounds (Cefas 2019) are located within the study area. There is also evidence that overwintering grounds for lobster may also be located nearshore, close to the Humber Estuary (SMart Wind 2015a). There is no direct overlap of the proposed array or ECC with lobster overwintering grounds, therefore considering the localised nature of the impact, there will be no impact on these grounds. Brown crab spawning habitats are located inshore of the array and across the offshore ECC. In a broader context, the spawning areas are also located across the English Channel and the Western Approaches, with spawning areas also being located within the Bay of Biscay and the Celtic Sea (Thompson et al. 1995; Pawson 1995). *Nephrops* spawning grounds overlapping the proposed array area also extend further offshore across the central North Sea. In addition to this, any loss of burrow habitat would be located directly adjacent to the rock protection, and therefore no long-term impacts are expected on the *Nephrops* population. The ECC crosses a large scallop ground running along the Hornsea coast, although the extent of disturbance along this scallop ground is considered to be minimal in the context of the wider spawning area due to the highly localised nature of this impact. Therefore, taking into consideration the broader context of these spawning grounds, overwintering grounds and resource areas, the proportion of these sites disturbed from this impact are considered small due to the localised nature of this impact, and consequently the magnitude of impact on these species is considered to be **minor** (adverse) from impacts at the array, the HVAC booster station search area and along the ECC.

3.11.2.27 All other VERs and their respective spawning grounds are distributed widely throughout the southern North Sea, and therefore taking the wider environment into context, and the localised and temporary nature of the impact, the magnitude of effect on all other VERs is assessed as being **minor** (adverse) from impacts at the array, the HVAC booster station search area and along the ECC.

Sensitivity of the receptor

3.11.2.28 Herring and sandeel are demersal spawners and are reliant upon the presence of suitable substrates for spawning (i.e. gravelly sediments for herring and sandy sediments for sandeel). Furthermore, as well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history. On account of this, these species are considered to be more vulnerable to long term habitat loss depending on the availability of habitat within the wider region. Sandeel and herring are consequently deemed to be of high vulnerability to long-term changes in substrate, with limited ability for recovery, and of regional importance within the southern North Sea, and therefore are both considered to be of **high** sensitivity.

3.11.2.29 Crab and *Nephrops* have burrowing habits during varying life stages, whilst scallops prefer softer sediment and as such, the introduction of hard substrate over the softer sediments within the Hornsea Four will reduce the habitat availability for these species. However, these species are substrate dependent rather than being philopatric and can therefore fully utilise adjacent, unaffected areas. As such, these receptors are considered to be of medium vulnerability and high recoverability and therefore considered to be of **medium** sensitivity.

3.11.2.30 All other VERs are generalists and relatively insensitive to local variations in seabed substrate with widely distributed spawning and feeding grounds. Therefore, these receptors are considered to be of low vulnerability and high recoverability to long term changes in seabed substrate and of regional importance within the southern North Sea and therefore are all considered to be **low** sensitivity.

Significance of the effect

3.11.2.31 Long-term habitat loss will represent a long-term and continuous impact throughout the lifetime of the project. However only a relatively small proportion of the fish and shellfish habitats are likely to be affected in the context of wider habitats in the area. Most receptors are predicted to have some tolerance to this impact. Overall, the magnitude of the impact has been assessed as **minor** for all species. The sensitivity of both herring and sandeel are assessed as **high**, with all other species having lower sensitivities. The minor magnitude and high sensitivities of herring and sandeel could result in either a slight or moderate effect (as per the matrix in **Table 3.13**), however taking into account the localised nature of the impacts, and the small area of direct impact compared to the overall extent of the herring and sandeel spawning grounds, the significance of effect therefore is deemed **slight** for herring and sandeel, which is not significant in EIA terms.

3.11.2.32 The **minor** magnitude and **medium** sensitivity for crab, *Nephrops* and scallop could result in either a slight or moderate effect, however taking into account the localised footprint in any single location and the availability of alternative habitat (directly adjacent to impacted areas), the significance of the effect is deemed **slight** for crab, *Nephrops* and scallop, which is not significant in EIA terms.

3.11.2.33 The **minor** magnitude and **low** sensitivity for all other VERs results in either a neutral or slight effect. The significance of the effect is deemed **slight** for all other VERs, which is not significant in EIA terms.

Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection (FSE-O-7)

3.11.2.34 Any introduction of infrastructure such as foundations and scour protection would result in the introduction of hard substrate to the currently predominantly soft seabed habitat of the Hornsea Four Order Limits. This would result in an increase in the heterogeneity of the seabed habitat and a change of the composition of the benthic community. As a result, an increase in the biodiversity if the benthic community in the vicinity of the area where hard substrate is introduced is expected to occur (Wilhelmsson and Malm 2008). This increase in diversity and productivity of the seabed communities expected may have an impact on fish and shellfish receptors, resulting in either attraction or increased productivity.

Magnitude of impact

3.11.2.35 Up to 4,759,171 m^2 of new hard substrate is likely to be created in Hornsea Four as a result of foundation installation, scour protection and cable protection, which represents 0.11% of the fish and shellfish study area. The potential impact is predicted to be of local spatial extent (within the Hornsea Four Order Limits), and of long-term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact has the potential to affect herring and sandeel receptors both directly and indirectly, and therefore the magnitude of effect is therefore considered to be **minor** (adverse) for herring and sandeel.

3.11.2.36 Effects on shellfish receptors from increased hard substrate and structural complexity are predicted to be restricted to within the Hornsea Four Order Limits, and to be long-term continuous and irreversible. It is predicted that shellfish receptors will be affected both directly and indirectly from this impact, and therefore the magnitude of effect on these receptors is considered to be **minor** (adverse).

3.11.2.37 The effects from this impact on all other VERs and their respective spawning grounds are considered to be minimal due to their wide distribution throughout the Southern North Sea, and lack of substrate dependency for spawning. Taking this into consideration and the localised nature of the impact, the magnitude of effect on all other VERs is assessed as being **negligible** (adverse). Irrespective of the sensitivity of the receptor, the significance of the impact on all other VERs is **not significant** as defined in the assessment of significance matrix (Table 3.13) and is therefore not considered further in this assessment.

Sensitivity of the receptor

3.11.2.38 Herring preferred spawning grounds consist of coarse sediments, typically sandy gravel, and gravelly sand. Sandeel preferred habitats and spawning areas are typically dominated by coarse sediments and sandy habitats. The nearshore section of the Hornsea Four ECC and the HVAC booster station search area are in close proximity to high intensity herring spawning grounds. With the offshore section of the ECC and the array area located in preferred sandeel habitat and spawning grounds. Due to the demersal nature of herring and sandeel spawning, and their specific habitat requirements, both of these receptors are considered to be of high vulnerability to permanent changes in the substrate, with no ability for recovery, and of regional importance. As a result of this, both herring and sandeel are of **high** sensitivity to this impact.

3.11.2.39 There is the potential for positive effects on crustacean species, such as brown crab and lobster, due to expansion of their natural habitats (Linley et al. 2007) and the creation of additional refuge areas. Novel habitats and new potential food sources may be created from foundations and scour protection installed in areas of sandy and coarse sediments, which could extend the habitat ranges of some shellfish species. However, the colonisation of new habitats by shellfish receptors could lead to the introduction of non-indigenous and invasive species (see **Chapter 2, Benthic Subtidal and Intertidal Ecology** for detailed discussion), this may have indirect adverse effects on shellfish populations as a result of competition. However, the implementation of a CPEMMP (Co111), which includes a biosecurity plan, will ensure that the risk of potential introduction and spread of Invasive Non-Native Species (INNS) will be minimised. Taking the above into consideration, shellfish receptors are deemed to not be vulnerable to increased hard substrate and structural complexity and are considered to be of local to regional importance to the area. Shellfish are therefore considered to be of **low** sensitivity to this impact.

Significance of the effect

3.11.2.40 There is some uncertainty associated with the likely effects of introduction of hard substrates into the marine environment on fish and shellfish receptors. Fish populations are unlikely to show noticeable benefits as a result of this impact, though there is evidence that shellfish populations (particularly brown crab and lobster) would benefit from the introduction of hard substrates (Roach and Cohen 2015; Hooper and Austen 2014; Krone et al. 2013). Demersal spawners, herring and sandeel are considered to have increased sensitivity to the introduction of hard substrate, due to their specific habitat requirements.

3.11.2.41 Overall, the magnitude of the impact on herring and sandeel has been assessed as **minor**, with the sensitivity of both receptors being assessed as **high**, this could result in either a slight or moderate effect (as per the matrix in **Table 3.13**). Considering the localised nature of the impacts, and the small area of direct impact compared to the overall extent of the herring and sandeel spawning grounds, the significance of effect therefore is deemed **slight** for herring and sandeel, which is not significant in EIA terms.

3.11.2.42 The magnitude of impact on shellfish receptors from increased hard substrate and structural complexity from the introduction of infrastructure such as foundations and scour protection has been assessed as **minor**, with the sensitivity assessed as **low** for all shellfish receptors. This could result in a neutral or slight effect (as per the matrix in Table 3.13). Therefore, taking into account the broad distribution of these species across the study area, the significant of effect to deemed to be **neutral**, which is not significant in EIA terms.

Direct disturbance resulting from maintenance during operation (FSE-O-10)

3.11.2.43 Direct disturbance is likely to occur during the operational phase of Hornsea Four as a result of major repairs within the array (including jack-up operations, cable repairs, and repairs to OSSs and accommodation platforms), along the cable corridor (cable reburial, protection replacement and cable repairs), and repairs to the HVAC booster stations.

Magnitude of impact

3.11.2.44 The maximum area of disturbance to subtidal habitat will arise from cable repair during the operation and maintenance phase of the development (including de-burial and re-burial of export and array cables). A total of up to 8,579,812 m^2 of temporary habitat disturbance is predicted to arise over the 35-year design life of Hornsea Four (equating to approximately 0.2% of the Hornsea Four fish and shellfish study area). Given that the habitats are common and widespread throughout the region impacts from the individual O&M activities will represent a very small footprint compared to their overall extent.

3.11.2.45 It is predicted that the impact has the potential to affect herring and sandeel receptors directly although will be of a localised extent. The nearshore section of the Hornsea Four ECC is located in proximity to areas of high intensity herring spawning activity (Figure 3.4 and Figure 3.6). The ECC and the HVAC booster station search area also overlap low intensity herring spawning grounds. Taking into consideration the proximity of herring spawning grounds to Hornsea Four, and the localised and short-term nature of the impact, the magnitude of impact from direct damage and disturbance, associated with the maintenance of Hornsea Four on herring is assessed as **minor** (adverse). The offshore section of the proposed Hornsea Four ECC and the array area are also located within preferred sandeel spawning and nursery habitats (Figure 3.5). However, the proportion of the preferred habitat within the fish and shellfish study area is considered small within the context of known sandeel habitats within the wider Southern North Sea. Considering the wide distribution of preferred sandeel spawning and nursery habitats across the Southern North Sea, and the short-term and localised nature of the impact, the magnitude of impact of direct damage and disturbance from maintenance activities of Hornsea Four on sandeel are considered to be **minor** (adverse).

3.11.2.46 Brown crab spawning grounds (Eaton et al. 2003) lie inshore of the array area and across the proposed ECC. Lobster overwintering grounds may also be located nearshore, close to the Humber Estuary (SMart Wind 2015a) however there is no direct overlap with the Hornsea Four fish and shellfish study area. *Nephrops* spawning grounds (Coull et al. 1998) overlap the proposed array area and extend further offshore across the central North Sea, and the proposed Hornsea Four ECC would also cross a large scallop ground (Cefas 2019) located along the Hornsea coast. Due to the commercial value and importance of scallop, brown crab, European lobster, *Nephrops* and common whelk to the region,

and proximity of key shellfish beds, spawning grounds and overwintering areas to the project, due consideration is given to the potential for impacts on these species from direct disturbance during maintenance activities. Taking this into account and the highly localised nature of the impact, the magnitude of effect on shellfish receptors is assessed as **minor** (adverse).

3.11.2.47 The effects from this impact on all other VERs and their respective spawning grounds are considered to be minimal due to their wide distribution throughout the Southern North Sea and mobile nature. Taking this into consideration and the localised nature of the impact, the magnitude of the impact on all other VERs is assessed as being **negligible** (adverse) at the array, the HVAC booster station search area and along the ECC. Irrespective of the sensitivity of the receptor, the significance of the impact on all other VERs is **not significant** as defined in the assessment of significance matrix (**Table 3.13**) and is therefore not considered further in this assessment.

Sensitivity of the receptor

3.11.2.48 The sensitivity of receptors to direct damage and disturbance are discussed in detail in **paragraph 3.11.1.4** *et seq.* The receptors affected by this impact during the operational phase would be largely restricted to those at discrete sections of the ECC. The receptors most likely to be affected are demersal spawning fish species and shellfish species whose life strategies are strongly connected to the use of the seabed for shelter (i.e., through burrowing) or for reproduction (e.g., herring and sandeel spawn eggs onto the seabed). Herring and sandeel were both deemed to be of high vulnerability, with medium recoverability, and of regional importance in the Southern North Sea and are therefore considered to be of **high** sensitivity.

3.11.2.49 Brown crab, scallop, *Nephrops* and common whelk had medium to high vulnerability, higher recoverability and local to regional importance, and therefore were assessed as having **medium** sensitivity. European lobster were deemed to be of medium vulnerability, high recoverability and of regional importance, and were therefore considered to be of **low** sensitivity to direct disturbance from maintenance activities.

Significance of the effect

3.11.2.50 Overall, the magnitude of the impact has been assessed as **minor** for both herring and sandeel, with the sensitivity of herring and sandeel being assessed as **high**. The high sensitivities and minor magnitude of the impact could result in either a slight or moderate effect (as per the matrix in **Table 3.13**), however, taking into account the localised and temporary nature of the impacts, and the small area of direct impact compared to the overall extent of the herring and sandeel spawning grounds, and the application of expert opinion (including for the reasoning stated in the construction phase assessment at paragraph **3.11.1.15**) the significance of effect therefore is deemed to be **slight** for herring and sandeel from the array, the ECC and the HVAC booster station, which is not significant in EIA terms.

3.11.2.51 The magnitude of the impact on shellfish receptors was assessed as **minor** from the array, the ECC and the HVAC booster station. The sensitivity of brown crab, scallop and *Nephrops* to direct disturbance was assessed as **medium**. The medium sensitivities and minor magnitude of the impact could result in either a slight or moderate effect (as per

the matrix in Table 3.13), however, taking into account the extensive distribution of these species along the coasts of the UK, and the small degree of overlap of Hornsea Four with identified shellfish resources and spawning grounds, it is concluded that the effect will be of **slight** effect, which is not significant in EIA terms.

3.11.2.52 The sensitivity of European lobster to direct disturbance was assessed as being **low** which could result in either a neutral or slight effect. Considering the broad distribution of the species along UK coasts, and the temporary and localised nature of the impacts, the significance of effect is deemed to be of **neutral** significance, which is not significant in EIA terms.

3.11.3 Decommissioning

3.11.3.1 The impacts of the offshore operation and maintenance of Hornsea Four have been assessed on fish and shellfish ecology. The environmental impacts arising from the decommissioning of Hornsea Four are listed in Table 3.10.

Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from decommissioning activities (FSE-D-13)

3.11.3.2 Direct damage and disturbance from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to direct damage and disturbance are detailed in paragraph 3.11.1.4 *et seq*.

3.11.3.3 To summarise, the magnitude of the impact on herring and sandeel has been assessed as **minor** (adverse) for impacts at the array, the ECC and the HVAC booster station, with the sensitivity of the receptor being **high**. The high sensitivity and minor magnitude of the impact could result in either a slight or moderate effect (as per the matrix in Table 3.13), however, taking into account the temporary and localised nature of the impact, the small area of direct impact compared to the overall extent of the herring and sandeel spawning grounds across the Southern North Sea, and the application of expert opinion, the significance of effect therefore is deemed **slight** for herring and sandeel from the locations, which is not significant in EIA terms.

3.11.3.4 The magnitude of impact on shellfish receptors was deemed to be **minor** (adverse) from the array, the ECC and the HVAC booster station. The sensitivity was assessed as **medium** for brown crab, scallop, *Nephrops* and common whelk, and **low** for lobster. The **medium** sensitivities and **minor** magnitude of the impact on the shellfish receptors (excluding lobster) could result in either a slight or moderate effect (as per the matrix in Table 3.13); for lobster, the **low** sensitivity and **minor** magnitude results in either a neutral or slight effect. Taking into account extensive distribution of these species along the coasts of the UK, the small degree of overlap of Hornsea Four with identified shellfish resources and spawning grounds, and the localised nature of the impact, it is concluded that the effect will be of **slight** significance for all receptors, which is not significant in EIA terms.

3.11.3.5 The magnitude of impact on all other VERs and their respective spawning grounds was assessed as being **negligible** (adverse), on account of their broad distribution across the southern North Sea, and the localised and temporary nature of the impact. Therefore, the potential for impact from direct damage and disturbance on these receptors was not considered further in the assessment as it will not lead to a significant effect.

Temporary localised increases in SSC and smothering (FSE-D-14)

3.11.3.6 Increases in SSC and sediment deposition from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to increased SSC and sediment deposition are described in detail in **paragraph 3.11.1.17** *et seq.*

3.11.3.7 The magnitude of the impact on herring and sandeel has been assessed as **minor** (adverse) for impacts at the array, the ECC and the HVAC booster station search area and along the ECC, with the maximum sensitivity of the receptors being **high**. The **high** sensitivity for herring l and **minor** magnitude of the impact could result in either a slight or moderate effect (as per the matrix in **Table 3.13**); for sandeel, the **low** sensitivity and **minor** magnitude could result in either a neutral or slight effect. Taking into account the short term and localised nature of the impact, and the tolerance of herring and sandeel eggs to this impact, and the application of expert opinion (taking into consideration the reasoning detailed in the construction phase assessment) the significance of effect from changes in SSC and associated sediment deposition occurring as a result of decommissioning activities in the subtidal and intertidal area has a maximum of **slight** significance of effect for both species, which is not significant in EIA terms.

3.11.3.8 The magnitude of the impact on shellfish receptors was assessed as **minor** (adverse) from the array, the ECC and the HVAC booster station. The maximum sensitivity was assessed as **medium** (for brown crab, European lobster and scallop). The medium sensitivities and minor magnitude of the impact on the shellfish receptors could result in either a slight or moderate effect (as per the matrix in **Table 3.13**). Considering the short term and localised nature of the impact and the tolerance of the shellfish receptors to the impact, the significance of effect from changes in SSC and associated sediment deposition occurring as a result of decommissioning activities is deemed to be of a **slight** significance of effect, which is not significant in EIA terms.

3.11.3.9 The magnitude of the impact on all other VERs was assessed as **minor (**adverse) from the array and the HVAC booster station, with a maximum sensitivity assessed as **low**. This could result in either a neutral or slight significance of effect (as per the matrix in **Table 3.13**). Taking into account the broad distribution of the species across the study area, and the small degree of impact in the context of the spawning grounds the significance of effect is deemed to be of **neutral** significance, which is not significant in EIA terms.

Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-D-15)

3.11.3.10 Direct and indirect disturbances of the seabed from the decommissioning works, leading to the release of sediment contaminants will be similar to that for construction and are of a similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to the release of sediment contaminants are described in detail in **paragraph 3.11.1.44** *et seq.*

3.11.3.11 To summarise, re-suspended sediments as a result of decommissioning activities are expected to be deposited in the immediate vicinity of the works, with the potential release of sediment bound contaminants likely to be rapidly dispersed with the tide and/ or currents. Contaminant levels found within the Hornsea Four study area were all comparable to the wider regional background, and therefore the magnitude of the impact has been assessed as **negligible (**adverse) for all receptors. Irrespective of the sensitivity of the receptor, the significance of the impact on all receptors is **not significant** as defined in the assessment of significance matrix (**Table 3.13**) and is therefore not considered further in this assessment.

Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-D-16)

3.11.3.12 Decommissioning of offshore infrastructure for Hornsea Four may result in temporarily elevated underwater noise levels which may have effects on fish and shellfish species, with subsequent effects on spawning and nursery habitats. These elevated noise levels may be due to increased vessel movements and removal of the turbine foundations with the resulting noise levels dependant on the method used for removal of the foundation. The decommissioning sequence will generally be the reverse of the construction sequence and involve similar types and numbers of vessels and equipment. As detailed in **Volume A4, Annex 4.5, Subsea Noise Technical Report**, the maximum levels of underwater noise during decommissioning would be from underwater cutting required to remove structures, with piled foundations cut approximately 1 m below the seabed. The noise levels from this process are expected to be much less than pile driving and therefore impacts would be less than as assessed during the construction phase (**paragraph 3.11.1.54** *et seq*).

3.11.3.13 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 local marine animals. Some temporary minor disturbance might be experienced in the immediate vicinity of the decommissioning activity, for example, from dynamically positioned (DP) vessels. The impact is predicted to be of highly local spatial extent, short term duration, intermittent and reversible. Based on the information available at the time of writing, and due to the localised spatial extent, the expected magnitude is considered to be **negligible (**adverse) for all receptors. Irrespective of the sensitivity of the receptor, the significance of the impact on all receptors is **not significant** as defined in the assessment of significance matrix (**Table 3.13**) and is therefore not considered further in this assessment.

3.12 Cumulative effect assessment (CEA)

3.12.1.1 Cumulative effects can be defined as effects upon a single receptor from Hornsea Four when considered alongside other proposed and reasonably foreseeable projects and developments. This includes all projects that result in a comparative effect that is not intrinsically considered as part of the existing environment and is not limited to offshore wind projects.

3.12.1.2 A screening process has identified several reasonably foreseeable projects and developments which may act cumulatively with Hornsea Four. The full list of such projects that have been identified in relation to the offshore environment are set out in **Volume A4, Annex 5.3: Offshore Cumulative Effects** and are presented in a series of maps within **Volume A4, Annex 5.4: Location of Offshore Cumulative Schemes**.

3.12.1.3 The CEA methodology undertaken is detailed in **Volume A4, Annex 5.3: Offshore Cumulative Effects**; as part of the assessment all projects and plans considered alongside Hornsea Four have been allocated into 'tiers' reflecting their current stage within the planning and development process, these are listed in **Table 3.18** below.

Table 3.18: Description of tiers of other developments considered for CEA (adapted from PINS Advice Note 17).

Tier 1	Project under construction.
	Permitted applications, whether under the Planning Act 2008 or other regimes, but not yet implemented.
	Submitted applications, whether under the Planning Act 2008 or other regimes, but not yet determined.
Tier 2	Projects on the Planning Inspectorate's Programme of Projects where a Scoping Report has been submitted.
Tier 3	Projects on the Planning Inspectorate's Programme of Projects where a Scoping Report has not been submitted.
	Identified in the relevant Development Plan (and emerging Development Plans with appropriate weight being given as they move closer to adoption) recognising that much information on any relevant proposals will be limited.
	Identified in other plans and programmes (as appropriate) which set the framework for future development consents/approvals, where such development is reasonably likely to come forward.

3.12.1.4 The plans and projects selected as relevant to the CEA of impacts to fish and shellfish ecology are based on an initial screening exercise undertaken on a long list (see **Volume A4, Annex 5.3: Offshore Cumulative Effects**). A consideration of effect-receptor pathways, data confidence and temporal and spatial scales has been given to select projects for a topic-specific short-list. For all potential effects for fish and shellfish ecology excluding underwater noise, planned projects were screened into the assessment based on a 10 km screening range surrounding the array, and a 14 km range around the offshore ECC (**Figure 3.22**), representing the tidal excursion. For the impact of underwater noise, a larger search area was used (100 km), as noise is predicted to have a greater area of effect than the other effects identified.

3.12.1.5 The specific projects scoped into the cumulative effects assessment for fish and shellfish ecology, as well as the tiers into which they have been allocated are presented in **Table 3.19** below, and shown in **Figure 3.22** (tidal excursion buffer) and **Figure 3.23** (100 km noise buffer). Note that this table only includes the projects screened into the

assessment for fish and shellfish ecology based on the criteria outlined above. For the full list of projects considered, including those screened out, please see **Volume A4, Annex 5.3: Offshore Cumulative Effects**.

Table 3.19: Projects screened into cumulative assessment.

Tier	Project/plan	Details/ relevant dates	Distance to Hornsea Four Array (km)	Distance to Hornsea Four ECC (km)	Distance to Hornsea Four HVAC Booster Area (km)	Reason for inclusion in CEA
1	Bridlington A Disposal Site	Site in operational phase	72.14	2.69	28.59	Part of the baseline but has an ongoing impact and is therefore considered relevant to the cumulative impact assessment.
1	Hornsea Project Two Offshore Wind Farm	Under construction, expected completion in 2022	3.46	10.61	67.23	Potential cumulative impact exists. Development not included as part of baseline, and therefore to be considered in cumulative assessment.
1	Hornsea Project Three Offshore Wind Farm	Consented 2020, with construction anticipated 2027-2028	46.47	60.28	116.91	Potential cumulative impact exists. Temporal overlap, with construction.
1	Sofia Offshore Wind Farm	Consented 2015, with construction anticipated 2021-2024	97.75	114.01	144.05	Potential cumulative impact exists. Temporal overlap, with construction.
1	Dogger Bank A Offshore Wind Farm	Consented 2015, with construction anticipated 2021-2024	65.86	83.83	108.33	Potential cumulative impact exists. Temporal overlap, with construction.
1	Dogger Bank B Offshore Wind Farm	Consented 2015, with construction anticipated 2021-2024	76.14	94.43	112.01	Potential cumulative impact exists. Temporal overlap, with construction.
2	Dudgeon Extension	PEIR published, construction expected 2026	69.49	69.48	92.80	Potential cumulative impact exists. Temporal overlap, with construction.
2	Sheringham Shoal Extension	PEIR published, construction expected 2026	83.60	82.32	100.68	Potential cumulative impact exists. Temporal overlap, with construction.
1	Viking Link Interconnector cable	Under construction, expected completion in 2023	1.98	4.04	42.23	Potential cumulative impact exists. Development not included as part of baseline,

Tier	Project/plan	Details/ relevant dates	Distance to Hornsea Four Array (km)	Distance to Hornsea Four ECC (km)	Distance to Hornsea Four HVAC Booster Area (km)	Reason for inclusion in CEA
						and therefore to be considered in cumulative assessment.
3	Scotland England Green Link 2 (SEGL2)	Pre-planning, planning application expected 2022, construction expected 2025	53.53	0.15	16.12	Potential cumulative impact exists. Temporal overlap, with construction.
1	Dana Petroleum Platypus pipeline	Consented 2019, with construction anticipated 2020-2022	17.01	0.00	20.56	Potential cumulative impact exists. Development not included as part of baseline, and therefore to be considered in cumulative assessment.
1	Dogger Bank A Export Cable	Consented 2015, with construction anticipated 2021-2024	28.88	0.00	9.16	Potential cumulative impact exists. Temporal overlap, with construction.
1	Dogger Bank B Export Cable	Consented 2015, with construction anticipated 2021-2024	28.88	0.00	9.16	Potential cumulative impact exists. Temporal overlap, with construction.
1	Hornsea Project Two Offshore Wind Farm export cable	Consented 2019, with construction 2020-2022	9.30	13.67	54.14	Potential cumulative impact exists. Development not included as part of baseline, and therefore to be considered in cumulative assessment.
1	Johnston WHPS	Operational with decommissioning- 2021-2031(onwards)	0.00	2.83	57.79	Potential cumulative impact exists. Temporal overlap, with decommissioning.
1	Johnston template/manifold	Operational with decommissioning- 2021-2031(onwards)	0.00	2.86	51.65	Potential cumulative impact exists. Temporal overlap, with decommissioning.
1	Tolmount Platform	Consented 2018, with construction commenced in 2020, anticipated to be operational during	35.36	1.46	3.98	Potential cumulative impact exists. Development not included as part of baseline, and therefore to be considered in cumulative assessment.

Tier	Project/plan	Details/ relevant dates	Distance to Hornsea Four Array (km)	Distance to Hornsea Four ECC (km)	Distance to Hornsea Four HVAC Booster Area (km)	Reason for inclusion in CEA
		Hornsea Four construction.				
3	Endurance Carbon Capture and Storage (CCS)	Not consented: It is expected that construction activities will commence in early 2023 with operations commencing in 2026.	0.00	2.15	18.78	Temporal overlap of operational activity with Hornsea Four construction. Development not included as part of baseline, and therefore to be considered in cumulative assessment.

3.12.1.6 The cumulative MDS described in **Table 3.20** have been selected as those having the potential to result in the greatest cumulative effect on an identified receptor group. The cumulative impacts presented and assessed in this section have been selected from the details provided in the project description for Hornsea Four (summarised for fish and shellfish ecology in **Table 3.10**, as well as the information available on other projects and plans in order to inform a cumulative maximum design scenario. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project design envelope to that assessed here, be taken forward in the final design scheme.

3.12.1.7 The following impacts assessed for the project alone are not considered in the cumulative assessment due to:

- The highly localised nature of the impacts (i.e. they occur entirely within the Hornsea Four boundary only);
- Management measures in place for Hornsea Four will also be in place on other projects reducing their risk of occurring; and/or
- Where the potential significance of the impact from Hornsea Four alone has been assessed as negligible.

3.12.1.8 The impacts excluded from the CEA for the above reasons are:

- Direct and indirect seabed disturbances leading to the release of sediment contaminants (construction phase) (FSE-C-3): the potential significance of the impact from Hornsea Four alone has been assessed as negligible;
- Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities (FSE-C-1): any effects from this impact are predicted to be high localised and to occur within the Hornsea Four boundary; and
- Direct disturbance resulting from maintenance during operation (FSE-O-10): any effects from this impact are predicted to be high localised and to occur within the Hornsea Four boundary.

3.12.1.9 Therefore, the impacts that are considered in the CEA are as follows:

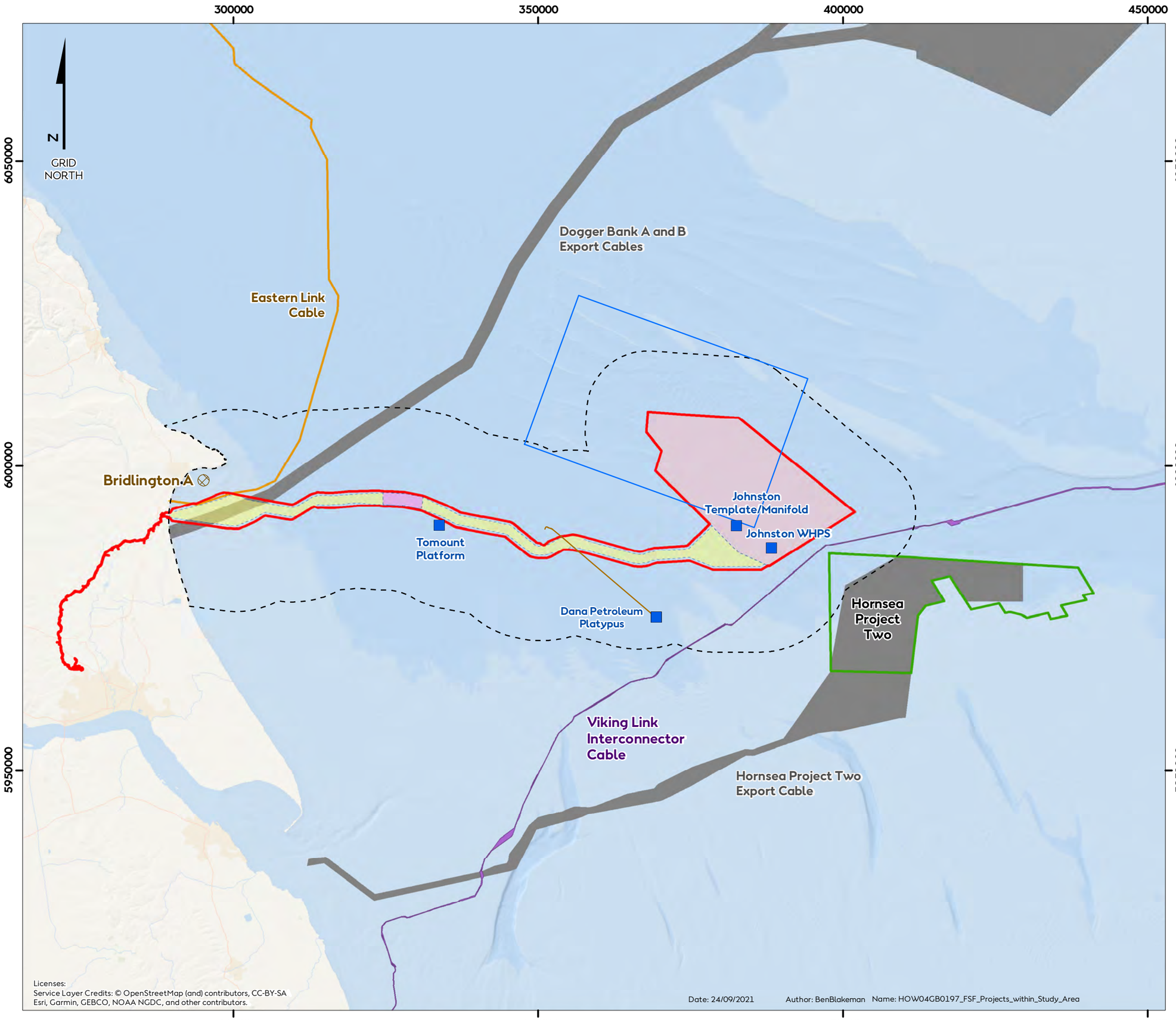
- Temporary localised increases in SSC and smothering (construction phase (FSE-C-2) and operation and maintenance phase (FSE-O-18));
- Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (construction phase) (FSE-C-4);
- Long term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (operation phase) FSE-O-6); and
- Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection (operation phase) (FSE-O-7).

3.12.1.10 The projects considered in this cumulative impact assessment are illustrated in **Figure 3.22** and **Figure 3.23** below.

Hornsea Four

Figure 3.22

The projects screened into the cumulative impact assessment within the tidal ellipse buffer (10 km surrounding the array, and 14 km around the ECC)



- Fish and Shellfish Study Area
- Order Limits
- Array Area
- HVAC Booster Station Works Area
- Offshore Export Cable Corridor
- Disposal Site
- Viking Link Interconnector Cable
- Endurance Carbon Capture and Storage Area
- Hornsea Project Two OWF (Consented)
- Offshore Wind Farm Export Cable
- Oil and Gas Subsea Structure
- Dana Petroleum Platypus Pipeline
- Scotland England Green Link 2 (SEGL2)

Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:600,000

0 10 20 Kilometres

0 5 10 Nautical Miles

REV	REMARK	DATE
...	First Issue	24/09/2021

Projects screened within Study Area
Document no: HOW04GB0197
Created by: BPHB
Checked by: AL
Approved by: LK

GoBe
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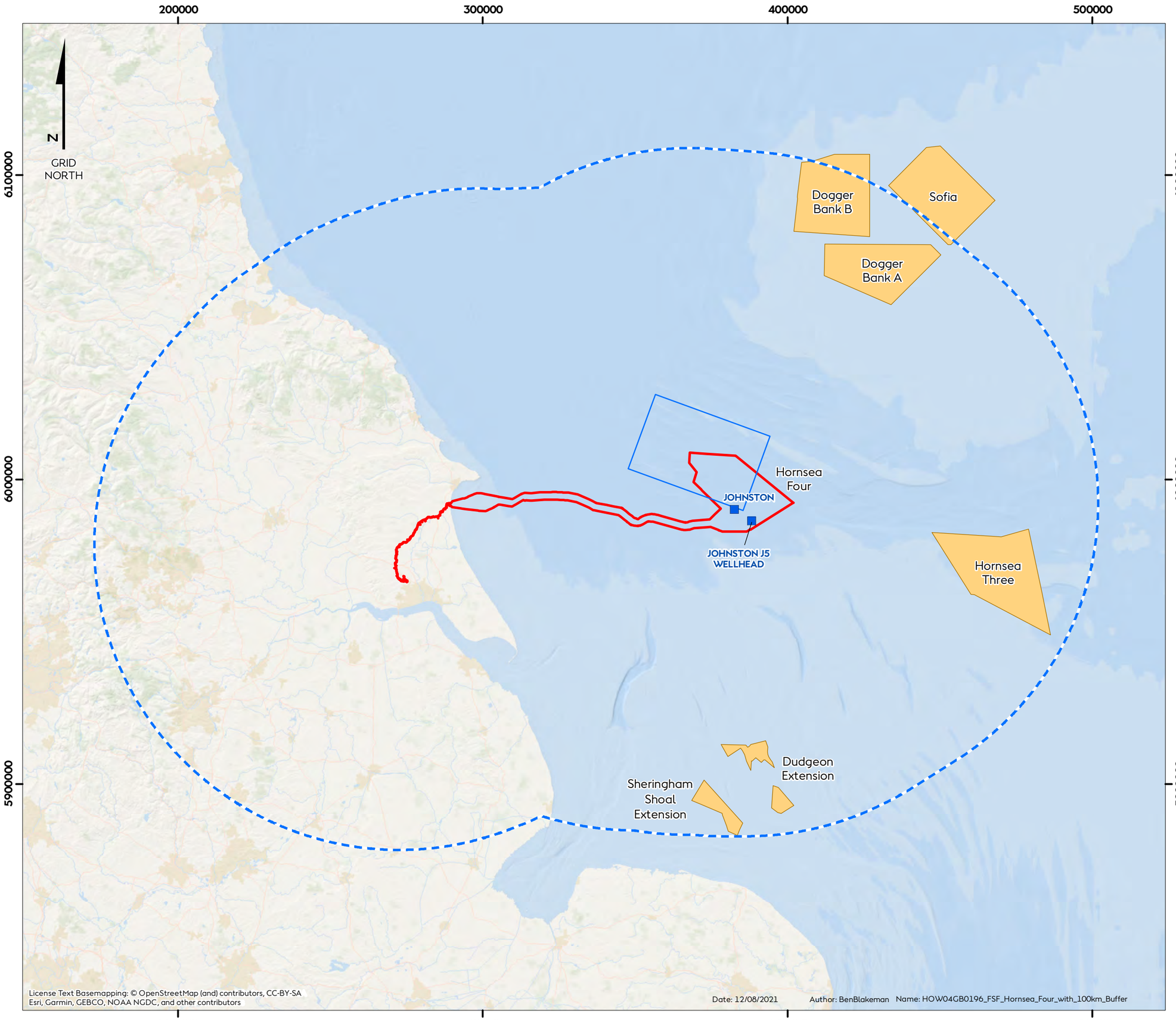
Date: 24/09/2021 Author: BenBlakeman Name: HOW04GB0197_FSF_Projects_within_Study_Area

Hornsea Four

Figure 3.23

The projects screened into the cumulative impact assessment within a 100 km buffer of Hornsea Four



- Order Limits
- 100km Buffer from Hornsea Four
- Endurance Carbon Capture and Storage Area
- Offshore Wind Farm
- Oil and Gas Subsea Structure

Coordinate system: ETRS 1989 UTM Zone 31N

Scale@A3: 1:1,200,000

0 25 50 Kilometres

0 10 20 Nautical Miles

REV	REMARK	DATE
...	First Issue fo PEIR	17/06/2019
A	Updated following PEIR consultations, for DCO	12/08/2021

Hornsea Four with
100km Buffer
Document no: HOW04GB0196
Created by: BPHB
Checked by: AL
Approved by: LK

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Table 3.20: Cumulative MDS.

Project Phase	Potential Impact	Maximum Design Scenario	Justification
Construction	Temporary localised increases in SSC and smothering	Maximum design scenario for Hornsea Four plus the cumulative full development of the following projects with the Hornsea Four study arear: **Tier 1:** -Disposal site (Bridlington A); -Operation and maintenance of offshore wind farms (Hornsea Project Two); -Cables and pipelines under construction (Dogger Bank A and Dogger Bank B export cables); -Maintenance of operational interconnector cables (Viking Link); -Maintenance of oil and gas pipelines (Dana Petroleum Platypus); -Operational oil and gas platform (Tolmount Platform); and -Decommissioning of oil and gas infrastructure (Johnston WHPS, Johnston template/manifold). **Tier 2:** No Tier 2 projects identified. **Tier 3:** -Operation and maintenance of Endurance CCS. -Construction of Scotland England Green Link 2 (SEGL2)	Maximum cumulative increases in SSC and smothering is calculated within a representative buffer of Hornsea Four to represent the maximum distance sediments may travel in one tidal excursion.
Construction	Mortality, injury, behavioural changes and auditory masking arising from noise and vibration	Maximum design scenario for Hornsea Four plus the cumulative full development of the following projects within 100 km of Hornsea Four: **Tier 1:** -Wind farm projects under construction (Sofia, Hornsea Three, Dogger Bank A and Dogger Bank B); and - Decommissioning of oil and gas infrastructure (Johnston WHPS, Johnston template/manifold). **Tier 2:** -Wind farm projects under construction (Dudgeon and Sheringham Shoal Extensions). **Tier 3:** -Operation and maintenance of Endurance CCS.	Maximum potential for interactive effects from underwater noise associated with offshore wind farm piling activities is considered within a representative 100 km buffer of the Hornsea Four array area. This buffer was chosen as underwater noise effects are expected to occur over a wider area than other impacts.
Operation	Temporary localised increases in SSC and smothering	Maximum design scenario for Hornsea Four plus the cumulative full development of the following projects with the Hornsea Four study arear: **Tier 1:**	Maximum cumulative increases in SSC and smothering is calculated within a representative buffer of Hornsea Four to

Project Phase	Potential Impact	Maximum Design Scenario	Justification
		-Disposal site (Bridlington A); -Operation and maintenance of offshore wind farms (Hornsea Project Two); -Maintenance of operational export cables (Hornsea Project Two, Dogger Bank A and Dogger Bank B); -Maintenance of interconnector cables (Viking Link); -Maintenance of oil and gas pipelines (Dana Petroleum Platypus); -Operational oil and gas platforms (Tolmount Platform); and -Decommissioning oil and gas infrastructure (Johnston WHPS, Johnston template/manifold). **Tier 2:** No Tier 2 projects identified. **Tier 3:** -Operation and maintenance of Endurance CCS. -Maintenance of interconnector cables (Scotland England Green Link 2 (SEGL2))	represent the maximum distance sediments may travel in one tidal excursion.
Operation	Long term loss of habitat due to the presence of turbine foundations, scour protection and cable protection	Maximum design scenario for Hornsea Four plus the cumulative full development of the following projects with the Hornsea Four study arear: **Tier 1:** -Operation and maintenance of offshore wind farms (Hornsea Project Two); -Maintenance of operational export cables (Hornsea Project Two, Dogger Bank A and Dogger Bank B); -Maintenance of interconnector cables (Viking Link); -Maintenance of oil and gas pipelines (Dana Petroleum Platypus); and -Operational oil and gas platforms (Tolmount Platform). **Tier 2:** No Tier 2 projects identified. **Tier 3:** -Operation and maintenance of Endurance CCS. -Maintenance of interconnector cables (Scotland England Green Link 2 (SEGL2))	Maximum cumulative habitat loss is calculated within a representative buffer of Hornsea Four as habitats within this buffer are representative of those within the Hornsea Four fish and shellfish study area.
Operation	Increased hard substrate and structural complexity as a result of the introduction of	Maximum design scenario for Hornsea Four plus the cumulative full development of the following projects with the Hornsea Four study arear: **Tier 1:**	Maximum cumulative increase in hard substrate and structural complexity is calculated within a representative buffer of Hornsea Four as habitats within this buffer are

Project Phase	Potential Impact	Maximum Design Scenario	Justification
	turbine foundations, scour protection and cable protection	-Operation and maintenance of offshore wind farms (Hornsea Project Two); -Maintenance of operational export cables (Hornsea Project Two, Dogger Bank A and Dogger Bank B); -Maintenance of interconnector cables (Viking Link); -Maintenance of oil and gas pipelines (Dana Petroleum Platypus); and -Operational oil and gas platforms (Tolmount Platform). **Tier 2:** No Tier 2 projects identified. **Tier 3:** -Operation and maintenance of Endurance CCS. -Maintenance of interconnector cables (Scotland England Green Link 2 (SEGL2))	representative of those within the Hornsea Four fish and shellfish study area.

3.12.1.11 A description of the significance of cumulative effects upon fish and shellfish ecology arising from each identified impact is given below. The cumulative effects assessment has been based on information available in Environmental Statements and it is noted that the project parameters quoted within Environmental Statements are often refined during the determination period and in the post-consent phase. The assessment presented here is therefore considered to be conservative, with the level of impacts expected to be reduced compared to those presented here.

3.12.2 Construction Phase

Temporary localised increases in SSC and smothering

Tier 1

3.12.2.1 There is potential for cumulative increases in SSC and associated sediment deposition as a result of construction activities associated with Hornsea Four and other projects (**Table 3.20** and **Figure 3.22**). For the purposes of this assessment, this additive impact has been assessed within 10 km of the Hornsea Four array area, and 14 km of the offshore ECC, which is representative of the maximum tidal excursion in the area, and therefore the furthest distance sediments can travel from the site. The projects identified in this Tier are the Bridlington A disposal site, the Hornsea Project Two offshore wind farm, the Dogger Bank A and B export cables, the Viking Link interconnector cable, the Dana Petroleum Platypus pipeline, the Tolmount Platform and the Johnston WHPS and Johnston Template/Manifold oil and gas infrastructure.

3.12.2.2 The Bridlington A disposal site (HU015) is located 2.69 km from the Hornsea Four ECC. The disposal site is used for the disposal of maintenance material from the port of Bridlington. The maximum quantity that is currently authorised for disposal in any one year is 30,000 tonnes, with the use of the site being relatively infrequent and on demand. Material deposited at HU015 varies in composition but is generally a mixture of fine sands and silts and can therefore be expected to move by both wave and tidal currents.

3.12.2.3 It is not known what volumes of sediment will be deposited at Bridlington A disposal site at any one time, and as the use of these sites is intermittent, it is not possible to determine if the use of these sites will overlap with sediment deposition from the construction phase of Hornsea Four. If Hornsea Four is discharging overspill of fine silts and sands in the nearshore from cable trenching by CFE on an ebb tide period at the same time as spoil disposal is occurring at HU015 then a larger sediment plume may form, however, this will also quickly disperse given the location of the spoil site in an area of faster flows.

3.12.2.4 Hornsea Project Two is located 3.46 km to the southeast of the Hornsea Four array area at its nearest point. The construction of Hornsea Project Two will cease in 2022 and therefore there will be no cumulative impact from construction activities within the array area and along the export cable corridor. However, there is the potential for cumulative impacts from cable works in the operational phase of the development. Remedial cable works are predicted to be short-term, intermittent, small scale and localised to the site. Taking this into consideration, there is not predicted to be any cumulative effects from the operational phase of Hornsea Project Two.

3.12.2.5 The Dogger Bank A and B ECCs are proposed to cross the Hornsea Four ECC in the nearshore section, running 9.16 km from the Hornsea Four HVAC booster station search area. The final year of construction, and the operational phase of both export cables will potentially coincide with the construction of Hornsea Four. The maximum volume of material displaced from the construction of the Dogger Bank A and B export cable will be approximately 502,000 m^3 (MDS for increased SSC) (Forewind 2013). Cumulatively with Hornsea Four this may result in the disturbance and deposition of up to 12,791,318 m^3 of sediment. However, it should be noted that the total volume of material displaced for the Dogger Bank A and B ECC construction accounts for the construction of the entire ECC, whilst only 29% of the Dogger Bank A and B ECC actually intersects with the Hornsea Four fish and shellfish study area, therefore the maximum amount of sediment released cumulatively with Hornsea Four will be considerably less. It should also be noted that the worst case scenario for the projects (Hornsea Four, Dogger Bank A and B) assumes that the whole volume of sediment from the excavated trenches for the export cables is released for dispersion regardless of the extraction method used and therefore the amount that is actually released is likely to be of a lower volume. Any cable maintenance repairs undertaken within the operational phase of the developments will also be short term, intermittent and localised to the site and therefore any cumulative impacts are expected to be minimal. Additionally, due to the naturally dynamic environment of the site, any sediment released from these operations during the construction and operational phases of the development will likely be dispersed in the faster flows. Therefore, taking this into consideration, there are not predicted to be any significant cumulative impacts from the construction or operation of the Dogger Bank A and B export cables.

3.12.2.6 The consented Viking Link interconnector cable is proposed to pass to the south of the Hornsea Four array area by 1.98 km. The cable is anticipated to be under construction from 2020 to 2023, and the Hornsea Four offshore wind farm is not scheduled for construction until 2024. The consented Dana Petroleum Platypus pipeline is proposed to cross the Hornsea Four ECC. The pipeline is under construction from 2020 to 2022, and the Hornsea Four offshore wind farm is not scheduled for construction until 2024. Therefore, there will be no temporal overlap of the construction between the developments, and consequently limited cumulative effects from increased SSC and deposition. Any maintenance activities undertaken on the Viking Link interconnector cable and the Dana Petroleum Platypus pipeline during the operational phase will be intermittent, with any increases in SSC and deposition expected to be minimal, short term and localised to the site, therefore no significant cumulative effects are predicted from maintenance of the Viking Link Interconnector cable and the Dana Petroleum Platypus pipeline and the construction of Hornsea Four.

3.12.2.7 Construction commenced on the Tolmount Platform in 2020, with the platform planned to be operational during the construction phase of Hornsea Four. The majority of the impacts from the platform are associated with the construction phase, with any activities association with the operation and maintenance of the platform occurring within a closed system. Therefore, there are not considered to be any cumulative effects from the operational phase of the Tolmount Platform with Hornsea Four.

3.12.2.8 The Johnston WHPS and Johnston template/manifold wellhead structures are proposed to begin decommissioning in 2022, with the process continuing through the proposed six-year construction period for Hornsea Four (2024 -2029). In the absence of an ES for these

projects, the Tolmount Platform ES (Premier Oil 2017) has been used to inform this assessment on the decommissioning of wellhead structures. Wellhead structures comprise a subsea steel lattice structure, which are typically cut below the level of the seabed and removed during decommissioning, with the remnants of the structure (below the seabed) abandoned. Given the small area of disturbance to the seafloor during this procedure, it is considered unlikely that there will be a cumulative impact from the increase in SSC and deposition from the decommissioning of the Johnston WHPS and Johnston template/manifold wellhead structures and the construction of Hornsea Four.

3.12.2.9 Cumulative effects can also be considered in terms of duration of exposure from multiple projects which do not overlap but happen consecutively. However, as the effects from the projects will be short-lived, there are likely to be significant temporal gaps between the discrete construction events, which will have localised effects. Due to the lack of significant effects identified in **Section 3.11**, and the tolerance of fish and shellfish receptors to increases in SSC and sediment deposition, cumulative effects in terms of duration of exposure are not expected.

3.12.2.10 The cumulative impacts of increased SSC and sediment deposition are expected to be of local spatial extent, short-term duration, intermittent and reversible. The magnitude of impacts from the Tier 1 sites identified is therefore considered to be **minor** (adverse).

3.12.2.11 Full discussion of the sensitivity of fish and shellfish to increased SSC and sediment deposition is presented in **paragraphs 3.11.1.27** *et seq.* which conclude that some species have relatively high vulnerability to increased SSC and deposition. The maximum sensitivity of receptors in the area is therefore assessed as **high**, with a **minor** magnitude of impact; this could result in either a slight or moderate effect (in accordance with **Table 3.13**). Taking into consideration the localised and short-term nature of the impact, and the likely rapid resuspension of any deposited sediment by natural water movement minimising any material sediment deposition anywhere outside of the immediate vicinity of the works, it is concluded that the significance of effect from an increase in SSC and deposition from the installation of Hornsea Four cumulatively, with the Tier 1 projects is **slight**, which is not significant in EIA terms.

Tier 3

3.12.2.12 The projects identified in this Tier are the Endurance CCS and the Scotland England Green Link 2 (SEGL2).

3.12.2.13 The Endurance CCS project could have the potential to create a cumulative temporary increase in SSC and smothering with Hornsea Four. Construction activities of pipelines, up to 30 wells and several platform structures are planned to commence in early 2023 with operation commencing in 2026, so whilst there will be no construction overlap, operation and maintenance activities will overlap with Hornsea Four construction. There is currently limited detail on the Endurance project and therefore it is not possible to make a detailed assessment of the significance of effect, however given that construction activities do not overlap and any temporary increases in SSC and smothering from operation and maintenance of Endurance is predicted to be minimal, short term and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

3.12.2.14 The SEGL2 cable could have the potential to create a cumulative temporary increase in SSC and smothering with Hornsea Four. Construction activities of the cable are planned to commence in 2025, with operations commencing by 2030 so both construction and operation and maintenance activities could overlap with Hornsea Four. There is currently limited detail on the SEGL2 and therefore it is not possible to make a detailed assessment of the significance of effect, however given that any temporary increases in SSC and smothering from construction or operation and maintenance of SEGL2 is predicted to be minimal, short term and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

Mortality, injury, behavioural changes and auditory masking arising from noise and vibration

Tier 1

3.12.2.15 There is potential for cumulative mortality, injury, behavioural changes and auditory masking from noise and vibration as a result of construction activities associated with Hornsea Four and other projects (**Table 3.19**). For the purposes of this assessment, this additive impact has been assessed within 100 km of Hornsea Four, which is considered the maximum extent of impacts from noise as highlighted in noise modelling undertaken as part of the EIA, detailed in **Section 3.11.1**.

3.12.2.16 The greatest risk of cumulative impacts of underwater noise on fish and shellfish species has been identified as being that produced by impact piling during the construction phase of other offshore wind farm sites within 100 km of Hornsea Four, and the decommissioning of the Johnston WHPS and Johnston template/manifold wellhead structures.

3.12.2.17 Injury or mortality of fish from piling noise and decommissioning activities would not be expected to occur cumulatively due to the small range within which potential injury effects would be expected (i.e. predicted to occur within tens to hundreds of metres of piling activity within each of the offshore wind farm projects) and the large distances between offshore wind farm projects, and the wellhead structures. Cumulative effects of underwater noise are therefore discussed in the context of behavioural effects, particularly on spawning or nursery habitats.

3.12.2.18 Piling operations will represent intermittent occurrences at these offshore wind farm sites with each individual piling event likely to be similar in duration to those at Hornsea Four. For Hornsea Four, the temporal MDS for piling duration is for piled jacket foundations for up to 180 WTGs, for up to four hours per pile (**Table 3.10**). For many other offshore wind farm projects monopile foundations have been assumed to represent the maximum design scenario.

3.12.2.19 It should be noted that the cumulative noise assessment has been based on information and assessments, where available, as presented in the respective Environmental Statements. Construction timescales, as outlined in **Table 3.19**, are indicative and subject to change.

3.12.2.20 For the purposes of this assessment the full length of the construction periods for all cumulative projects (i.e. 2024 to 2029 or six years) have been considered for potential cumulative effects due to a lack of data or information regarding the piling timescales for the Sofia Offshore Wind Farm, Dogger Bank A and B, and Hornsea Three, and the decommissioning of the Johnston WHPS and Johnston template/manifold wellhead structures.

3.12.2.21 Based on the MDS for piling duration at Hornsea Four and the MDS piling duration for Sofia Offshore Wind Farm, Dogger Bank A and B and Hornsea Three (**Table 3.21**), piling activities will occur over a maximum of 1,422 days, over six years, equating to approximately 65% of the cumulative construction period. This is considered to be highly precautionary, however, since the duration of piling events is likely to be shorter, in most cases, and simultaneous piling operations (between and within offshore wind farm sites) will also result in a reduction in the total piling duration. The construction periods for the Sofia Offshore Wind Farm, Dogger Bank A and B, and Hornsea Three are also likely to include the combination of onshore and offshore construction periods and as such the projects may, in reality, not overlap temporally with the construction period of Hornsea Four.

3.12.2.22 The Johnston WHPS and Johnston template/manifold wellhead structures are proposed to begin decommissioning in 2022, with the process continuing through the proposed six-year construction period for Hornsea Four (2024 -2029). In the absence of an ES for these projects, the Tolmount Platform ES (Premier Oil 2017) has been used to inform this assessment on the decommissioning of wellhead structures. Wellhead structures comprise a subsea steel lattice structure, which are typically cut below the level of the seabed and removed during decommissioning, with the remnants of the structure (below the seabed) abandoned. These cutting activities result in noise emissions which are short term and intermittent, and as such the decommissioning activities may, in reality no overlap temporally with the construction of Hornsea Four.

Table 3.21: Cumulative piling durations for Hornsea Four and other offshore wind farms within a representative 100 km buffer of Hornsea Four (where construction occurs concurrently).

Project	Maximum design scenario for piling duration (hours)	Source
Tier 1 offshore wind farms		
Hornsea Four	3,326	Total piling duration for all infrastructure assuming 4.4 hours per pile (**Volume A1, Chapter 4: Project Description**).
Hornsea Three	7,392	Total piling duration taken from ES (Orsted 2018) for all infrastructure assuming four hours per pile.
Sofia Offshore Wind Farm	3,600	Total piling duration taken from ES (Forewind 2014) for all infrastructure.
Dogger Bank A	9,900	Total piling duration taken from ES (Forewind 2013) for all infrastructure.
Dogger Bank B	9,900	Total piling duration taken from ES (Forewind 2013) for all infrastructure.

Project	Maximum design scenario for piling duration (hours)	Source
Tier 1 offshore wind farms		
Total Tier 1	34,118 hours	

3.12.2.23 The following paragraphs describe the spatial extent of potential behavioural effects on fish and shellfish species, as described in the impact assessments for the Tier 1 offshore wind farms. Each of the impact assessments consider the MDS for hammer energy and/or the largest pile diameter and therefore result in the greatest propagation ranges. It should be noted, however, that the project specific assessments may have used behavioural response criteria which differ from the approach used for Hornsea Four and from the other projects in the cumulative assessment. The project specific assessments were undertaken using the best scientific evidence available at the time that the assessments were drafted. However, more recent papers on the effects of underwater noise on fish and shellfish species have highlighted the lack of clear evidence to support setting thresholds for impacts on fish and shellfish receptors (Hawkins and Popper 2016; Popper et al. 2014). These papers have highlighted some of the shortcomings of historic impact assessments, including the use of broad criteria for injury and behavioural effects based on limited studies. As such, it is not appropriate to make direct comparisons between the behavioural response ranges across projects, however the following paragraphs do give an indication of the extents of behavioural responses from fish and shellfish to support this cumulative assessment.

3.12.2.24 The Sofia offshore wind farm assessment (Forewind 2014) assessed the spatial MDS for noise impacts, of piling of jacket foundations using hammer energies of up to 2,300 kJ for up to 18 hours per jacket foundation (six piles per foundation, and three-hour piling duration). This assessment assumed a maximum of 200 turbines across the site and predicted behavioural effects in the ranges of 10 to 19.5 km for pelagic species and 7 to 15.5 km for demersal species at the 2,300 kJ hammer energy. The assessment predicted minor adverse effects on fish spawning and nursery habitats (specifically sandeel and herring spawning and nursery habitats). For herring this was due to the small proportion of historic spawning habitats affected; no effects were predicted in areas of recent spawning activity (e.g. the Banks spawning habitat at Flamborough Head). Underwater noise from piling was predicted to affect a small area of high density sandeel habitat, with no impacts on the high-density areas in the west of the Dogger Bank Zone.

3.12.2.25 The Hornsea Three assessment (Orsted 2018) assessed the spatial MDS from the piling of up to 319 monopiles, using hammer energies of up to 5,000 kJ, for up to four hours per foundation. The temporal MDS was predicted to result from the installation of up to 1,848 pin piles, for up to 319 jacket foundations, using a maximum hammer energy of 2,500 kJ. The assessment predicted minor adverse effects on fish spawning and nursery habitats (specifically herring spawning and nursery habitats). For herring this was due to the small proportion of historic spawning habitats affected (Hornsea Three does not overlap any key spawning grounds), and the site not representing a particularly important habitat for these species (e.g. for foraging). Minor adverse impacts were also predicted on whiting, sprat and cod, due to the occurrence of spawning grounds within the Hornsea Three array area and offshore ECC. However, in the context of the wider spawning grounds, the impacts were deemed to be small.

3.12.2.26 The Dogger Bank A and B assessment (Forewind 2013) assessed the spatial MDS for noise impacts, of piling of up to 300 turbines on jacket foundations (six piles per foundation, and a five and a half hour piling duration), using hammer energies of up to 3,000 kJ. The assessment predicted minor adverse effects on fish spawning and nursery habitats (specifically herring spawning and nursery habitats) for both Dogger Bank A and B. A minor adverse impact was also predicted for migratory species in the area, prey species (and impacts on feeding) and shellfish.

3.12.2.27 The decommissioning of the Johnston WHPS and Johnston template/manifold wellhead structures is proposed to be short term and intermittent, and as such any noise impacts from this activity on fish and shellfish receptors are deemed to be small.

3.12.2.28 The cumulative impact of underwater noise on fish and shellfish is predicted to be of regional spatial extent, medium term duration (i.e. cumulatively over approximately six years), intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor.**

3.12.2.29 Sensitivities of fish and shellfish receptors to underwater noise are fully detailed in **paragraph 3.11.1.54** *et seq*. Fish injury as a result of piling noise would only be expected in the immediate vicinity of piling operations, and the area within which effects on fish larvae would be expected is similarly small, though it is unclear whether effects on fish larvae would include injury or mortality. Effects on shellfish species are also predicted to be limited as these species are less sensitive to noise than fish species or would only be affected at ranges much less than those predicted for fish.

3.12.2.30 Behavioural effects on fish species as a result of piling noise are predicted to be dependent on the nature of the receptors, with larger impact ranges predicted for pelagic fish than for demersal fish species. The predicted behavioural response may be sufficient to result in temporary avoidance of these areas by these species, with some temporary redistribution of fish in the wider area between the affected areas. Between piling events, fish may resume normal behaviour and distribution, as evidenced by work of McCauley et al. (2000) which showed that fish returned to normal behavioural patterns within 14 to 30 minutes after the cessation of seismic airgun firing. However, there are some uncertainties over the response of fish to intermittent piling over a prolonged period and the extent that behavioural reactions will cause a negative effect in individuals.

3.12.2.31 The proportions of fish spawning and nursery habitats predicted to be affected by underwater noise from piling operations are expected to be small, particularly in the context of available spawning and nursery habitats within the southern North Sea (particularly for pelagic spawning species). The spread of behavioural impact ranges predicted for the different Tier 1 offshore wind farms reflects some of the uncertainty associated with behavioural effects criteria, with any behavioural effects also dependent on factors such as type of fish, its sex, age and condition, stressors to which the fish is or has been exposed or the reasons and drivers for the fish being in the area.

3.12.2.32 Herring and sandeel are considered to be of high vulnerability, with medium recoverability and of regional importance. The sensitivity of these receptors is therefore considered to be **medium**.

3.12.2.33 Shellfish are considered to be less sensitive to noise than fish as they do not possess a swim bladder, however they do show some sensitivity to increased particle motion (Roberts et al. 2016), with studies showing behavioural changes in shellfish in response to increased noise levels (Samson et al. 2016; Spiga et al. 2016). As a result of this, the sensitivity of shellfish is considered to be **medium**.

3.12.2.34 The majority of all other fish receptors within the study area lack swim bladders and are therefore deemed to be of low vulnerability, medium recoverability and of local to international importance. The sensitivity of these receptors to cumulative noise impacts is therefore considered to be **low**.

3.12.2.35 Overall, the magnitude of the cumulative impact is deemed to be **minor (**adverse), the sensitivity of herring and sandeel were assessed as **medium** and therefore the effect could be of slight or moderate significance in accordance to the significance matrix in **Table 3.13**. Taking into account, the intermittent and reversible nature of the impact and the regional spatial extent, the significance of the cumulative effect of noise impacts on herring and sandeel receptors is deemed to be of **slight** significance.

3.12.2.36 Shellfish are assessed as **medium** sensitivity to cumulative noise impacts, therefore considering the **minor** magnitude of impact, the effect could be of slight or moderate significance. Taking into account the broad distribution of these receptors across the southern North Sea, and the short term and intermittent nature of the impact, it is considered unlikely for there for be a population level effect, and therefore the significance of effect is assessed as **slight** which is not significant in EIA terms.

3.12.2.37 All other fish species are assessed as **low** sensitivity to cumulative noise impacts, therefore, considering the **minor** magnitude of the impact, the effect is of **slight** significance, which is not significant in EIA terms.

Tier 2

3.12.2.38 The Dudgeon Extension and Sheringham Shoal Extension projects could have the potential for cumulative mortality, injury, behavioural changes and auditory masking from noise and vibration with Hornsea Four. The anticipated construction date for those projects is 2026 and so may overlap with the construction of Hornsea Four.

3.12.2.39 Injury or mortality of fish from piling noise and decommissioning activities would not be expected to occur cumulatively due to the small range within which potential injury effects would be expected (i.e. predicted to occur within tens to hundreds of metres of piling activity within each of the offshore wind farm projects) and the large distances between offshore wind farm projects. Cumulative effects of underwater noise are therefore discussed in the context of behavioural effects, particularly on spawning or nursery habitats.

3.12.2.40 The PEIR for the Dudgeon and Sheringham Shoal Extensions (Equinor 2021) assessed the spatial MDS for noise impacts of piling of up to 56 turbines on monopile foundations using hammer energies of up to 5,500 kJ over four hours per pile. The temporal MDS was predicted to result from the installation of up to 240 pin piles, for up to 58 jacket foundations, using a maximum hammer energy of 3,000 kJ, with an installation time of

three hours per pin pile. The assessment predicted minor adverse effects on fish and shellfish receptors.

3.12.2.41 The cumulative impact of underwater noise on fish and shellfish is predicted to be of regional spatial extent, medium term duration (i.e. cumulatively over approximately six years; the duration of the Hornsea Four installation), intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor.**

3.12.2.42 Overall, the magnitude of the cumulative impact is deemed to be **minor (**adverse), the sensitivity of herring and sandeel were assessed as **medium** and therefore the effect could be of slight or moderate significance in accordance with the significance matrix in **Table 3.13**. Taking into account the intermittent and reversible nature of the impact and the regional spatial extent, the significance of the cumulative effect of noise impacts on herring and sandeel receptors is deemed to be of **slight** significance.

3.12.2.43 Shellfish are assessed as **medium** sensitivity to cumulative noise impacts, therefore considering the **minor** magnitude of impact, the effect could be of slight or moderate significance. Taking into account the broad distribution of these receptors across the southern North Sea, and the short term and intermittent nature of the impact, it is considered unlikely for there for be a population level effect, and therefore the significance of effect is assessed as **slight** which is not significant in EIA terms.

3.12.2.44 All other fish species are assessed as **low** sensitivity to cumulative noise impacts, therefore, considering the **minor** magnitude of the impact, the effect is of **slight** significance, which is not significant in EIA terms.

Tier 3

3.12.2.45 The Endurance CCS project could have the potential for cumulative mortality, injury, behavioural changes and auditory masking from noise and vibration with Hornsea Four. Construction activities of pipelines, up to 30 wells, and several platform structures are planned to commence in early 2023 with operation commencing in 2026, so whilst there will be no construction overlap, operation and maintenance activities will overlap with Hornsea Four construction. There is currently limited detail on the Endurance CCS project and therefore it is not possible to make a detailed assessment of the significance of effect, however given that construction activities do not overlap and impacts from noise and vibration from operation and maintenance of Endurance is predicted to be minimal, short term and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

3.12.3 Operation and Maintenance Phase

Temporary localised increases in SSC and smothering

Tier 1

3.12.3.1 There is potential for cumulative increases in SSC and associated sediment deposition associated with maintenance activities in Hornsea Four (cable remedial burial and cable repairs) and other operational projects (**Table 3.19**). As detailed in **paragraph 3.12.2.1** *et*

seq. cumulative impacts from additional sources have been assessed within the maximum tidal ellipse distance. Projects identified in this Tier are the operational Bridlington A disposal site, the operation and maintenance of the Hornsea Project One and Hornsea Project Two offshore wind farms, Dogger Bank A and B offshore wind farm export cables, the maintenance of the Viking Link interconnector cable and the Dana Petroleum Platypus pipeline, the operation of the Tolmount Platform, and the decommissioning of the Johnston WHPS and the Johnston template/manifold infrastructure. There are no Tier 2 or Tier 3 projects.

3.12.3.2 Temporary localised increases in SSC and associated sediment deposition are expected to result from the Bridlington A disposal site. The cumulative impacts of this site with Hornsea Four are assessed for the construction phase in **paragraph 3.12.2.2** *et seq*; it is concluded that due to the intermittent use of the disposal site, it is not possible to determine if sediment disposal will be undertaken simultaneously with cable maintenance at Hornsea Four. In the case that this does occur the sediments are expected to quickly disperse given the location of the spoil site in an area of faster flows.

3.12.3.3 Cumulative impacts of temporary localised increases in SSC and associated sediment deposition are predicted to have the potential to result from remedial cable burial and cable repairs of offshore wind export cables (Hornsea Project Two, Dogger Bank A and B) the Viking Link interconnector cable, the Dana Petroleum Platypus pipeline, operation activities at the Tolmount Platform, and Hornsea Four, as all sites are predicted to be operational simultaneously. Cumulative impacts may also arise from the decommissioning of Johnston WHPS and Johnston template/manifold wellhead structures, and the operation of Hornsea Four.

3.12.3.4 Maintenance activities undertaken on the sites are undertaken intermittently and are therefore considered unlikely to have a temporal overlap with Hornsea Four cable works. In addition to this, any increase in SSC arising from the works is considered to be short-term and small scale, with impacts remaining localised to the site, therefore it is unlikely that there will be any cumulative impacts arising from these operations. The Tolmount Platform will also be operational during the operation and maintenance phase of Hornsea Four; as discussed in **paragraph 3.12.2.7** any activities undertaken at this platform that may cause an increased in SSC and deposition (e.g. drilling), will be undertaken within a closed system and therefore will not have any cumulative effects with the operational phase of Hornsea Four.

3.12.3.5 As stated in **paragraph 3.12.2.22**, the Johnston WHPS and Johnston template/manifold wellhead structures are proposed to be decommissioned during the operational phase of Hornsea Four. This process typically involves cutting the subsea steel lattice structure below the level of the seabed, which is then removed, and the remnants of the structure (below the seabed) are abandoned. Given the small area of disturbance to the seafloor during this procedure, it is considered unlikely that there will be a cumulative impact from the increase in SSC and deposition from the decommissioning of the Johnston WHPS and Johnston template/manifold wellhead structures and the operation and maintenance of Hornsea Four.

3.12.3.6 The MDS for increases in SSC and deposition during the operation and maintenance phase of Hornsea Four results from the use of CFE for cable remedial burial and cable repairs. The worst-case volume of sediment disturbed from these processes is expected

to be less than that in the construction phase of development (see **Table 3.10**) (as detailed in **paragraph 3.12.2.2** *et seq*), and therefore the predicted cumulative impacts from the operational phase of Hornsea Four and the intermittent use of the disposal sites within the maximum tidal ellipse distance are expected to be less than those in the construction period.

3.12.3.7 **Table 3.10** presents the MDS associated with temporary increases in SSC and deposition from remedial cable burial and cable repairs in Hornsea Four. The MDS results from the use of CFE for maintenance activities, resulting in the total release of 692,916 m^3 of sediment in the array area and offshore ECC. The resulting sediment plumes and associated deposition are expected to occur a maximum of 6 km from the source over a neap tide, with the plume dissipating rapidly following the cessation of the activity. Cumulative temporary increases in SSC and deposition from remedial cable burial and cable repairs are predicted to be short term, intermittent, and to occur local to the source.

3.12.3.8 The cumulative impacts of increased SSC and sediment deposition are expected to be of local spatial extent, short-term duration, intermittent and reversible. Due to the intermittent nature of the maintenance activities, it is considered unlikely that there will be a temporal overlap from the projects within 14 km of the proposed Hornsea Four ECC and 10 km of the array area. The magnitude of impacts from the Tier 1 sites identified is therefore considered to be **minor** (adverse). Full discussion of the sensitivity of fish and shellfish to increased SSC and sediment deposition is discussed in **paragraphs 3.11.1.27** *et seq.* which conclude that most species have relatively high vulnerability to increased SSC and deposition. The maximum sensitivity of receptors into these impacts are assessed as **high**, and the magnitude has been assessed as **minor**; this could result in either a slight or moderate significance of effect (in accordance to **Table 3.13**). Taking into account the localised and short-term nature of the time, the significance of effect from an increase in SSC and deposition from the installation of Hornsea Four cumulatively, with the Bridlington A disposal site, Hornsea Project Two, Dogger Bank A and B, the Viking Link interconnector cable, the Dana Petroleum Platypus pipeline, the Tolmount Platform, the Johnston WHPS and Johnston template/manifold wellhead structures is **slight**, which is not significant in EIA terms.

Tier 3

3.12.3.9 The Endurance CCS project could have the potential to create a cumulative temporary increase in SSC and smothering with Hornsea Four. Construction activities of pipelines, up to 30 wells, and several platform structures are planned to commence in early 2023 with operation commencing in 2026, so whilst there will be no construction overlap, operation and maintenance activities will overlap with Hornsea Four operation and maintenance. There is currently limited detail on the Endurance CCS project and therefore it is not possible to make a detailed assessment of the significance of effect, however given that construction activities do not overlap and any temporary increases in SSC and smothering from operation and maintenance of Endurance is predicted to be minimal, short term and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

3.12.3.10 The SEGL2 could have the potential to create a cumulative temporary increase in SSC and smothering with Hornsea Four. Construction activities of the cable are planned to

commence in 2025, with operations commencing by 2030 so both construction and operation and maintenance activities could overlap with Hornsea Four operation and maintenance. There is currently limited detail on the SEGL2 and therefore it is not possible to make a detailed assessment of the significance of effect, however given that any temporary increases in SSC and smothering from construction or operation and maintenance of SEGL2 is predicted to be minimal, short term and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

Long term loss of habitat due to the presence of turbine foundations, scour protection and cable protection

Tier 1

3.12.3.11 Cumulative long-term habitat loss is predicted to occur as a result of the presence of Hornsea Four infrastructure, offshore wind farms which are consented or under construction, cables and pipelines and oil and gas decommissioning activities within a representative 14 km buffer of the Hornsea Four ECC, and 10 km buffer of the array area. Long term habitat loss may result from the physical presence of foundations, scour protection and cable/pipeline protection, which are assumed to be in place for the lifetime of the relevant offshore wind, cable or pipeline projects and potentially beyond the lifetime of these projects. The CEA has been based on information available in Environmental Statements where available and it is noted that the project parameters quoted in Environmental Statements are often refined during the determination period of the application or post consent. The assessments presented within this section are therefore considered to be conservative, with the level of impact on fish and shellfish ecology expected to be reduced from those presented here.

3.12.3.12 The predicted cumulative long-term habitat loss from all Tier 1 projects is estimated to be 15.81 km^2 which equates to 0.37% of the total area of subtidal habitat within a representative 14 km buffer of the Hornsea Four ECC, and 10 km buffer of the array area. Comparable habitats are widely distributed in the southern North Sea (see **Volume A5, Annex 3.1: Fish and Shellfish Technical Report**) so this loss is not predicted to diminish regional ecosystem functions. Furthermore, it is important to note that the overlap of these planned projects with herring spawning grounds in particular, but also sandeel spawning grounds, is very spatially limited and, combined with the expected reductions in as-built parameters (particularly relevant for Hornsea Project Two and the Dogger Bank projects all of which have publicly announced reductions in planned infrastructure over the maximum consented), the impact on spawning grounds will be much reduced from the total spatial area identified above.

3.12.3.13 The cumulative impact of long-term habitat loss is predicted to be of a localised spatial extent, long term duration, continuous and irreversible (during the lifetime of the projects considered). It is predicted that the impact will affect herring and sandeel receptors directly. The magnitude is therefore considered to be **minor (**adverse), when considering the potential overlap with herring and sandeel spawning grounds, rather than just the total area of the introduced hard substrate currently consented and included in this assessment.

Table 3.22: Cumulative long-term habitat loss for Hornsea Four and other Tier 1 projects within a representative the Hornsea Four study area.

Project	Total predicted long-term habitat loss (km²)	Source
Tier 1		
Hornsea Four (array and export cable)	3.7	Volume A1, Chapter 4: Project Description and Table 3.10
Hornsea Project Two (array and export cable)	5.45	Total habitat loss taken from ES (SMart Wind 2015).
Dogger Bank A (export cable)	1.4	Total habitat loss taken from ES (Forewind 2013)
Dogger Bank B (export cable)	1.34	Total habitat loss taken from ES (Forewind 2013)
Tolmount Platform	0.6	Total habitat loss taken from ES (Premier Oil 2017)
Viking Link Interconnector cable	2.86 (within UK sector)	Total habitat loss taken from ES (National Grid Viking Link Limited 2017)
Dana Petroleum Platypus pipeline	0.007	Total habitat loss taken from ES (Dana Petroleum 2018)
Total Tier 1	**15.81 km²**	

3.12.3.14 Sandeel and herring are deemed to be of high vulnerability and of regional importance within the study area (recoverability is not applicable for this impact which will occur over the lifetime of the Tier 1 projects). Due to the specific habitat requirement of these species, the sensitivity of these receptors is therefore considered to be **high**.

3.12.3.15 Cumulative long-term habitat loss will represent a long term and continuous impact throughout the lifetime of the Tier 1 projects. However, only a relatively small proportion of the herring and sandeel habitats and spawning grounds are likely to be affected. Overall, the cumulative magnitude of the impact was deemed to be minor. A minor magnitude of effect, and high receptor sensitivity can result in either a slight or moderate effect (in accordance with Table 3.13). Considering the localised nature of the impact, and the small proportion of herring and sandeel habitats and spawning grounds directly impacted, expert opinion concludes that the effect will be of **slight** significance, which is not significant in EIA terms.

Tier 3

3.12.3.16 The Endurance CCS project could have the potential to result in cumulative long-term habitat loss with Hornsea Four. Construction activities of pipelines, up to 30 wells, and several platform structures are planned to commence in early 2023 with operation commencing in 2026, so whilst there will be no construction overlap, operation and maintenance activities will overlap with Hornsea Four operation and maintenance. There is currently limited detail on the Endurance CCS project and therefore it is not possible to make a detailed assessment of the significance of effect, however given that any long-term habitat loss from Endurance is predicted to be minimal and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

3.12.3.17 The SEGL2 could have the potential to cumulative long-term habitat loss with Hornsea Four. Construction activities of the cable are planned to commence in 2025, with

operations commencing by 2030 so both construction and operation and maintenance activities could overlap with Hornsea Four operation and maintenance. There is currently limited detail on SEGL2 and therefore it is not possible to make a detailed assessment of the significance of effect, however given that any long-term habitat loss from SEGL2 is predicted to be minimal and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection

Tier 1

3.12.3.18 As discussed in **paragraphs 3.11.2.34** *et seq*. the introduction of hard substrate into areas of predominantly soft sediments has the potential to alter fish community composition including potentially acting as fish aggregation devices, thereby resulting in localised redistribution of fish and shellfish populations within offshore wind farms. Cumulative introduction of hard substrates is predicted to occur as a result of the presence of Hornsea Four infrastructure, OWFs which are consented or under construction, cables and pipelines and oil and gas platforms within a representative 14 km buffer of the Hornsea Four ECC, and 10 km buffer of the array area (see **Table 3.20** and **Figure 3.22**). Effects may result from the physical presence of foundations, scour protection and cable/pipeline protection.

3.12.3.19 The cumulative assessment has been based on information available in Environmental Statements where available and it is noted that the project parameters quoted in Environmental Statements are often refined during the determination period of the application or post consent. The assessments presented within this assessment are therefore considered to be conservative, with the level of impact on fish and shellfish ecology expected to be reduced from those presented here.

3.12.3.20 It is difficult to accurately quantify the total area of hard substrate that will be introduced within the buffer of Hornsea Four, particularly since this is not quantified in assessments for some of the other OWFs included within the Tier 1 assessment (see **Table 3.20**). The extent of habitat creation will depend on the exact foundation size and scour protection and cable protection requirements which will vary for each site. However, from a review of the relevant Environmental Statements, it is estimated that approximately 540 turbines may be constructed from all projects included within Tier 1 (**Table 3.23**). This assessment is precautionary as the MDS has assumed the habitat created as a result of the installation of the maximum number of turbines consented for each offshore wind farm project which may be, in reality, greater than the number of turbines actually constructed.

Table 3.23: Cumulative habitat creation for Hornsea Four and other offshore infrastructure in the Tier 1 assessment within the Hornsea Four study area.

Project	MDS scenario for number of turbines	Total predicted habitat creation (km^2)	Source
Tier 1			
Hornsea Four	180	5.4	**Volume A1, Chapter 4: Project Description**

Project	MDS scenario for number of turbines	Total predicted habitat creation (km²)	Source
Tier 1			
Hornsea Project Two (array and export cable)	360	6.2	Total habitat creation taken from ES (SMart Wind 2015).
Dogger Bank A (export cable)	N/A	1.4	Total habitat creation taken from ES (Forewind 2013)
Dogger Bank B (export cable)	N/A	1.34	Total habitat creation taken from ES (Forewind 2013)
Viking Link interconnector cable	N/A	0.6	Total habitat creation taken from ES (National Grid Viking Link Limited 2017)
Dana Petroleum Platypus pipeline	N/A	2.86 (within UK sector)	Total habitat creation taken from ES (Dana Petroleum 2018)
Tolmount Platform	N/A	0.007	Total habitat creation taken from ES (Premier Oil 2017)
Total Tier 1	**540**	**17.81**	

3.12.3.21 The total cumulative habitat creation is estimated to be approximately 17.8 km² for all Tier 1 projects within a 14 km buffer of the Hornsea Four ECC and a 10 km buffer from the array area. This is considered to be a highly precautionary MDS as in many cases fewer turbines may actually be constructed than the number consented. Therefore, given the precaution included in the assessment these areas are likely to be well within the total cumulative estimate of 17.8 km².

3.12.3.22 The impact will extend over the regional area but will be highly localised within each of the offshore wind farm arrays and cable routes, pipelines, and platforms will be of long-term duration, continuous and irreversible during the lifetime of the projects. The magnitude of the impact is therefore, considered to be **minor** (adverse).

3.12.3.23 There is some uncertainty associated with the likely cumulative effects of introduction of hard substrates into the marine environment on fish and shellfish VERs. Fish populations are unlikely to show noticeable benefits as a result of this impact, though there is evidence that shellfish populations (particularly brown crab and lobster) would benefit from the introduction of hard substrates. Overall, the sensitivity of herring and sandeel receptors is **high** and determined to be **low** for shellfish receptors.

3.12.3.24 A **minor (**adverse) magnitude, and **high** receptor sensitivity, can result in either a slight or moderate effect (in accordance to Table 3.13), therefore taking into account the localised nature of the impact and the small proportion of herring and sandeel habitats and spawning grounds directly affected by the impact, expert option concludes that the effects on sandeel and herring receptors will, therefore, be of **slight** significance, which is not significant in EIA terms.

3.12.3.25 Impacts on shellfish receptors are predicted to be small scale and localised to the development, with the potential for beneficial effects on some shellfish species due to the expansion of their natural habitats (Linley et al. 2007). Taking this into account, and the implementation of a CPEMMP (Co111) with a biosecurity plan to minimise the risk of

introduction and spread of INNS, the effects on shellfish receptors are concluded to be of **neutral** significance which is not significant in EIA terms.

3.12.3.26 Conclusions on the effect on the site integrity of European sites within the Southern North Sea fish and shellfish study area are beyond the scope of this Environmental Statement. A full account of the screening and appropriate assessment is presented within **B2.2: Report to Inform Appropriate Assessment**.

Tier 3

3.12.3.27 The Endurance CCS project could have the potential to result in cumulative introduction of hard substrate with Hornsea Four. Construction activities of pipelines, up to 30 wells, and several platform structures are planned to commence in early 2023 with operation commencing in 2026, so whilst there will be no construction overlap, operation and maintenance activities will overlap with Hornsea Four operation and maintenance. There is currently limited detail on the Endurance CCS project and therefore it is not possible to make a detailed assessment of the significance of effect, however given that any introduced hard substrate from Endurance is predicted to be minimal and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

3.12.3.28 The SEGL2 could have the potential to cumulative long-term habitat loss with Hornsea Four. Construction activities of the cable are planned to commence in 2025, with operations commencing by 2030 so both construction and operation and maintenance activities could overlap with Hornsea Four operation and maintenance. There is currently limited detail on SEGL2 and therefore it is not possible to make a detailed assessment of the significance of effect, however given that any introduced hard substrate from SEGL2 is predicted to be minimal and localised to the site, it is not anticipated that any effects once quantified would result in a significant impact.

3.13 Transboundary effects

3.13.1.1 Transboundary effects are defined as those effects upon the receiving environment of other European Economic Area (EEA) states, whether occurring from Hornsea Four alone, or cumulatively with other projects in the wider area. A transboundary screening exercise was undertaken at Scoping (**Annex L** of the Scoping Report) which identified that there was the potential for transboundary effects to occur in relation to fish and shellfish ecology. The potential transboundary impacts screened into the assessment for fish and shellfish ecology were:

- Direct effects as a result of underwater noise from piling operations during the installation of subsea infrastructure; and
- Indirect effects may occur in relation to fish and shellfish habitat or disturbance to habitat due to increased suspended sediment concentrations and deposition from the placement/removal of foundations and cables in or on the seabed.

3.13.1.2 Underwater noise levels expected to elicit behavioural responses in certain fish and shellfish, are predicted to extend to several 10s of kilometres beyond Hornsea Four and therefore have the potential to affect fish and shellfish habitats of the Netherlands, an EEA state (87 km from Hornsea Four) during the construction period. These impacts were

predicted to be short term and intermittent, with recovery of fish and shellfish populations to affected areas following completion of all piling activities. Overall, the sensitivity of fish and shellfish receptors to this impact were assessed as low to high (herring) and the magnitude predicted to be minor adverse. The minor magnitude, and maximum sensitivity of high could result in either a slight or moderate effect, however taking into account the short-term and intermittent nature of the impact, and the distance to the nearest EEA state, the expected recovery of the fish and shellfish populations after piling, and the implementation of mitigation to reduce the impacts of underwater noise, the significance of effect therefore is deemed a maximum of **slight**, which is not significant in EIA terms.

3.13.1.3 Effects of increases in SSC are predicted to occur up to 14 km from Hornsea Four and are therefore not predicted to extend into the waters of other EEA states. Effects on herring and sandeel from all impacts, including habitat loss and disturbance and increases in SSC, were predicted to be **not significant** in EIA terms.

3.14 Inter-related effects

3.14.1.1 Inter-related effects consider impacts from the construction, operation or decommissioning of Hornsea Four on the same receptor (or group). The potential inter-related effects that could arise in relation to fish and shellfish ecology are presented in Table 3.24. Such inter-related effects include both:

- Project lifetime effects: i.e. those arising throughout more than one phase of the project (construction, operation, and decommissioning) to interact to potentially create a more significant effect on a receptor than if just one phase were assessed in isolation; and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor (or group). Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

3.14.1.2 A description of the process to identify and assess these effects is presented in Section 5.8 of Volume A1, Chapter 5: Environmental Impact Assessment Methodology.

Table 3.24: Inter-related effects assessment for fish and shellfish ecology.

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
Project-lifetime effects			
Construction, operation and maintenance and decommissioning	Temporary or long-term habitat loss resulting in indirect effects on fish and shellfish ecology	Impacts were assessed as having a maximum significance of Slight for all receptors.	Temporary or long-term habitat loss will represent a long-term and continuous impact throughout the lifetime of the project. However only a relatively small proportion of the fish and shellfish habitats are likely to be affected in the context of wider habitats in the area. The impacts were assigned a significance of Neutral to Slight significance, which are not significant in EIA terms.

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
Construction and decommissioning	Increased SSC and sediment deposition resulting in indirect effects on fish and shellfish ecology (i.e. through avoidance behaviour, physiological effects, effects on eggs and larvae, smothering effects)	Impacts were assessed as having a maximum significance of Slight across all receptors.	The majority of seabed disturbance resulting in increased suspended sediment and deposition will be within the construction and decommissioning phases. There is potential for some disturbance within the operational phase however, these activities will be spatially localised and temporally discrete. It is therefore considered that impacts in the operation phase will not materially contribute to inter-related effects, and that the construction and decommissioning phases are significantly temporally separate such that there will be no interaction between the two. There will therefore be no inter-related effects of greater significance compared to the impacts considered alone.
Receptor-led effects			
Interrelated effects from the interaction of increased SSC, underwater noise and through the interaction of contamination due to the accidental release of pollutants and the re-suspension of contaminants from sediments.	With respect to the interaction with increased SSC and sediment deposition and underwater noise, these individual impacts were assigned a significance of Slight to Moderate as standalone impacts and although potential inter-related impacts may arise, it is important to recognise that some of the activities are mutually exclusive. Furthermore, underwater noise from piling which is predicted to result in displacement of mobile fish species will in turn mean that these species will not be exposed to the greatest predicted increases in SSC from seabed preparation and drilling in the array area. Therefore, effects of greater significance than the individual impacts in isolation are not predicted for mobile fish species. For those species predicted to exhibit more stationary behaviours (e.g. spawning herring), the implementation of a piling restriction during peak spawning times will reduce any potential impacts. With respect to the second interaction of contamination effects, the likelihood for accidental release of pollutants is low given the control measures that will be applied. In addition, the recorded level of offshore sediment contamination has been found to be unlikely to result in adverse biological effects. As such, with the appropriate measures in place, it is concluded that the significance of effect will be no greater than the individual effects assessed in isolation within the individual effect's assessments.	

3.15 Conclusion and summary

3.15.1.1 This chapter has assessed the potential effects on fish and shellfish ecology receptors arising from Hornsea Four. The range of potential impacts and associated effects considered has been informed by scoping responses, as well as reference to existing policy and guidance. The impacts considered include those brought about directly (e.g. by the presence of infrastructure at the seabed), as well as indirectly (e.g. the release of

sediment contaminants from seabed disturbances). Potential impacts considered in this chapter, alongside any mitigation and residual effects are listed below in **Table 3.25**.

3.15.1.2 The impacts on relevant receptors from all stages of the project were assessed, including impacts from habitat loss, underwater noise, increased SSC and deposition and release of sediment contaminants.

3.15.1.3 Throughout the construction, operation and decommissioning phases, all impacts assessed were found to have either neutral, or slight effects on fish or shellfish receptors within the study area (i.e. not significant in EIA terms).

3.15.1.4 The assessment of cumulative impacts from Hornsea Four and other developments and activities, including offshore wind farms, concluded that the effects of any cumulative impacts would generally be of slight significance, and not significant in EIA terms. Habitat loss was predicted to affect a relatively small proportion of the habitats in the Hornsea Four study area, with effects predicted to be spatially and temporally limited at any one time, meaning that other habitats within the study area would remain undisturbed. The cumulative effects of underwater noise were also considered with regard to construction and operational phases of other offshore wind farms. These impacts may result in temporary displacement of fish populations however these were not predicted to have any significant effects on fish and shellfish populations and no potential for barrier effects to migratory fish species.

3.15.1.5 The screening of transboundary impacts identified that there was potential for transboundary effects for fish and shellfish ecology from Hornsea Four upon the interests of other EEA States, including direct effects as a result of underwater noise from piling, and indirect effects in relation to fish and shellfish habitat or disturbance to habitat due to increased suspended sediment concentrations and deposition. Following consideration of the relevant impact assessments, the only impact predicted to have a significant effect on fish and shellfish populations was underwater noise, however the impact of underwater noise on sensitive species is expected to be reduced by the implementation of mitigation (**Table 3.25**). All other impacts were not predicted to have significant effects on fish and shellfish populations of other EEA States.

Table 3.25: Summary of potential impacts assessed for fish and shellfish ecology.

Impact and Phase	Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
Construction						
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities (FSE-C-1)	Herring	Minor Adverse	High	Slight	None	Slight
	Sandeel	Minor Adverse	High	Slight	None	Slight
	Brown crab	Minor Adverse	Medium	Slight	None	Slight
	European lobster	Minor Adverse	Low	Slight	None	Slight
	Scallop	Minor Adverse	Medium	Slight	None	Slight
	Nephrops	Minor Adverse	Medium	Slight	None	Slight
	Common whelk	Minor Adverse	Medium	Slight	None	Slight
	All other VERs	Negligible Adverse		As the magnitude of this impact is assessed as negligible, the assessment is not taken any further for these species, as it will not lead to a significant effect.		
Temporary localised increases in SSC and smothering (FSE-C-2).	Herring	Minor Adverse	High	Slight	None	Slight
	Sandeel	Minor Adverse	Low	Neutral	None	Neutral
	Brown crab	Minor Adverse	Medium	Slight	None	Slight
	European lobster	Minor Adverse	Medium	Slight	None	Slight
	Scallop	Minor Adverse	Medium	Slight	None	Slight
	Nephrops	Minor Adverse	Low	Neutral	None	Neutral
	Common whelk	Minor Adverse	Low	Neutral	None	Neutral
	All other VERs	Minor Adverse	Low	Neutral	None	Neutral
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-C-3).	Herring	Negligible Adverse		As the magnitude of this impact is assessed as negligible, the assessment is not taken any further, as it will not lead to a significant effect.		
	Sandeel					
	Brown crab					
	European lobster					
	Scallop					
	Nephrops					

Impact and Phase		Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
		Common whelk All other VERs					
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-C-4).	Mortality and potential mortal injury	Herring	Minor Adverse	High	Slight	None	Slight
		Sandeel	Minor Adverse	Medium	Slight	None	Slight
		Eggs and larvae	Minor Adverse	High	Slight	None	Slight
		Brown crab	Minor Adverse	Medium	Slight	None	Slight
		European lobster	Minor Adverse	Medium	Slight	None	Slight
		Scallop	Minor Adverse	Medium	Slight	None	Slight
		Nephrops	Minor Adverse	Medium	Slight	None	Slight
		Common whelk	Minor Adverse	Medium	Slight	None	Slight
		All other VERs	Minor Adverse	Medium	Slight	None	Slight
	Recoverable injury	Herring	Minor Adverse	High	Slight	None	Slight
		Sandeel	Minor Adverse	Medium	Slight	None	Slight
		Eggs and larvae	Minor Adverse	High	Slight	None	Slight
		Brown crab	Minor Adverse	Medium	Slight	None	Slight
		European lobster	Minor Adverse	Medium	Slight	None	Slight
		Scallop	Minor Adverse	Medium	Slight	None	Slight
		Nephrops	Minor Adverse	Medium	Slight	None	Slight
		Common whelk	Minor Adverse	Medium	Slight	None	Slight
		All other VERs	Minor Adverse	Medium	Slight	None	Slight
	Temporary Threshold Shift (TTS)/ Hearing Damage	Herring	Minor Adverse	High	Slight	None	Slight
		Sandeel	Minor Adverse	Medium	Slight	None	Slight
		Eggs and larvae	Minor Adverse	High	Slight	None	Slight
		Brown crab	Minor Adverse	Medium	Slight	None	Slight
		European lobster	Minor Adverse	Medium	Slight	None	Slight
		Scallop	Minor Adverse	Medium	Slight	None	Slight

Impact and Phase		Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
		Nephrops	Minor Adverse	Medium	Slight	None	Slight
		Common whelk	Minor Adverse	Medium	Slight	None	Slight
		All other VERs	Minor Adverse	Medium	Slight	None	Slight
	Behavioural Impacts	Herring	Minor Adverse	High	Slight	None	Slight
		Sandeel	Minor Adverse	Medium	Slight	None	Slight
		Eggs and larvae	Minor Adverse	High	Slight	None	Slight
		Brown crab	Minor Adverse	Medium	Slight	None	Slight
		European lobster	Minor Adverse	Medium	Slight	None	Slight
		Scallop	Minor Adverse	Medium	Slight	None	Slight
		Nephrops	Minor Adverse	Medium	Slight	None	Slight
		Common whelk	Minor Adverse	Medium	Slight	None	Slight
		All other VERs	Minor Adverse	Medium	Slight	None	Slight
Operation and Maintenance							
Temporary localised increases in SSC and smothering (FSE-O-18).		Herring	Minor Adverse	High	Slight	None	Slight
		Sandeel	Minor Adverse	Low	Neutral	None	Neutral
		Brown crab	Minor Adverse	Medium	Slight	None	Slight
		European lobster	Minor Adverse	Medium	Slight	None	Slight
		Scallop	Minor Adverse	Medium	Slight	None	Slight
		Nephrops	Minor Adverse	Low	Neutral	None	Neutral
		Common whelk	Minor Adverse	Low	Neutral	None	Neutral
		All other VERs	Minor Adverse	Low	Neutral	None	Neutral
Long term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (FSE-O-6).		Herring	Minor Adverse	High	Slight	None	Slight
		Sandeel	Minor Adverse	High	Slight	None	Slight
		Brown crab	Minor Adverse	Medium	Slight	None	Slight
		European lobster	Minor Adverse	Low	Neutral	None	Neutral
		Scallop	Minor Adverse	Low	Slight	None	Neutral

Impact and Phase	Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
	Nephrops	Minor Adverse	Medium	Slight	None	Slight
	Common whelk	Minor Adverse	Low	Neutral	None	Neutral
	All other VERs	Minor Adverse	Low	Neutral	None	Neutral
Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection (FSE-O-7).	Herring	Minor Adverse	High	Slight	None	Slight
	Sandeel	Minor Adverse	High	Slight	None	Slight
	Brown crab	Minor Adverse	Low	Neutral	None	Neutral
	European lobster	Minor Adverse	Low	Neutral	None	Neutral
	Scallop	Minor Adverse	Low	Neutral	None	Neutral
	Nephrops	Minor Adverse	Low	Neutral	None	Neutral
	Common whelk	Minor Adverse	Low	Neutral	None	Neutral
	All other VERs	Negligible Adverse	As the magnitude of this impact is assessed as negligible, the assessment is not taken any further for these species, as it will not lead to a significant effect.			
Direct disturbance resulting from maintenance during operation (FSE-O-10)	Herring	Minor Adverse	High	Slight	None	Slight
	Sandeel	Minor Adverse	High	Slight	None	Slight
	Brown crab	Minor Adverse	Medium	Slight	None	Slight
	European lobster	Minor Adverse	Low	Neutral	None	Neutral
	Scallop	Minor Adverse	Medium	Slight	None	Slight
	Nephrops	Minor Adverse	Medium	Slight	None	Slight
	Common whelk	Minor Adverse	Medium	Slight	None	Slight
	All other VERs	Negligible Adverse	As the magnitude of this impact is assessed as negligible, the assessment is not taken any further for these species, as it will not lead to a significant effect.			
Decommissioning						
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from	Herring	Minor Adverse	High	Slight	None	Slight
	Sandeel	Minor Adverse	High	Slight	None	Slight
	Brown crab	Minor Adverse	Medium	Slight	None	Slight
	European lobster	Minor Adverse	Low	Slight	None	Slight
	Scallop	Minor Adverse	Medium	Slight	None	Slight

Impact and Phase	Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
construction activities (FSE-D-13)	*Nephrops*	Minor Adverse	Medium	Slight	None	Slight
	Common whelk	Minor Adverse	Medium	Slight	None	Slight
	All other VERs	Negligible Adverse		As the magnitude of this impact is assessed as negligible, the assessment is not taken any further for these species, as it will not lead to a significant effect		
Temporary localised increases in SSC and smothering (FSE-D-14).	Herring	Minor Adverse	High	Slight	None	Slight
	Sandeel	Minor Adverse	Low	Slight	None	Neutral
	Brown crab	Minor Adverse	Medium	Slight	None	Slight
	European lobster	Minor Adverse	Medium	Slight	None	Slight
	Scallop	Minor Adverse	Medium	Slight	None	Slight
	Nephrops	Minor Adverse	Low	Neutral	None	Neutral
	Common whelk	Minor Adverse	Low	Neutral	None	Neutral
	All other VERs	Minor Adverse	Low	Neutral	None	Neutral
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-D-15).	Herring	Negligible Adverse		As the magnitude of this impact is assessed as negligible, the assessment is not taken any further for these species, as it will not lead to a significant effect.		
	Sandeel					
	Brown crab					
	European lobster					
	Scallop					
	Nephrops					
	Common whelk					
	All other VERs					
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-D-16).	Herring	Negligible Adverse		As the magnitude of this impact is assessed as negligible, the assessment is not taken any further for these species, as it will not lead to a significant effect		
	Sandeel					
	Brown crab					
	European lobster					
	Scallop					

Impact and Phase	Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
	Nephrops					
	Common whelk					
	All other VERs					

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