Hornsea Project Four: Preliminary Environmental Information Report (PEIR)

Volume 2, Chapter 3: Fish and Shellfish Ecology

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Glossary

Term	Definition
Commitment	A term used interchangeably with mitigation. Commitments are embedded mitigation measures. Commitments are either primary (design) or tertiary (Inherent) and embedded within the assessment at the relevant point in the Environmental Impact Assessment (EIA) (e.g. at Scoping or Preliminary Environmental Information Report (PEIR)). The purpose of Commitments are to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms.
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 Four	The proposed Hornsea Project Four offshore wind farm project; the term covers all elements within the Development Consent Order (i.e. both the offshore and onshore components).
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.

Term	Definition
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 or PEIR).
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.
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).
Spawning	The release or deposition of eggs and sperm, usually into water, by aquatic animals.

Acronyms

Acronym	Definition
ASA	Acoustical Society of America
BGS	British Geological Society
CEA	Cumulative Effects Assessment
CIEEM	Chartered Institute of Ecology and Environmental Management
CMS	Construction Method Statement
CPA	Coast Protection Act 1949
CSIP	Cable Specification and Installation Plan
DBT	Dibutyltin
DCO	Development Consent Order
dML	Deemed Marine Licence
DP	Dynamically Positioned
EA	Environment Agency
ECC	Export Cable Corridor
EEA	European Economic Area
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
ES	Environmental Statement
EUNIS	The European Nature Information System
FEPA	Food and Environment Protection Act 1985
GC	Gas Chromatography
GES	Good Environmental Status
HRA	Habitats Regulations Assessment
HVAC	High Voltage Alternating Current
IBTS	International Bottom Trawl Surveys

Acronym	Definition
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larval Survey
IPC	Infrastructure Planning Commission
MCAA	Marine and Coastal Access Act
MCA	Maritime and Coastguard Agency
MDS	Maximum Design Scenario
MGN	Marine Guidance Note
MFE	Mass Flow Excavation
MHWS	Mean High Water Springs
MPCP	Marine Pollution Contingency Plan
MMO	Marine Management Organisation
MPA	Marine Protection Area
MPS	Marine Policy Statement
NPS	National Policy Statement
ORJIP	Offshore Wind, 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 Windfarm
PEIR	Preliminary Environmental Information Report
PEMMP	Project Environmental Management and Monitoring Plan
PINS	Planning Inspectorate
PSA	Particle Size Analysis
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SEL	Sound Exposure Level
SPA	Special Protection Area
SPL	Sound Pressure Levels
SSC	Suspended Sediment Concentration
SSSI	Site of Species Scientific Importance
TBT	Tributyltin
TTS	Temporary Threshold Shift
UXO	Unexploded Ordinance
UKCS	UK Continental Shelf
VER	Valued Ecological Receptor
WTG	Wind Turbine Generator

Units

Unit	Definition
dB	Decibel
kJ	Kilojoules
km	Kilometre

Unit	Definition
dB	Decibel
m	Meter

3.1 Introduction

3.1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents a preliminary assessment of the potential impacts of the Hornsea Project Four offshore wind farm (hereafter Hornsea Four) on fish and shellfish ecology. The chapter considers the potential impact of Hornsea Four seaward of Mean High Water Springs (MHWS) during its construction, operation and maintenance, and decommissioning phases. The chapter provides a summary of the **Volume 5, 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 and survey data from across the former Hornsea Zone, including the Hornsea Four array area and offshore cable corridor, and includes information on fish and shellfish species of ecological importance and of commercial and conservation value.

3.1.1.2 Orsted Hornsea Project Four Limited (the Applicant) is proposing to develop Hornsea Four. Hornsea Four will be located approximately 65 km from the coast of 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 1, Chapter 1: 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 1, Chapter 4: Project Description** for full details on the Project Design).

3.2 Purpose

3.2.1.1 This PEIR presents the preliminary environmental information for Hornsea Four and sets out the findings of the Environmental Impact Assessment (EIA) to date to support the pre-application Development Consent Order (DCO) consultation activities required under the Planning Act 2008.

3.2.1.2 The feedback from the Section 42 consultation will be used to inform the final project design and the associated EIA (which will be reported in an Environmental Statement (ES)) that will accompany the DCO application to the Planning Inspectorate (PINS).

3.2.1.3 This PEIR chapter:

- Presents a summary of the existing environmental baseline established from desk studies;
- Presents the potential environmental effects on fish and shellfish ecology receptors arising from Hornsea Four, based on the information gathered and the maximum design scenarios (MDS);
- Identifies any assumptions and limitations encountered in compiling the environmental baseline; 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 PEIR
"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 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)

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the PEIR
	sites are also considered in the 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." (PS 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." (PS 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 within the region is undertaken in **Volume 5, 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.**
"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 5, 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;*	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 4, Annex 5.2: Commitments Register**, with the Commitments of relevance to fish and shellfish are detailed in **Table 3.9**.

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the PEIR
• *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)	

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 PEIR
Biodiversity	
"The Secretary of State should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it." (paragraph 2.6.68 of NPS EN-3).	.The 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 Export Cable Corridor (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.
"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) . The proportionate approach to the EIA which Hornsea Four is promoting has been an integral part of the development approach and has led to design refinements between Scoping and PEIR to ensure that adverse effects are avoided."	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 4, 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 EMF (see below) the residual effects of electromagnetic fields (EMF) on sensitive species from cable infrastructure during operation are not likely to be significant.	The impacts of EMF on fish and shellfish receptors have been considered and scoped out at the Scoping stage (see **Volume 4, Annex 5.1: Impacts Register**).

Summary of NPS EN-1 and EN-3 provisions	How and where considered in the PEIR
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)	
"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 **Volume 4, 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 (See **Volume 1, 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 conservation of ecologically sensitive areas throughout the planning process and mitigation or compensatory actions where significant harm cannot be avoided (paragraph 2.6.1 of the MPS).

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 (MMO, 2014a). Key provisions are set out in **Table 3.3** along with details as to how these have been addressed within the PEIR assessment

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

Policy	Key provisions	How and where considered in the PEIR 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 5: 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 Good Environmental Status (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 PEIR 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 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.
Descriptor 4: Elements of marine food webs. All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long term abundance of the species and the retention of their full reproductive capacity.	The effects on 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 **3.12.2**, respectively).
Descriptor 6: Sea floor integrity. Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected	The effects 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 **3.12.2**, 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 **3.11.1.11** *et seq.* (construction) and paragraphs **3.11.3.4** *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 **3.11.1.11** *et seq.* (construction) and paragraphs **3.11.3.4** *et seq.* (decommissioning).
Descriptor 10: Marine litter. Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	A Project Environmental Management and Monitoring Plan (PEMMP) will be developed and implemented prior to the start of construction (as part of the pre-commencement documentation (required under the deemed Marine Licence (dML) conditions) which will be submitted to the MMO) to cover the construction, and operation and maintenance phases of Hornsea Four. The PEMMP will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details. A Decommissioning

Summary of MSFD high level descriptors of GES relevant to fish and shellfish ecology	How and where considered within the PEIR chapter
	Programme will be developed[1] 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 3.11.1.15** *et seq.* (construction), **paragraphs 3.11.2.23** *et seq.* (operation) and **paragraphs 3.11.3.6** *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 the Evidence Plan process via Technical Panel meetings and through the EIA scoping process (Scoping Report, Ørsted, 2018). The Marine Processes and Ecology Technical Panel is comprised of Hornsea Four, technical specialists, Natural England, MMO and Cefas. The technical panel meetings are a forum to agree relevant impacts and assessment methodologies in a cooperative manner between Hornsea Four and the statutory stakeholders, all meetings are minuted and meeting minutes will be presented within the Consultation Report that will be submitted as part of the Hornsea Four DCO application. A summary of the project consultation process is presented within **Volume 1, Chapter 6: Consultation**.

3.4.1.2 A summary of the key issues raised during consultation specific to fish and shellfish ecology is outlined below in

3.4.1.3 **Table** 3.5, together with how these issues have been considered in the production of this PEIR chapter.

Table 3.5: Consultation Responses.

Consultee	Date, Document, Forum	Comment	Where addressed in the PEIR
The Planning Inspectorate	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, and is detailed in **Volume 4, Annex 4.5: Subsea Noise Technical Report**. Impacts of subsea noise on fish and shellfish receptors have been assessed in **Section 3.11 below**

[1] Pursuant to section 105(2) of the Energy Act 2004.

		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 5, Annex 3.1: Fish and Shellfish Ecology Baseline Technical Report**.
		The Inspectorate does not agree to scope out the following impacts: Construction phase: • Temporary increases in suspended sediment concentrations (SSC) and smothering; • Seabed disturbances leading to the release of sediment contaminants; Operational phase: • Long-term loss of habitat; • Increased hard substrate and structural complexity; • Operational underwater noise; • Changes to fishing pressures; Decommissioning phase: • Temporary increases in SSC and smothering; • Seabed disturbances leading to the release of sediment contaminants; and • Impacts from underwater noise.	These impacts have not been scoped out and are considered in full in **Section 3.11**. Please refer to **Volume 4, Annex 5.1: Impacts Register** for a full scope of the Hornsea Four EIA at PEIR.
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting One 12 September 2018	It was agreed that the baseline will utilise existing data sources available from across the former Hornsea Zone.	No response required.
		It was noted that high levels of arsenic in the muds should be considered in the assessment.	Sediment contaminants are assessed in **Section 3.11**.
		It was agreed that site specific survey data is to be used to ground truth the EUSeaMap.	Site specific Particle Size Analysis (PSA) data has been used to ground-truth the EUSeaMap, and is presented in **Figure 3.4** and **Figure 3.5**.
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting Two 12 December 2018	It was agreed that International Herring Larvae Survey (IHLS) data is to be used to identify areas of recent spawning activity.	IHLS data have been presented as 'heat maps' in **Figure 3.7** to **Figure 3.14**.
MMO	Response to Marine Ecology and Processes Fish Technical	It was agreed 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

	Note from the MMO received on 25 February 2019		has been supported with PSA data as illustrated in Figure 3.5.
		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 Project Four.	Impacts to herring and sandeel are assessed in Section 3.11.
		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 of sufficient coverage to characterise the array and ECC.	Impacts to spawning herring (using PSA data) are assessed in paragraphs 3.11.2.10 *et seq*.
MMO, Natural England and Cefas	Marine Processes and Ecology Technical Panel Meeting Three 30 April 2019	It was agreed that complete datasets for the North Sea are utilized to provide data on herring functional maturity analysis.	Analysis of complete datasets are used to provide data on the presence of functionally mature herring.
		It was agreed that the maturity class 62 is to be included in the functionally mature group along with class 63 (actively spawning fish) and 64 (recently spawned fish)	Maturity classes 62, 63 and 64 will all be considered functionally mature for the purposes of the Hornsea Four assessment.
		Agreement from Cefas on the fish and shellfish assessment only considering herring and sandeel.	These assessments are undertaken in Section 3.11.
		It was agreed that all impacts that will be scoped in to the assessment will be simple assessments as defined by the proportionate approach.	Hornsea Four have undertaken simple assessments for all impacts, with the exception of noise, which is a detailed assessment.

3.5 Study area

3.5.1.1 For the purposes of this report, the Hornsea Four fish and shellfish study area (Figure 3.1) was defined based on the relevant potential impacts on fish and shellfish receptors, these include direct and indirect impacts from sediment disturbance and indirect impacts from noise. The study area is defined by a 10 km buffer encompassing the array area, and a 15 km buffer surrounding the offshore ECC, to represent the tidal ellipse distance as informed by **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Processes**, in order to incorporate the maximum distance sediments will travel in one tidal cycle.

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

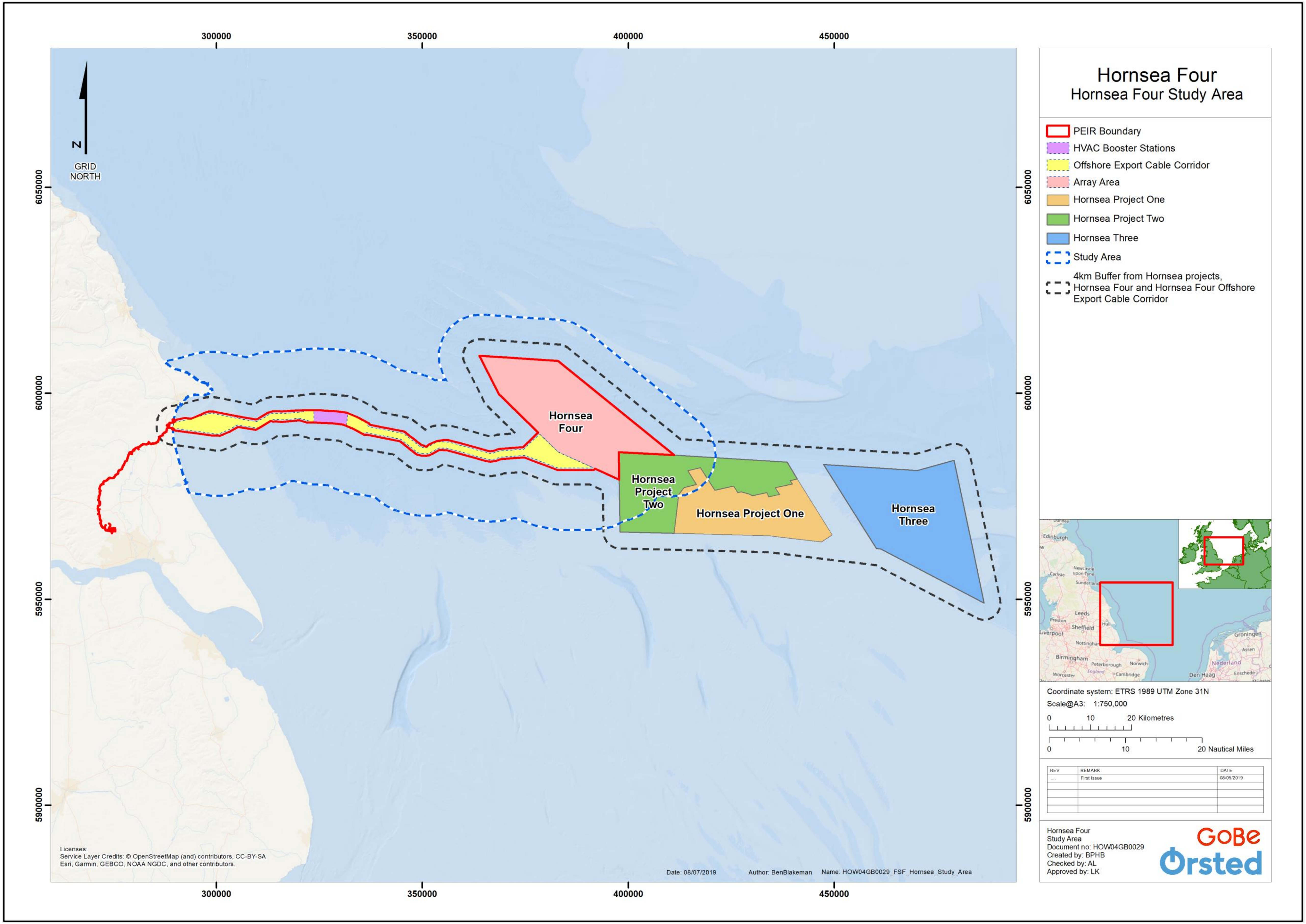

Figure 3.1: The Hornsea Four fish and shellfish study area, with HVAC booster station locations shown on ECC (not to scale).

3.6 Methodology to inform baseline

3.6.1 Evidence-based approach

3.6.1.1 The approach taken by Hornsea Four to develop a robust characterisation of the fish and shellfish ecology baseline environment was evidence-based, combining 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 site-specific survey data, and a comprehensive desktop study. Further details on the evidence-based approach undertaken are detailed in **Volume 5, 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 5, 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 have been used to inform the baseline characterisation, as agreed with the Marine Processes and Ecology Evidence Plan Technical Panel (**Section 3.4**). 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 5, 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 Wind, 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 5, 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
The International Bottom Trawl Surveys (IBTS) (2017)	Data collected 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 – ongoing
Cefas 2015 full coverage Folk and 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)	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
The International Herring Larval Survey (IHLS) data (ICES, 2007–2017)[2]	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.	1967-2017
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
BGS Marine Sediment Particle Size dataset sourced from the BGS GeoIndex Offshore portal[3]	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

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

Table 3.7: Summary of site-specific survey data.

Source	Summary	Coverage of Hornsea Four development area
Hornsea Four Habitat Classification Report (Gardline, 2019)	Site specific grab surveys within the Hornsea Four array and ECC were undertaken with Particle Size Analysis (PSA) conducted using the grab samples.	Samples collected from within the Hornsea Four array area; the sampling locations are detailed in **Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.
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.
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.
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.

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 5, Annex 3.1: Fish and Shellfish Technical Report**, with a summary provided here. This PEIR 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 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 Creyke Beck baseline characterisation surveys. Spatial variability was found to influence species composition across the study area, with deeper offshore areas (**Figure 3.2**), including the proposed 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.

3.7.1.3 Pelagic species recorded within the study area included sprat *Sprattus sprattus*, herring and mackerel *Scomber scombrus*, with sprat and herring being a key characterising species of the otter and beam trawl surveys. 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, that 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 5, 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 will be the focus of the assessment (full details of agreements are detailed in **Section 3.4**).

3.7.1.6 Potential sandeel habitats were mapped using PSA data (using data from EUNIS and Folk (1954) (Stephens and Diesing 2015), and site-specific PSA data from the Hornsea Four Habitat Classification report (Gardline, 2019), which 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 5, Annex 3.1: Fish and Shellfish Technical Report**). The results of these analyses largely reflected the patterns identified by the Hornsea Three and Creyke Beck surveys discussed above (note that sandeel preferred habitats are contiguous with sandeel spawning habitat). Sandeel habitats were considered to be "preferred" across most of the Hornsea Four array, and offshore ECC. The nearshore ECC was characterised by coarser gravelly sediments and assigned a "marginal" to "unsuitable" preference for sandeels (**Figure 3.4**).

3.7.1.7 Herring spawning areas were identified using the IHLS dataset (ICES, 2007-2017), showing areas of high intensity spawning activity within the region (**Figure 3.3**). This data largely reflects patterns shown by PSA data (data from EUNIS and Folk (1954) (Stephens and Diesing 2015) and from site specific PSA data from the Hornsea Four Habitat Classification report (Gardline, 2019). The PSA 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 3.5**) (full details of these methodologies and results are detailed in **Volume 5, Annex 3.1: Fish and Shellfish Technical Report**. High intensity spawning habitats, as identified by the IHLS data, are located north of the ECC and HVAC booster station, with areas of low intensity spawning overlapping with the ECC and HVAC booster station search area (**Figure 3.3**). Herring spawning habitats, as identified by the PSA datasets, were considered to be "preferred" and "marginal" across the inshore section of the ECC.

Figure 3.2: Bathymetry within the region of Hornsea Four (based on EMODnet bathymetry data) (not to scale).

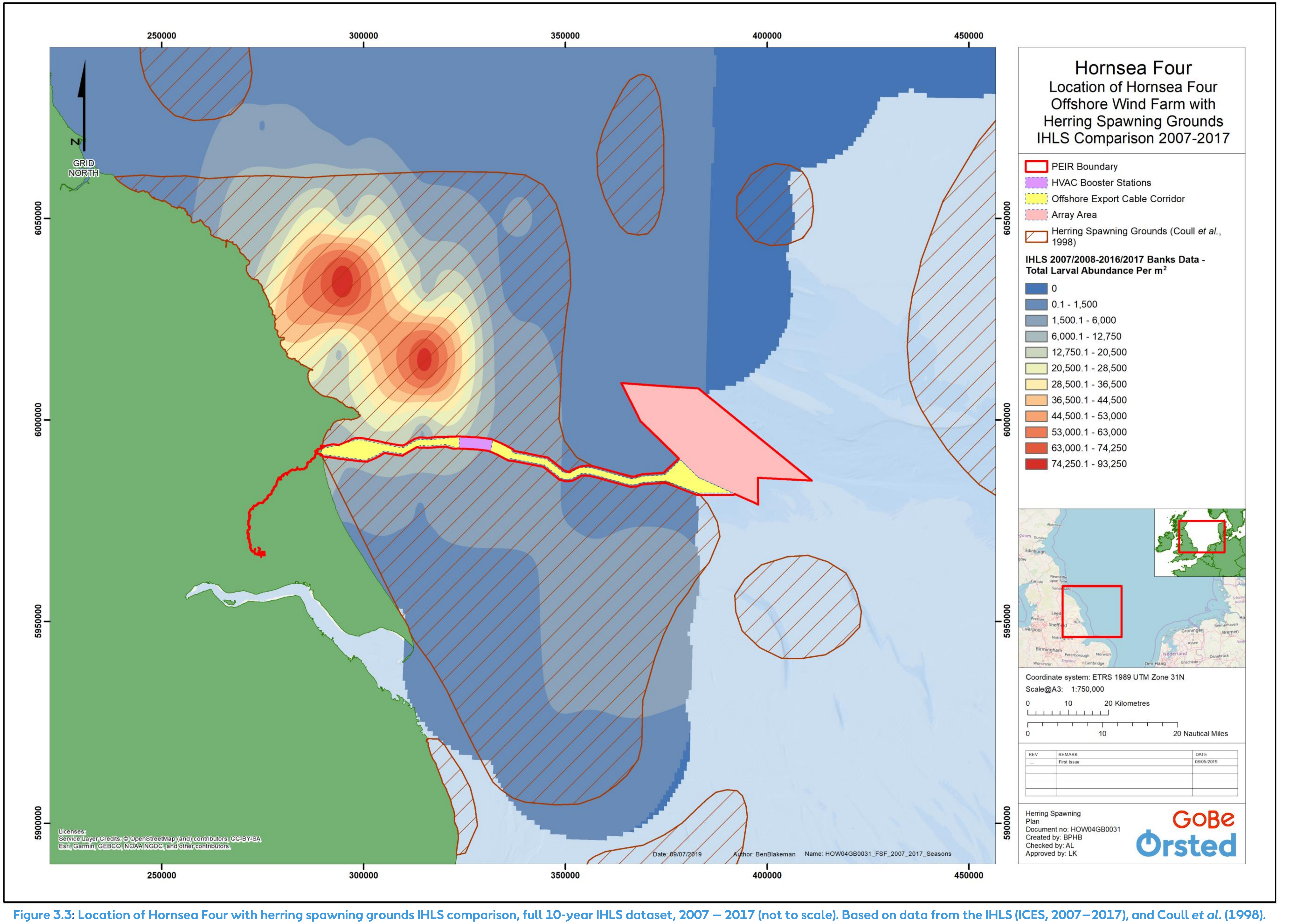

Figure 3.3: Location of Hornsea Four with herring spawning grounds IHLS comparison, full 10-year IHLS dataset, 2007 – 2017 (not to scale). Based on data from the IHLS (ICES, 2007–2017), and Coull *et al.* (1998).

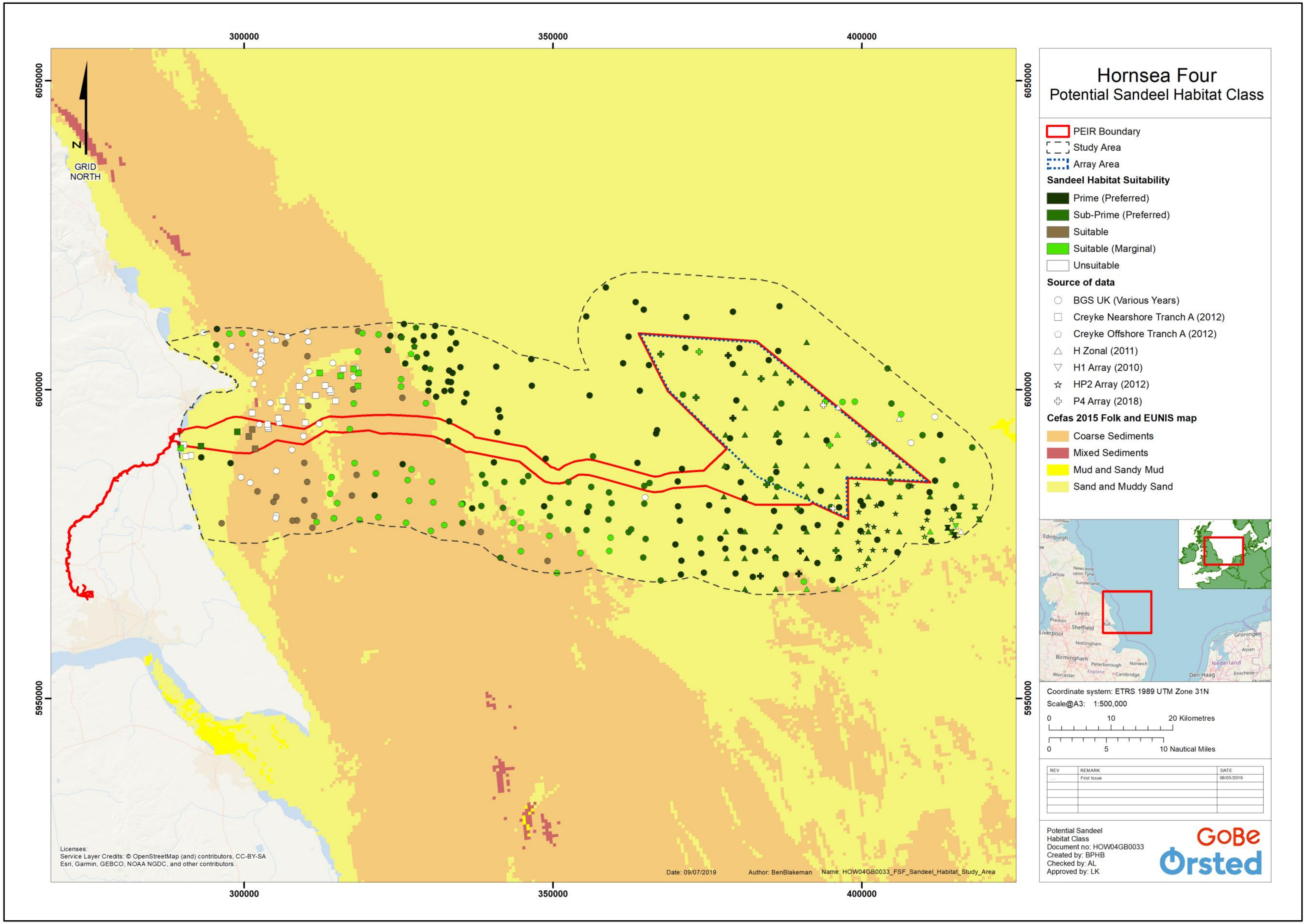

Figure 3.4: Potential sandeel habitat sediment classifications within the Hornsea Four study area following methods in Reach *et al.* (2013) (not to scale). Based on data from Cefas 2015 full coverage Folk and EUNIS map (Stephens and Diesing 2015) and PSA data from the Hornsea baseline characterisation surveys and the BGS GeoIndex Offshore Portal.

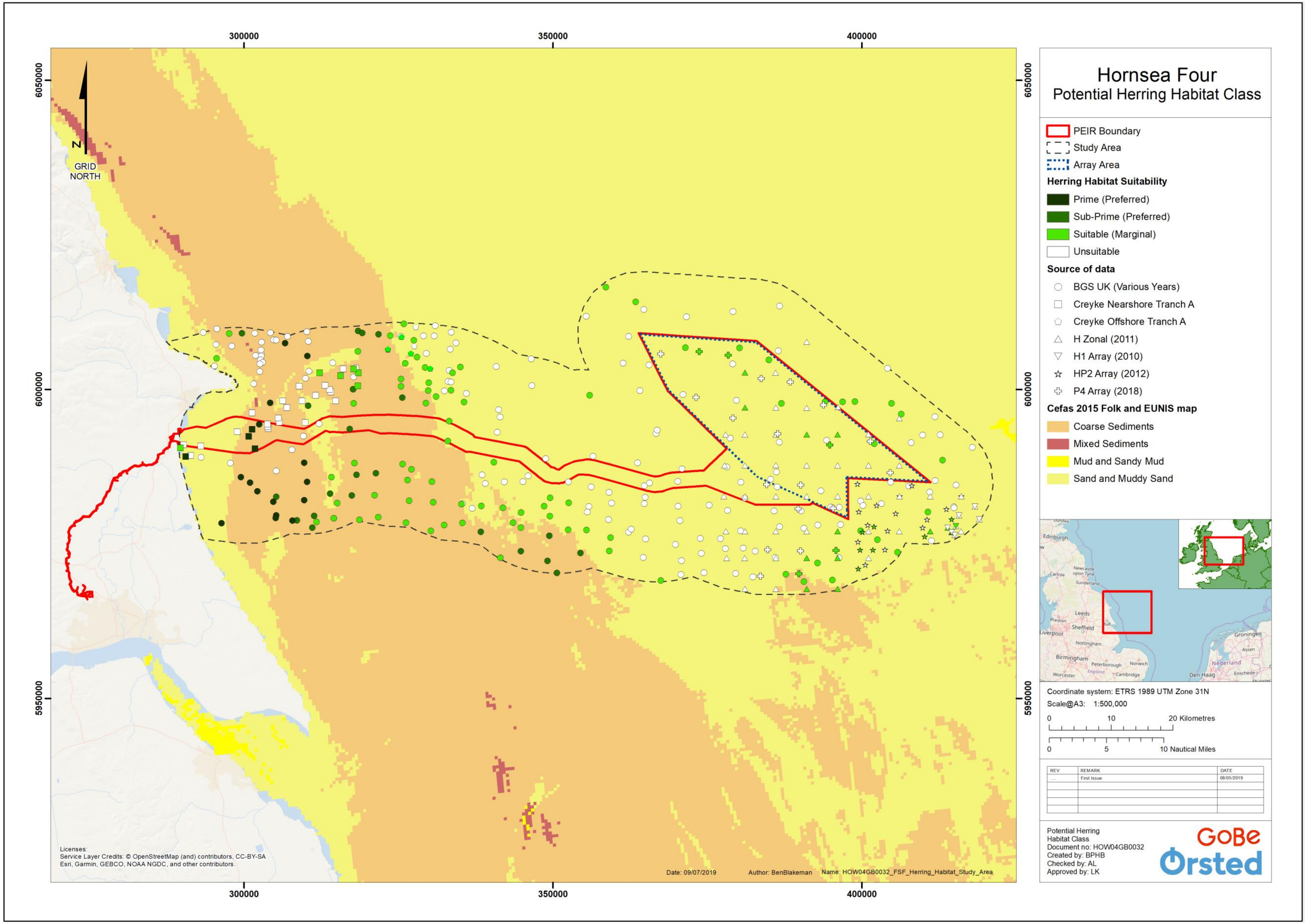

Figure 3.5: Potential herring habitat sediment classifications within the Hornsea Four study area following methods in Reach *et al.* (2013) (not to scale). Based on data from Cefas 2015 full coverage Folk and EUNIS map (Stephens and Diesing 2015) and PSA data from the Hornsea baseline characterisation surveys and the BGS GeoIndex Offshore Portal.

3.7.1.8 A number of migratory fish species have the potential to occur in the Southern North Sea fish and shellfish study area, migrating to and from rivers and other freshwater bodies in the area which these species 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 growth and development to the adult phase with spawning occurring at sea (i.e. European eel *Anguilla Anguilla*). These species are fully discussed in **Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report**.

3.7.1.9 The shellfish ecology of the Hornsea Four fish and shellfish study area was found to be primarily characterised by four commercial species: brown crab *Cancer pagurus*, European lobster *Homarus gammarus*, *Nephrops* and common whelk *Buccinum undatum*. (see **Volume 5, Annex 3.1: Fish and Shellfish Technical Report** for further discussion).

3.7.2 Designated sites and protected species

3.7.2.1 All designated sites within the Hornsea Four study area (**Figure 3.6**), whereby impacts to fish or shellfish receptors could impact the conservation objectives or features of the site by Hornsea Four, are described below and discussed in full in **Volume 5, 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. These species are known to migrate through the Humber Estuary to freshwater spawning habitats. A full assessment of the impacts on these species is undertaken through the RIAA (to be submitted following PEIR submission) which will examine 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 Favourable Conservation for the harbour porpoise, which includes the maintenance of the availability of prey (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 PEIR. Further details of this assessment are presented in **Volume 5, Annex 2.3: Marine Conservation Zone Assessment**.

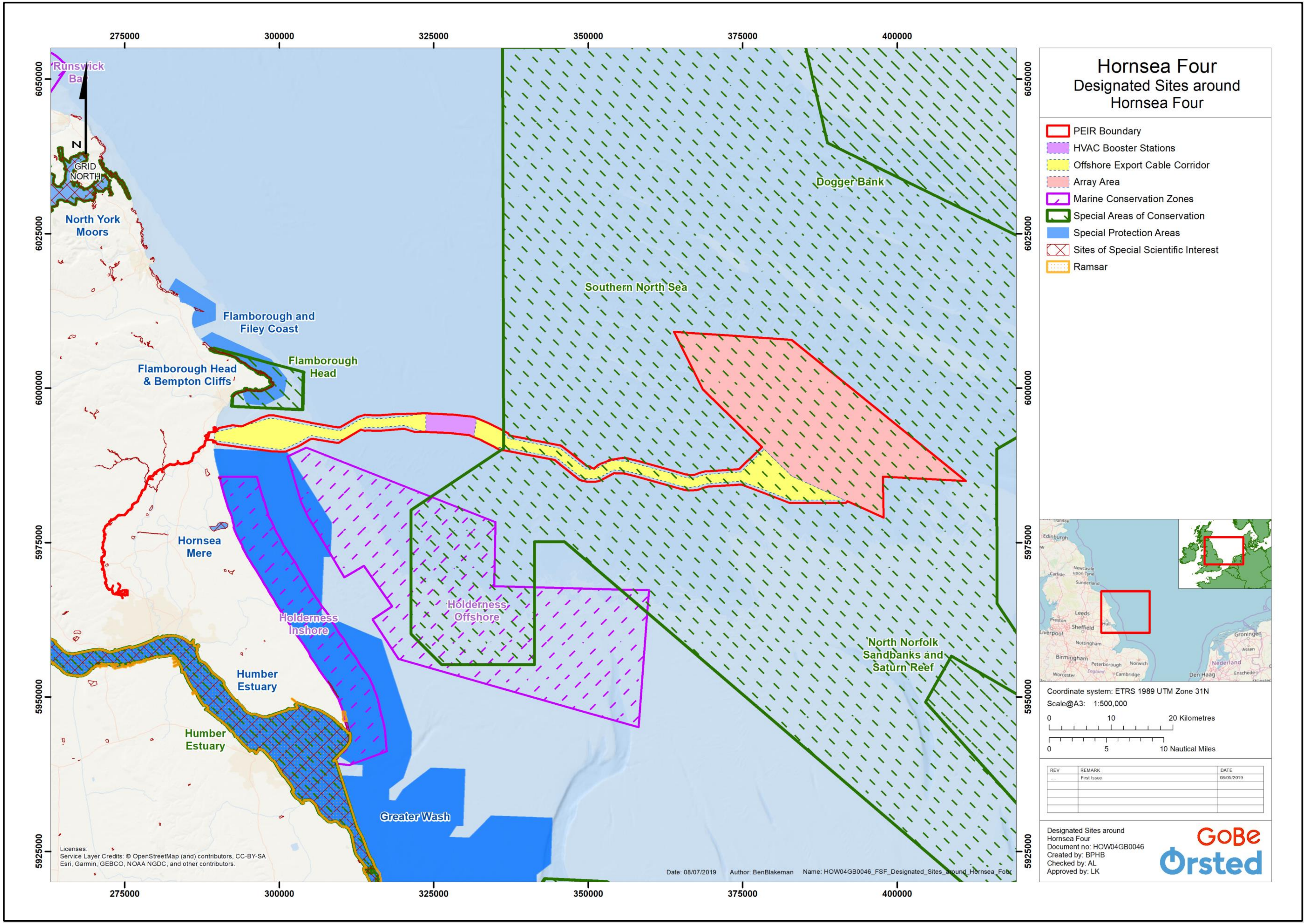

Figure 3.6: Designated sites surrounding Hornsea Four (not to scale).

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 5, Annex 3.1: Fish and Shellfish Technical Report**. Based on the baseline characterisation summarised above and presented in full within **Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report**, a number of VERs were identified within the fish and shellfish study area these are detailed in **Volume 5, 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. Due to the demersal nature of herring and sandeel spawning behaviours, the proximity of their spawning and nursery grounds, and the high sensitivity of herring to noise disturbances, these species are the primary focus of this assessment.

3.7.4 Predicted future baseline

3.7.4.1 The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 require that the ES includes "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".

3.7.4.2 An assessment of the future baseline conditions in the absence of Hornsea Four has been carried out and is described within this section.

3.7.4.3 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 variation 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 activities such as climate change and overfishing.

3.7.4.4 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 ocean climate and plankton abundance, and bottom-up factors, such as predation. Fish and shellfish are important prey items for top marine predators including elasmobranchs, seabirds, cetaceans and humans, and small planktivorous species such as sandeel and herring act as important links between zooplankton and top predators (Frederiksen *et al.* 2006).

3.7.4.5 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).

3.7.4.6 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).

3.7.4.7 In addition to climate change, overfishing subjects 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). OSPAR's 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.

3.7.4.8 The Hornsea Four fish and shellfish baseline characterisation described in the preceding sections (and presented in detail in **Volume 5, 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 anthropogenic effects, including climate change, overfishing and other environmental impacts.

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) and Coull *et al.* (1998), and the IHLS data. The IHLS data is used to complement the Ellis *et al* (2012) papers, providing a composite of inter annual variation across 10 years. The limitations of these sources of information should, however, be 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, where available, additional research publications have also been reviewed to provide site specific information.

3.7.5.2 Mobile species, such as fish, exhibit varying spatial and temporal patterns. All of the wind farm project site specific surveys, including, for example, 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, however, that the data collected during these surveys 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 Creyke Beck ES. With this in mind, 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 "scoped out"

3.8.1.1 Based on the baseline environment, the project description outlined in **Volume 1, Chapter 4: Project Description** and the Commitments detailed within **Volume 4, Annex 5.2: Commitments Register**, a number of impacts are proposed to be "scoped out" of the PEIR assessment for fish and shellfish ecology. These impacts are outlined, together with a justification for scoping them out, in **Table 3.8**. Further detail is provided in **Volume 4, 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
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities (FSE-C-1).	No likely significant effect	Scoped Out	Affected species are likely to be mobile and can move away from disturbance. The habitats that will be disturbed represent a small area of the total distribution of that habitat type in the central southern North Sea. Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance within the southern North Sea fish and shellfish study area.
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	Sensitivity of fish and shellfish species to pollution vary depending on the species lifecycle and behaviour. Highly mobile far ranging species generally are less sensitivity to pollution. However, less mobile species and eggs and larvae are more likely to have increased sensitivity. Species that generally stay within the development area and that have the potential to bioaccumulate toxins through trophic dynamics will have increased sensitivity.
EMF effects arising from cables (FSE-O-9).	No likely significant effect	Scoped Out	Species known to use EMFs for prey detection or navigation are molluscs and crustaceans, elasmobranchs and migratory fish. Based on the limited research for each species the sensitivity varies by species.
Direct disturbance resulting from maintenance during operation (FSE-O-10).	No likely significant effect	Scoped Out	Affected species are likely to be mobile and can move away from disturbance. The habitats that will be disturbed represent a small area of the total distribution of that habitat type in the central southern North Sea. Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance within the southern North Sea fish and shellfish study area.

Project activity and impact	Likely significance of effect	Approach to assessment	Justification
Indirect disturbance resulting from the accidental release of pollutants (FSE-O-11).	No likely significant effect	Scoped Out	Sensitivity of fish and shellfish species to pollution vary depending on the species lifecycle and behaviour. Highly mobile far ranging species generally are less sensitivity to pollution. However, less mobile species and eggs and larvae are more likely to have increased sensitivity. Species that generally stay within the development area and that have the potential to bioaccumulate toxins through trophic dynamics will have increased sensitivity.
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from decommissioning activities (FSE-D-13).	No likely significant effect	Scoped Out	Affected species are likely to be mobile and can move away from disturbance. The habitats that will be disturbed represent a small area of the total distribution of that habitat type in the central southern North Sea. Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance within the southern North Sea fish and shellfish study area.
Accidental pollution events during the construction phase resulting in potential effects on fish and shellfish receptors (FSE-D-17).	No likely significant effect	Scoped Out	Sensitivity of fish and shellfish species to pollution vary depending on the species lifecycle and behaviour. Highly mobile far ranging species generally are less sensitivity to pollution. However, less mobile species and eggs and larvae are more likely to have increased sensitivity. Species that generally stay within the development area and that have the potential to bioaccumulate toxins through trophic dynamics will have increased sensitivity.

Notes:
Grey – Potential impact is scoped out and both PINS and Hornsea Four agree.

3.8.2 Commitments

3.8.2.1 Hornsea Four has made several commitments (primary design principles inherent as part of the project, installation techniques and engineering designs/modifications as part of its pre-application phase, to eliminate a number of impacts or reduce impacts as far as possible). Further commitments (adoption of best practice guidance) are embedded as an inherent aspect of the EIA process (see **Volume 4: Annex 5.2 Commitments Register**).

3.8.2.2 The commitments adopted by Hornsea Four in relation to fish and shellfish ecology are presented in **Table 3.9**.

Table 3.9: Relevant fish and shellfish commitments.

Commitment ID	Measure Proposed	How the measure will be secured
Co44	The Holderness Inshore Marine Conservation Zone (MCZ) will not be crossed by the offshore export cable corridor including the associated temporary works area.	DCO Schedule 1, Part 1 Authorised Development
Co45	The Holderness Offshore MCZ will not be crossed by the offshore export cable corridor including the associated temporary works area.	DCO Schedule 1, Part 1 Authorised Development
Co83	Where possible, cable burial will be the preferred option for cable protection.	DCO Schedule 11, Part 2 - Condition 12(1)(h) and; DCO Schedule 12, Part 2 - Condition 12(1)(h) (Cable specification and installation plan)
Co85	No more than two foundations to be installed simultaneously.	DCO Schedule 11, Part 2 - Condition 12(1)(g) and; DCO Schedule 12, Part 2 - Condition 12(1)(g) (Marine mammal mitigation protocol)
Co110	A piling Marine Mammal Mitigation Protocol (MMMP) will be implemented during construction and will be developed in accordance with JNCC (2010) guidance. The piling MMMP will include details of soft starts to be used during piling operations with lower hammer energies used at the beginning of the piling sequence before increasing energies to the higher levels.	DCO Schedule 11, Part 2 - Condition 12(1)(g) and; DCO Schedule 12, Part 2 - Condition 12(1)(g) (Marine mammal mitigation protocol)
Co111	A Marine Pollution Contingency Plan (MPCP) will be developed. This MPCP will outline procedures to protect personnel working and to safeguard the marine environment and mitigation measures in the event of an accidental pollution event arising from offshore operations relating to Hornsea Four. The MPCP will also include relevant key emergency contact details.	DCO Schedule 11, Part 2 - Condition 12(1)(d)(i) and; DCO Schedule 12, Part 2 - Condition 12(1)(d)(i) (Marine pollution contingency plan)
Co113	A Decommissioning Marine Mammal Mitigation Protocol (MMMP), will be implemented during decommissioning. The Decommissioning MMMP will include measures to ensure the risk of permanent threshold shift (PTS) to marine mammals is negligible and will be in line with the latest relevant available guidance.	A separate Marine License will be applied for at the point of decommissioning which will include Conditions relevant to minimising impacts on marine mammals where appropriate.

3.9 Maximum Design Scenario

3.9.1.1 The maximum design scenarios (MDS) identified in **Table 3.10** have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in the project description (**Volume 1, Chapter 4: Project Description**). Effects of greater adverse significance are not predicted to arise should any other development scenario to that assessed here, based on details within the MDS (e.g. different turbine layout), be taken forward in the final design scheme.

Table 3.10: Maximum design scenario for impacts on fish and shellfish ecology.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Construction			
Temporary localised increases in SSC and smothering (FSE-C-2).	Primary: Co44 Co45	**Wind Turbine Foundations:** • 180 turbines on suction caisson jacket foundations requiring seabed preparation, resulting in the suspension of 2,134,440 m^3 of sediment; *Or* • 180 turbines on piled foundations with 10% of locations requiring drilling to the full length of the pile, resulting in a drill arising volume of 127,235 m^3. **OSS Foundations:** • Nine suction caisson foundations requiring seabed preparation, resulting in the suspension of 737,130 m^3 of sediment; *Or* • Nine piled foundations drilled to 10% of pile depth, resulting in a drill arising volume of 13,854 m^3. **Offshore Accommodation Platform Foundations:** • One suction caisson foundation requiring seabed preparation, resulting in the suspension of 57,245 m^3 of sediment; *Or* • One piled foundation drilled to 10% of pile depth, resulting in a drill arising volume of 1,540 m^3. **Array Cable Sandwave Clearance:** • Sandwave clearance across 18 km^2 of seabed with an impact width of 15 m per cable resulting in the suspension of 961,000 m^3 of sediment. **Array Cable Trenching:** • Cable installation by MFE of array cables, interconnector cables, and part of the export cables within the array resulting in the suspension of 4,140,000 m^3 of sediment.	The maximum adverse scenario for foundation installation results from the largest volume suspended from seabed preparation (suction caisson jackets) or the largest volume suspended from potential drilling of foundations (monopiles) as these are mutually exclusive, both with the maximum number of foundations (180). For cable installation, the maximum adverse scenario results from the greatest volume from sandwave clearance and installation using energetic means (MFE). This also assumes the largest number of cables and the greatest burial depth.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		HVAC Booster Station Foundations: • 3 suction caisson foundations requiring seabed preparation, resulting in the suspension of 171,735 m^3 of sediment; *Or* • 3 piled foundations drilled to 10% of pile depth, resulting in a drill arising volume of 4,618 m^3. **Sandwave Clearance:** • Sandwave clearance across a 99 km corridor for 6 cables resulting in the suspension of 757,000 m^3 of sediment. **Cable Trenching:** • Installation of 6 cables by MFE resulting in the suspension of 3,543,000 m^3 of sediment (excluding the part of the export cable within the array). **Cable Jointing:** • Up to 17,500 m^3 of sediment from up to four cable joints per export cable. **Total:** • 12,879,050 m^3 (seabed preparation for suction caisson foundations). *Or* • 9,925,747 m^3 (drilling for piled foundations).	
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-C-3).	Primary: Co44 Co45	The MDS for seabed disturbance are presented in the rows above.	As above.
Mortality, injury, behavioural changes and auditory	Primary: Co85	**Array Area (spatial MDS):** • Monopile wind turbine foundations • 180 wind turbine foundations	Piling: The spatial worst case results from the installation of monopile foundations for 180 WTGs, 9 offshore substations and an

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
masking arising from noise and vibration (FSE-C-4).	Tertiary: Co110	• Six offshore transformer substations • Three offshore converter substations • One offshore accommodation platform • Maximum hammer energy 5,000 kJ • 4-hour piling duration • 1.2 days per monopile • 216 piling days (single vessel) • 106 piling days (2 vessels) **Array Area (temporal MDS):** • 180 wind turbines on piled jacket foundations (3 piles per jacket) – 540 pin piles • Six offshore transformer substations on piled jacket foundations (6 legs per jacket and 4 piles per leg – 144 pin piles • Three offshore converter substations on piled jacket foundations (8 legs per jacket and 2 piles per leg – 48 pin piles • One offshore accommodation platform on a piled jacket foundation (6 legs and 4 piles per leg – 24 pin piles • *Total of 756 pin piles in the array* • Maximum hammer energy 2,500 kJ • 1.5 days per jacket foundation • 270 piling days (single vessel) • 135 days (2 vessels) **HVAC Booster Area of Search (spatial MDS):** • Three HVAC booster stations on monopile foundations • Maximum hammer energy 5,000 kJ • 4-hour piling duration • 1.2 days per monopile **HVAC Booster Area of Search (temporal MDS):** • Three HVAC booster stations on piled jackets (6 legs per jacket and 4 piles per leg – 72 pin piles	offshore accommodation platform using 5,000 kJ hammer energy. This would result in the largest spatial noise impact at any given time. The temporal worst case would be associated with the installation of the maximum number of piles; the worst-case scenario would be the installation of 180 WTGs using piled jacket foundations, resulting in the piling of 540 piles. The worst case for OSS installation is the greatest number of piles, based on the installation of six medium OSSs on six leg jacket foundations, requiring 4 piles per leg requiring 144 piles and three large OSSs on 8 leg jackets requiring 24 pin piles. In addition, on accommodation platform could be installed on a 6 leg jacket with 4 piles per leg requiring 24 pin piles. For HVAC booster stations, the spatial MDS is based on 3 stations on monopiles, and the temporal MDS is based on 3 stations on piled jacket foundations. Cable Installation: The MDS for cable installation would result in the greatest noise impacts from construction activities. Vessel Activity: The instalment of WTG foundations is predicted to have the greatest noise impacts from vessel activity. UXO clearance: The MDS for UXO clearance would result in 86 detonations, across 86 days. UXO clearance will be carried out

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		Interconnector Cable Installation: • 6 circuits/cables • Total length of interconnector cables: 90 km • Total duration of cable installation: 24 months **Export Cable Installation:** • Where possible, the export cables will be buried below the seabed through to landfall. • Total length of export cables: 654 km • Total duration of cable installation: 24 months **Vessel Disturbance During Wind Turbine Foundation Installation:** • 4 installation vessels (90 return trips) • 16 support vessels (360 return trips) • 40 Transport / Feeder vessels (incl. Tugs) (360 return trips) **Wind Turbine Installation:** • 2 installation vessels (90 return trips) • 12 Support vessels (270 return trips) • 24 transport (540 return trips) **Substation Foundation Installation (including Accommodation and HVAC Booster Station Foundations):** • 2 installation vessels (24 return trips) • 12 support vessels (108 return trips) • 4 transport vessels (48 return trips) **Substation Platform Installation (including Accommodation and HVAC Booster Station Platforms):** • 2 installation vessels (36 return trips) • 12 support vessels (162 return trips) • 4 transport vessels (72 return trips)	~one to two years prior to the start of offshore construction works. The MDS assumes UXO will be identified and it will not be possible to be avoided or removed from the seabed and disposed of in a designated area

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		Inter-Array and Interconnector Cable Installation: • 3 Main cable laying vessels (204 return trips) • 3 Main burial vessels (204 return trips) • 12 support vessels (1,080 return trips) **Offshore Export Cable Installation:** • 3 main cable laying vessels (96 return trips) • 3 main cable jointing vessels (72 return trips) • 3 main cable burial vessels (96 return trips) • 15 support vessels (144 return trips). **Unexploded Ordnance (UXO) Clearance:** • Estimated 2,263 targets • 86 UXOs may require clearance. • One UXO will be cleared every 24 hours • 86 detonations in 86 days	
Operation			
Temporary localised increases in SSC and smothering FSE-O-18).	Primary: Co44 Co45	**Array and Interconnector Remedial Cable Burial:** • 2000 m per replacement • 10 m wide corridor • 49 km total lifetime replacement • Maximum volume of sediment from cable reburial over lifetime: 294,000 m^3 **Array and Interconnector Cables Repairs:** • 20,000 m^2 per repair event • 15 repair events over lifetime • 3 m burial depth • Maximum volume of sediment from cable repairs over lifetime: 900,000 m^3 **Export Cables Remedial Cable Reburial:**	The worst case impacts from remedial cable burial and cable repairs of array, interconnector and export cables result from the use of MFE. This assumes the largest number of cables, repair events, the greatest burial depth and greatest length/area of maintenance. This results in the worst case sediment volume disturbance of 3,382,624 m^3.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• 2000 m per replacement • 10 m corridor • 14 km replacement over lifetime • Maximum volume of sediment from cable reburial over lifetime: 88,624 m^3 **Export Cable Repairs:** • 20,000 m^2 per event • 35 repair events over lifetime • 3 m burial depth • Maximum volume of sediment from cable repairs over lifetime: 2,100,000 m^3 **Total:** • 3,382,624 m^3 (volume of sediment from cable replacement and reburial in the array and offshore area)	
Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (FSE-O-6).	Primary: Co44 Co45 Co83	**Wind Turbine Foundations (including scour protection):** • 180 WTGs • suction bucket jacket foundations = 795,216 m^2 **Offshore Transformer Substation Foundations (including scour protection):** • 6 small and 3 large OSS • HVDC: GBS (Box-type) & GBS (Large OSS) foundations = 371,250 m^2 **Offshore HVAC Booster Substations (including scour protection):** • GBS (Box-type) foundations = 91,875 m^2 **Offshore Accommodation Platform (including scour protection):** • GBS (Box-type) foundations = 30,625 m^2 **Cable Protection:** • 624,000 m^2 array cables = (scour protection from construction phase) + 156,000m^2 (25% replenishment of scour protection during O&M phase) = 780,000 m^2	Cable protection (based on worst case scenario of rock berm) may be required in the unlikely event that cables cannot be buried (based on 10% of the length), in addition to this, cable replenishment may also be required (based on 25% of the cable protection area) resulting in a footprint of 1,887,500 m^2 (based on a post lay protection width of 10.4 m). The maximum area of cable protection deployed will result in the greatest area of habitat loss.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
		• Offshore interconnector cables = 94,000 m^2 + 23,500m^2 (25% cable replenishment) = 117,500 m^2 • Offshore export cables = 792,000 m^2 + 198,000 m^2 (25% cable replenishment) = 990,000 m^2 • Total footprint = 1,887,500 m^2 **Cable Crossings:** • Cable crossings within the array area (Pre- and post-lay rock berm area) = 255,000 m^2 (40 crossings) • Cable crossings in the ECC area (Pre- and post-lay rock berm area) = 268,000 m^2 (10 crossings) • Total footprint = 523,000 m^2 **Total Habitat Loss/Change:** • 3,699,466 m^2	
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	**Total Introduced Hard Substrate:** • 3,699,466 m^2	Cable protection (based on worst case scenario of rock berm) may be required in the unlikely event that cables cannot be buried (based on 10% of the length) in addition to this, cable replenishment may also be required (based on 25% of the cable protection area) resulting in a footprint of 1,887,500 m^2 (based on a post lay protection width of 10.4 m). The maximum area of cable protection deployed will result in the greatest area of habitat loss.
Underwater noise as a result of operational turbines (FSE-O-8).	N/A	• 180 operational wind turbines	This results in the maximum potential for noise disturbance on fish and shellfish receptors during the operation and maintenance phase.

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
Potentially reduced fishing pressure within the Hornsea Four array area and increases fishing pressure outside the array area due to displacement (FSE-O-12).	N/A	**Project Design Life:** • 35 years **Safety Zones:** • 500 m safety zone around infrastructure (construction and decommissioning) • 50 m safety zone around incomplete structures (construction and decommissioning) • 500 m safety zone around manned infrastructures (operation and maintenance) • 500 m safety zone around infrastructure undergoing major maintenance (operation and maintenance). **Total Reduced Area:** • 662,240 m^2	Assessment assumes that fisheries will not be excluded from the Hornsea Four proposed development area, however, due to logistical constraints, fishing pressure may be reduced.
Decommissioning			
Temporary localised increases in SSC and smothering (FSE-D-14).	Primary: Co44 Co45	MDS is identical (or less) to that of the construction phase.	WTGs will be removed by reversing the methods used to install them. Pile foundations will likely be cut approximately 1m below the seabed. The area of seabed impacted during the removal of the WTGs would be the same as the area impacted during installation. The OSSs will likely be a reverse installation. The area of the seabed disturbed by decommissioning activities will be the same as the area impacted during installation. If piled foundations are used, they will likely be cut approximately 1 m below the seabed. It is likely that equipment similar to that which is used to install the cables could be used to reverse the burial process and expose them. Therefore, the area of seabed impacted during the removal of the cables

Impact and Phase	Embedded Mitigation Measures	Maximum Design Scenario	Justification
			could be the same as the area impacted during the installation of the cables. Any scour protection will be left in situ.
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-D-15).	Primary: Co44 Co45	MDS is identical (or less) to that of the construction phase.	See row above.
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-D-16).	Tertiary: Co113	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 Guidance

3.10.1.1 Guidance on the EIA process has been sought from the following resources:

- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater and Coastal, Second Edition (Chartered Institute of Ecology and Environmental Management (CIEEM) 2016); and
- Guidance note for EIA in Respect of Food and Environment Protection Act 1985 (FEPA) and Coast Protection Act 1949 (CPA) Requirements (Cefas *et al.* 2004).

3.10.1.2 In addition, the EIA will follow the legislative framework as defined by the Wildlife and Countryside Act 1981 (as amended), the Water Framework Directive and the Marine and Coastal Access Act, 2009, with consideration of the Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017, although these relate to the Habitats Regulations Assessment (HRA) and not specifically to EIA.

3.10.2 Impact assessment criteria

3.10.2.1 The criteria for determining the significance of effects is a two-stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The terms used to define sensitivity and magnitude are based on those used in the CIEEM (2016) methodology.

3.10.2.2 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)
	Very minor benefit to, or positive addition of one or more characteristics, features or elements (Beneficial)

3.10.2.3 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, with the final assessment for each effect based upon expert judgement. For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations.

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

		Magnitude of Impact/Degree of Change			
		Negligible	**Minor**	**Moderate**	**Major**
Value, Importance, Sensitivity	Low	Not Significant	Not Significant or Minor (Not Significant)	Minor (Not Significant)	Minor (Not Significant) or Moderate (Significant)
	Medium	Not Significant	Minor (Not Significant)	Moderate (Significant)	Moderate (Significant) or Major (Significant)
	High	Not Significant	Minor (Not Significant) or Moderate (Significant)	Moderate (Significant) or Major (Significant)	Major (Significant) or Substantial (Significant)
	Very High	Not Significant	Moderate (Significant) or Major (Significant)	Major (Significant) or Substantial (Significant)	Substantial (Significant)

3.10.2.4 Where Natura 2000 sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the interest features of internationally designated sites as described within **Section 3.7.1.8** of this chapter (with the assessment on the site itself deferred to the RIAA Report for Hornsea Four). The draft RIAA has been prepared in accordance with PINS Advice Note Ten: Habitats Regulations Assessment Relevant to Nationally Significant Infrastructure Projects (PINS, 2017) and will be submitted to stakeholders for consultation alongside the PEIR.

3.10.2.5 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 Report for Hornsea Four), 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.

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

3.11.1.2 Temporary localised increases in suspended sediment concentration (SSC) and associated sediment deposition are expected from foundation and cable installation works and seabed preparation works (including sandwave clearance). **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Process** and **Volume 5, Annex 1.1: Marine Processes Technical Report** provide a full description of the offshore physical environment assessment, with a summary of the MDS associated with the impact, as detailed in **Table 3.10** of this PEIR chapter.

Magnitude of impact

3.11.1.3 **Table 3.10** presents the MDS associated with increases in SSC and deposition. MDS for SSC and deposition during the construction phase of Hornsea Four to be the total release of 12,879,050 m^3 of sediment in the array area and offshore ECC, from seabed preparation for suction caisson foundations.

3.11.1.4 Seabed preparation for foundation cables, sandwave clearance, cable trenching, drilling for foundations and spoil dispersal are all predicted to cause sediment plumes. Plumes are expected to be restricted to well-within the tidal excursion from slack water to peak flows, with plumes expected to occur over a maximum distance of 2 km. An increase in SSC of 2 mg/l above background levels is predicted local to the source; these concentrations are expected to reduce with dispersion, with sediments remaining in suspension for up to three hours.

3.11.1.5 At the disposal site the sediment plume is expected to an increase in SCC of > 10 mg/l above background over an excursion distance of up to 13.5 km from the foundations. Peak concentrations of 500 to 800 mg/l were predicted at a site very close to the release of spoil. All peak concentrations were localised and short-lived.

3.11.1.6 Sediment deposition from the plume is predicted to occur up to 2 km from the source, with maximum depth of 2 mm from the deposition of finer sediments (silts and muds). Coarser sediments are predicted to be deposited local to the source. In the case of drilling for monopiles the deposition of coarse sediments may result in the accumulation of sediment of up to tens of centimetres to meters. For this assessment, this will be considered as habitat loss, and is therefore assessed in **paragraphs 3.11.2.10** *et seq.*

3.11.1.7 The magnitude of the maximum potential increase in SSC resulting from construction activities is within the natural range of SSC (2 to 14 mg/l closer inshore, reducing offshore to around 2 to 3 mg/l.), within the region and the impact will be short-term, intermittent and of localised extent (within one tidal excursion) and reversible. Taking into consideration the localised nature of herring spawning grounds to Hornsea Four, the magnitude of impact from an increase in SSC from construction within the array area on herring is assessed as **minor**, and the magnitude of impact on herring from construction within the HVAC booster station location is assessed as **minor**. Due to the presence of sandeel habitats across the southern North Sea, the magnitude of impact from increased SSC from construction within the array area and the HVAC booster station is also considered to be **minor.**

Sensitivity

3.11.1.8 High intensity spawning sites for herring occur in the vicinity of the HVAC booster station location along the ECC, and therefore the spawning sites are likely to be indirectly impacted by sediment deposition. 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 no recoverability to the impact, and of regional importance, and therefore the sensitivity of the receptor is **high**.

3.11.1.9 Sandeel spawning grounds and preferred habitats (**Figure 3.4**) 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. 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 to 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, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is **medium**.

Significance of effect

3.11.1.10 Increases in SSC and associated 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. Overall, the magnitude of the impact has been assessed as Minor for both herring and sandeel at both the array area and the HVAC booster station, with the sensitivity of herring being assessed as High**.** The significance of effect therefore is deemed **minor** for herring, which is not significant in EIA terms. The sensitivity of sandeel is assessed as Medium and therefore the significance of effect is **minor** for sandeel which is also not significant in EIA terms.

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

3.11.1.11 As identified in **Table 3.10** and assessed in the above section, 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.

3.11.1.12 An assessment of subtidal sediment contamination within the array area was undertaken in **Volume 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**. The results revealed that the majority of hydrocarbons observed within the Hornsea Four array were within expected background concentrations with some elevation present close to existing infrastructure which was as expected. Gas Chromatography (GC) traces across the Hornsea Four array were generally indicative of background levels of hydrocarbons in areas of historic oil and gas exploration and suggested a mixture of petrogenic and pyrogenic sources. All hydrocarbons were below thresholds likely to exert an effect on the marine environment. All metals concentrations were below their respective apparent effect threshold (Buchman, 2008), which indicated that toxicological impacts are therefore unlikely to pose a threat to the marine environment. Values of dibutyltin (DBT) and tributyltin (TBT) across the Hornsea Four array area were reportedly below the limit of detection.

Magnitude of Impact

3.11.1.13 The total MDS area that is likely to be disturbed by construction activities, and therefore the potential volume of material disturbed will be 12,879,050 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 5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**), typically with relatively low levels of fines adhering to them.

3.11.1.14 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 3.11.1.2 *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 bio-availability 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 of a low quality that may result in a significant effect-receptor pathway if made bioavailable. The impacts to herring and sandeel from construction in both the array area and the HVAC booster station as a result of the release of sediment-bound contaminants are therefore considered to be of **negligible** magnitude, and are not considered further in this assessment, as it will not lead to a significant effect.

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

3.11.1.15 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 offshore substations). While other activities such as cable laying, dredging and vessel movements will result in underwater noise, these have the potential to affect a relatively small area in the immediate vicinity of activities and are therefore considered insignificant in the context of the underwater noise from piling operations.

3.11.1.16 To inform this impact assessment, predictive subsea noise modelling has been undertaken at four locations, with consideration of the key parameters associated with these two scenarios (e.g. hammer energies and pile diameters). Full details of the modelling undertaken are presented in **Volume 4, Annex 4.5: Subsea Noise Technical Report**.

3.11.1.17 The spatial and temporal MDS hammer energies are detailed in **Table 3.10,** however the estimates are considered conservative. In order to present a realistic picture of piling impacts throughout the construction phase the following piling scenarios, with associated hammer energies, have been defined to inform the assessment:

- Absolute maximum hammer energy of up to 5,000 kJ for monopiles; and
- Most likely maximum hammer energy of 4,000 kJ.

3.11.1.18 The temporal MDS represents the longest duration of effects from subsea noise (the maximum number of piles installed). The temporal MDS hammer energies are detailed in full in **Table 3.10,** however estimates are considered conservative. As with the spatial maximum design scenario, the following piling scenarios, with associated hammer energies for pin pile installation, have been defined to inform the assessment:

- Absolute maximum hammer energy of up to 2,500 kJ; and
- Most likely maximum hammer energy of 1,750 kJ.

3.11.1.19 As detailed in **Table 3.10**, as part of the site preparation activities for Hornsea Four, UXO clearance will be completed within the Hornsea Four array area and ECC, one to two years prior to the start of construction. Until detailed pre-construction surveys are undertaken across the Hornsea Four array area and ECC, the 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 is 86. The MDS assumes that each of these will be detonated, noting that many of these may not be UXO or may be left *in situ* and microsited around. 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, these effects would be considerably reduced compared to those associated with piling operations. As such, since Hornsea Four are not applying for licence to detonate UXO at this stage, therefore no further consideration of the impacts from UXO clearance is provided here.

3.11.1.20 Underwater noise can potentially have a negative impact on fish 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. However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. Fish 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 key data gap.

3.11.1.21 For the purposes of the assessment, **Volume 4, Annex 4.5: Subsea Noise Technical Report** presents the results of modelling for a range of noise levels, representing both the MDS and the most likely noise levels. The modelling results for cumulative sound exposure level (SEL_{cum}) represent 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 and nursery grounds. Demersal spawners herring and sandeel are considered stationary receptors to account for their spawning behaviours.

Injury Criteria

3.11.1.22 The fish receptors within the Hornsea Four study area have been grouped into the Popper *et al*. (2014) categories (see **Table 4** of **Volume 4, Annex 4.5: Subsea Noise Technical Report**) based on their hearing system, as outlined in **Table 3.14** below. The injury criteria for fish are also summarised in **Table 4** of **Volume 4, Annex 4.5: Subsea Noise Technical Report**.

Table 3.14: 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)

3.11.1.23 The worst-case results of the modelling for injury ranges for fleeing and stationary fish (from modelled locations Northwest of the array, and at the HVAC booster station) are presented in **Appendix A** of this document for monopile (spatial MDS) and pin pile (temporal MDS) installation. The complete noise modelling dataset is presented in the **Subsea Noise Technical Report (Volume 4, Annex 4.5)**.

Mortality and potential mortal injury

Sandeel

3.11.1.24 Sandeel (>219 dB SEL_{cum}) 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 lack a swim bladder and are therefore less sensitive to sound pressures, however they are thought to be affected by vibration through the seabed, particularly when buried in the seabed during hibernation. The noise modelling undertaken in Hornsea Four suggests that the potential for mortality and potential mortal injury of spawning sandeel from noise impacts of monopile installation may occur up to 760 m from the array area and the HVAC booster station (5,000 kJ hammer energy, based on SEL_{cum}). Noise modelling for the most likely impacts from monopile installation (4,000 kJ hammer energy) showed the potential for mortality and potential mortal injury may occur up to 300 m from the array, and from the HVAC booster station, a significantly reduced impact than that proposed in from the MDS. Sandeel preferred habitats and spawning grounds are widely distributed across the Southern North Sea (**Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report**), and therefore in the context of the wider environment, the impacts are considered to be small.

Herring

3.11.1.25 Herring (207 dB SEL_{cum}) are a mobile species and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' pilin, however herring are considered sensitive to sound pressure components of underwater noise, due to having a swim bladder involved in hearing, and from their demersal spawning nature. Due to key herring spawning grounds located within the vicinity of the array area and the HVAC booster station (**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 sake of this assessment. Monopile installation (5,000 kJ hammer energy) in the array area and the HVAC booster station location, represent the spatial MDS for noise impacts on herring; the noise contours are shown in relation to herring spawning grounds and larvae abundances (IHLS and Coull *et al.*, 1998 data sources) in **Figure 3.7** to **Figure 3.14**. Noise modelling undertaken within the Hornsea Four study area suggests the potential for mortality and potential mortal injury of herring during peak spawning season (October to September) may occur up to 5,100 m from the array area and 5,000 m from the HVAC booster station (5,000 kJ hammer energy, based on SEL_{cum}). However, there is no overlap from the array noise contours with herring spawning grounds, or areas of high larval abundances (**Figure 3.7**, and **Figure 3.8**). The noise contour 207 dB SEL_{cum} from monopile installation at the HVAC booster station location however, does occur within moderate intensity herring spawning grounds and spawning activity (**Figure 3.10**). Noise impacts from monopile installation at the HVAC booster station location on fleeing (non-spawning) herring are expected to be significantly less (< 100 m), and within the immediate vicinity of the piling activity (**Figure 3.9**).

3.11.1.26 Noise modelling for the most likely impacts from monopile installation (4,000 kJ hammer energy) showed the potential for mortality and potential mortal injury in this scenario may occur up to 2,400 m from the array and from the HVAC booster station on (spawning herring), a significantly reduced impact than that proposed from the MDS hammer energies. There is no overlap from the most likely array noise contours with herring spawning grounds, or areas of high larval abundances (**Figure 3.12**. The noise contour 207 dB SEL_{cum} from monopile installation at the HVAC booster station location however, does occur within moderate intensity herring spawning grounds and spawning activity (**Figure 3.14**). Noise impacts from monopile installation at the HVAC booster station location on fleeing (non-spawning) herring are expected to be significantly less (< 100 m), and within the immediate vicinity of the piling activity (**Figure 3.13**).

Eggs and larvae

3.11.1.27 Sandeel (Group 1 receptors) and herring (Group 3 receptors) both have spawning grounds within the vicinity of Hornsea Four; eggs and larvae are considered organisms of concern by Popper *et al*. (2014), due to their vulnerability, reduced mobility and small size. Modelling results from the Hornsea Four study area show that for the spatial MDS hammer energy of 5,000 kJ (monopile foundations) the greatest mortality and potentially mortal injury of eggs and larvae may occur between a mean range of 1,300 m from the array area, and up to 1,200 m from the HVAC booster station location (based on SPL_{peak}). For 2,500 kJ hammer energy (pin pile foundations), the greatest mortality and potentially mortal injury effects may occur between a mean range of 770 m from the array area and 760 m from the HVAC booster station (based on SPL_{peak}). Taking into consideration the cumulative sound energy, the modelling results for monopile installation (5,000 kJ hammer energy) show that mortality and potential mortal injury of eggs and larvae may occur up to a mean range of 3,300 m from the array area and from the HVAC booster station. Mortality and potential mortal injury of eggs and larvae from noise impacts from pin pile installation (2,500 kJ) in the array area may occur up to a mean range of 2,200 m from the array area, and up to 2,100 m from the HVAC booster station (based on SEL_{cum}).

3.11.1.28 The most likely mortality and potentially mortal injury of eggs and larvae has also been modelled for the array area and the HVAC booster station locations; these are presented in **Appendix A**. Modelling results from the Hornsea Four study area show that for the most likely hammer energy of 4,000 kJ (monopile foundations) the greatest mortality and potentially mortal injury of eggs and larvae may occur up to a mean range of 1,100 m from the array area, and from the HVAC booster station location (based on SEL_{peak}). For 1,750 kJ hammer energy (pin pile foundations), the greatest mortality and potentially mortal injury effects may occur up to a mean range of 550 m from the array area and from the HVAC booster station (based on SPL_{peak}). Taking into consideration the cumulative sound energy, the modelling results for monopile installation (4,000 kJ hammer energy) show that mortality and potential mortal injury of eggs and larvae may occur up to a mean range of 1,100 m from the array area and up to 1,500 m from the HVAC booster station. Mortality and potential mortal injury of eggs and larvae from noise impacts from pin pile installation (1,750 kJ) in the array area may occur up to a mean range of 760 m from the array area, and the HVAC booster station (based on SEL $_{cum}$).

Other fish and shellfish VERs

3.11.1.29 The majority of other fish and shellfish VERs of Hornsea Four are Group 1 fish receptors, with the exception of whiting and cod (Group 3 receptors); these species are all considered mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. Both whiting and cod have spawning grounds and nursery grounds across the array area and offshore Section of the ECC. MDS noise impacts (5,000 kJ hammer energy) from monopile installation in the context of eggs and larvae (207dB SEL $_{cum}$) may occur up to 3,300 m from the array area and the HVAC. With the most likely noise impacts (4,000 kJ) having the potential to occur up to 1,500 m from the array area and the HVAC booster station. In the context of the wider spawning and nursery grounds in the region, the impacts are considered to be small. In addition to this, prolonged exposure could be reduced by any drift of eggs/larvae due to water currents which may reduce the risk of mortality.

Recoverable Injury

3.11.1.30 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 and mortality/potentially 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.

3.11.1.31 The results of the noise modelling for recoverable injury in different receptor groups are presented in **Table 3.23** for modelling locations surrounding the array, and **Table 3.24** showing results from the HVAC booster station. For the spatial MDS hammer energy of 5,000 kJ (monopiles) recoverable injury may occur up to 1,100 m from the array in receptor Groups 2 and 3 (based on SPL $_{peak}$.). For the temporal MDS of pin pile installation (2,500 kJ hammer energy) recoverable injury may occur in Group 3 receptors, up to 770 m from the array area (based on SPL $_{peak}$).

3.11.1.32 Considering cumulative sound energy, the spatial MDS modelling results for monopile installation (5,000 kJ hammer energy) within the array area show that recoverable injury would be greater for stationary receptors than for fleeing receptors (fleeing at a rate of 1.5 ms^{-1}). The spatial MDS noise impacts causing recoverable injury may occur up to 8,200 m from the array in receptor Groups 2 and 3 (based on SEL $_{cum}$). For 2,500 kJ hammer energy (pin pile foundations in the array area) the temporal MDS of recoverable injury may occur in receptor Groups 2 and 3, up to 5,900 m from the array (based on SEL $_{cum}$).

3.11.1.33 The most likely hammer energy of 4,000 kJ for monopile installation (represents the spatial MDS) recoverable injury may occur up to 370 m from the array and the HVAC booster station in receptor Group 1, and 1,100 m from the array and the HVAC booster station in receptor groups 2 and 3 (based on SPL $_{peak.}$). The most likely hammer energy of 1,750 kJ for pin pile installation (temporal MDS) recoverable injury may occur in Group 1 receptors, up to 180 m from the array area and HVAC booster station, and up to 550 m from the array area and HVAC booster station in receptor groups 2 and 3 (based on SPL $_{peak.}$).

3.11.1.34 Considering the most likely cumulative noise energy, the modelling results for the spatial MDS of monopile installation (4,000 kJ hammer energy) show that recoverable injury would be greater for stationary receptors than for fleeing receptors (fleeing at a rate of 1.5 ms^{-1}). The most likely noise impacts from monopile installation causing recoverable injury in fleeing receptors in all receptor groups are predicted to occur <100 m from the array, and from the HVAC booster station (based on SEL $_{cum}$). In comparison, recoverable injury in stationary receptors is predicted to occur up to 520 m from the array area and 1,500 m from the HVAC booster station in Group 1 receptors, 4,400 m from the array area and 510 m from the HVAC booster station in Group 2 receptors, and 4,400 m from the array area and 4300 m from the HVAC booster station in Group 3 receptors.

Sandeel

3.11.1.35 The potential for recoverable injury of sandeel from the spatial MDS noise impacts of monopile installation (5,000 kJ hammer energy) may occur up to 430 m from the array area and 1,300 m from the HVAC booster station (based on SEL $_{cum}$). Noise modelling for the most likely impacts from monopile installation (4000 kJ hammer energy) show that the potential for recoverable injury in this scenario may occur up to 520 m from the array area on stationary receptors, and 300 m from the HVAC booster station, a significantly reduced impact than that proposed in from the MDS. Sandeel preferred habitats and spawning grounds are widely distributed across the Southern North Sea (**Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report**), and therefore in the context of the wider environment, the impacts are considered to be small.

Herring

3.11.1.36 Monopile installation (5,000 kJ hammer energy) in the array area and the HVAC booster station location, 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 3.7** to **Figure 3.10**. The potential for recoverable injury of herring during spawning season (October to September) may occur up to 8,200 m from the array area and 8,100 m from the HVAC booster station (5,000 kJ hammer energy, based on SEL $_{cum}$). However, there is no overlap from the array modelling locations with herring spawning grounds (Coull *et al*, 1998), or areas of high larval abundances (IHLS data) (**Figure 3.7** and **Figure 3.8**). The noise contour 203 dB SEL_{cum} from monopile installation at the HVAC booster station location however, does occur within moderately high intensity herring spawning grounds and spawning activity (**Figure 3.10**). Noise impacts from monopile installation on fleeing (non-spawning) herring are expected to be significantly less (up to 460 m from piling surrounding the array), and within the immediate vicinity of the piling activity (**Figure 3.9**).

3.11.1.37 Noise modelling for the most likely impacts from monopile installation (4,000 kJ hammer energy) showed the potential for recoverable injury in this scenario may occur up to 4,400 m from the array area, and 2,499 m from the HVAC booster station, on stationary (spawning) herring, a significantly reduced impact than that proposed from the MDS modelling scenario. No overlap from the array modelling locations with herring spawning grounds (Coull *et al*, 1998) or areas of high larval abundances (IHLS data) are observed (**Figure 3.11** and **Figure 3.12**). The noise contour 203 dB SEL_{cum} from monopile installation at the HVAC booster station location however, does occur within moderately high intensity herring spawning grounds and spawning activity (**Figure 3.14**). Noise impacts from monopile installation on fleeing (non-spawning) herring are expected to be significantly less (< 100 m from piling surrounding the array), and within the immediate vicinity of the piling activity (**Figure 3.13**).

Eggs and larvae

3.11.1.38 Eggs and larvae close to the substrate are considered vulnerable to vibration associated with the ground roll generated by pile driving (Popper *et al*, 2014). 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 3.4** to **Figure 3.5**), and therefore in accordance to 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.

Other fish and shellfish VERS

3.11.1.39 The majority of other fish and shellfish VERs of Hornsea Four are Group 1 receptors, with the exception of whiting and cod being Group 3 receptors; these species are all considered mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. Both whiting and cod have spawning grounds and nursery grounds across the array area and offshore Section of the ECC. The areas impacted by noise in the context of the wider spawning and nursery grounds in the region are considered to be small.

Temporary Threshold Shift (TTS)

3.11.1.40 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.

3.11.1.41 **Appendix A**, **Table 3.23** and **Table 3.24** present the ranges at which TTS in fish may occur as a result of piling operations during the Hornsea Four construction phase, for the spatial MDS hammer energy for monopiles (5,000 kJ) and the temporal MDS scenario represented by pin pile installation (2,500 kJ), for both stationary and mobile receptors surrounding Hornsea Four (Note: TTS ranges for most likely hammer energies, i.e. 4,000 kJ and 1,750 kJ, were also modelled, the results of which are tabulated in **Appendix A**, **Table 3.25** and **Table 3.26**, these are drawn upon in the following assessment).

3.11.1.42 The spatial MDS modelling results for monopile installation (5,000 kJ) within the array area show that TTS would be greater for stationary receptors than fleeing receptors (fleeing at a rate of 1.5ms $^{-1}$). The MDS noise impacts from monopile installation (5,000 kJ) causing TTS on stationary receptors may occur up to 29 km from the array in receptor Groups 2 and 3 (based on SEL $_{cum}$), and up to 28 km from the HVAC booster station. The temporal modelling for pin pile installation (2,500 kJ) TTS may occur in all three receptor groups, up to 25 km from the array, and 24 km from the HVAC booster station (based on SEL $_{cum}$).

3.11.1.43 The most likely scenario modelling results for monopile installation (4,000 kJ) within the array area show that TTS would be greater for stationary receptors than fleeing receptors (fleeing at a rate of 1.5ms -1). The noise impacts from monopile installation (4,000 kJ) causing TTS on stationary receptors may occur up to 21 km from the array and HVAC booster station in all receptor groups (based on SEL $_{cum}$). For 1,750 kJ hammer energy (pin pile installations) TTS may occur in all three receptor groups, up to 16 km from the array, and 17 km from the HVAC booster station (based on SEL $_{cum}$). In comparison, fleeing receptors (at 1.5 ms^{-1}) may experience TTS up to 9 km from the array area, and 14 km from the HVAC booster station (based on SEL $_{cum}$).

Sandeel

3.11.1.44 The potential for TTS of sandeel (> > 186 dB SEL $_{cum}$) may occur up to 29 km from the array area and up to 28 km from the HVAC booster station (MDS of 5,000 kJ hammer energy, based on SEL $_{cum}$). Noise modelling for the most likely impacts from monopile installation (4,000 kJ hammer energy) showed the potential for TTS in this scenario may occur up to 21 km from the array area and from the HVAC booster station, a reduced impact than that predicted from the MDS hammer energies.

Herring

3.11.1.45 The spatial MDS noise contours representing monopile installation (5,000 kJ) are shown in relation to herring spawning grounds (Coull *et al.*, 1998) and larvae abundances (IHLS data) in (**Figure 3.7** to **Figure 3.10**). The potential for TTS on herring (>> 186 dB SEL$_{cum}$) during spawning season (October to September) may occur up to 29 km from the array area and 28 km from the HVAC booster station (5,000 kJ hammer energy, based on SEL $_{cum}$). Temporal MDS modelling for pin pile installation (2,500 kJ) TTS may occur in all three receptor groups, up to 25 km from the array, and 24 km from the HVAC booster station (based on SEL $_{cum}$).

3.11.1.46 Noise modelling for the most likely impacts from pin-pile installation (4,000 kJ) showed the potential for TTS in this scenario may occur up to 21 km from the array area and from the HVAC booster station, a reduced impact than that predicted from the MDS hammer energies. Modelling locations from the array area show monopile noise contours (>> 186 dB SEL $_{cum}$) overlap with herring spawning grounds (Coull *et al.*, 1998) (**Figure 3.7** and **Figure 3.8**), and the most significant potential for TTS on spawning herring may occur from monopile installation at the HVAC booster station location (**Figure 3.10**), where the >> 186 dB SEL $_{cum}$ noise contour overlaps an area of peak larval abundance.

Eggs and larvae

3.11.1.47 Impacts on herring eggs and larvae were assessed using the Popper *et al.* (2014) criteria, in terms of risk of recoverable injury **paragraph 3.11.1.38**. The Popper *et al.* (2014) criteria for TTS are the same, and therefore a moderate degree of disturbance at a near field distance from the source is predicted on herring eggs and larvae.

Other fish and shellfish VERs

3.11.1.48 The majority of other fish and shellfish receptors of Hornsea Four are Group 1 receptors, with the exception of whiting and cod being Group 3 receptors; these species are all considered mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. Both whiting and cod have spawning grounds and nursery grounds across the array area and offshore Section of the ECC. The areas impacted by noise in the context of the wider spawning and nursery grounds in the region are considered to be small.

Behavioural Impacts

3.11.1.49 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. 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. The ASA guidelines (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 4, Annex 4.5: Subsea Noise Technical Report**.

3.11.1.50 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 fish (e.g. sandeel) and shellfish (e.g. *Nephrops*) in close proximity to piling operations.

Herring

3.11.1.51 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 or auditory masking 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. Key spawning habitats for herring are located in close proximity to the Hornsea Four HVAC booster station, and therefore adult spawning herring within these habitats would be expected to be affected by 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 or auditory masking in herring from piling are expected to be Moderate in the far field, and High within the intermediate field.

Sandeel

3.11.1.52 Sandeel (Group 1 receptor) lack a swim bladder, and therefore have low sensitivity to impacts from noise, therefore behavioural effects on this species are expected to be reduced. 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.

Eggs and larvae

3.11.1.53 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 3.11.1.38**. The Popper *et al.* criteria for behavioural effects are the same, and therefore a moderate degree of disturbance at a near field distance from the source is predicted on eggs and herring eggs and larvae.

Other fish and shellfish VERs

3.11.1.54 The majority of other fish and shellfish receptors of Hornsea Four are Group 1 receptors, with the exception of whiting and cod being Group 3 receptors; these species are all considered mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. Therefore, taking into consideration the Popper *et al* (2014) criteria, any risk of behavioural effects or auditory masking in Group 1 VER receptors from piling are expected to be a low degree of disturbance at a far field distance. The Group 3 VER receptors from piling are expected to be Moderate in the far field, and High within the intermediate field.

Magnitude of impact

3.11.1.55 Considering the temporal impacts on sandeel and herring, the impact of construction related underwater noise is predicted to be of short to medium term duration. The total piling time for three HVAC booster stations (the location of closest proximity to high intensity herring spawning grounds), with six legged jackets, and four piles per leg equates to 288 hours. In the context of a peak eight-week spawning period for both herring and sandeel (1,344 hours), this equates to approximately 21.4% of the spawning period potentially impacted by piling noise. This also assumes that piling will occur within the spawning periods of both herring and sandeel, with noise contours overlapping the entire spawning ground. Noise contours from the array area have no overlap with high intensity herring spawning grounds (**Figure 3.7, Figure 3.8, Figure 3.11,** and **Figure 3.12**), and therefore the temporal impacts from piling on herring are predicted to be low. Sandeel spawning habitats are located across the southern North Sea (See **Volume 5, Annex 3.1: Fish and Shellfish Ecology Technical Report**) and therefore temporal impacts on sandeel in the context of the wider environment are considered small. The spatial impacts are expected to be of local to regional extent. Taking into consideration the locations of herring spawning grounds relative to the piling locations of Hornsea Four (**Figure 3.3**), and the limited temporal impacts, the magnitude of effect on herring from piling within the array area and the HVAC booster station are both assessed as being **minor.** Sandeel spawning habitats are located across the southern North Sea and the Hornsea Four study area (**Figure 3.1**), and therefore taking this into account, the magnitude of impact in the context of the wider environment is considered small, and therefore the magnitude of effect on sandeel at both the array area, and the HVAC booster station is assessed as being **minor.**

3.11.1.56 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 effect on all other VERs is assessed as being **minor** from impacts at both the array and the HVAC booster station.

Sensitivity

3.11.1.57 Sandeel (Group 1 receptor) are deemed to be of low vulnerability, medium recoverability and of regional importance. The sensitivity of the receptor to noise impacts is therefore considered to be **medium**.

3.11.1.58 Herring (Group 3 receptor) are considered to be of high vulnerability, with no ability for recovery and of regional importance. With reference to **Figure 3.7** to **Figure 3.14**, the HVAC booster station modelling location resulted in the greatest potential for impacts on receptors, with noise contours occurring within the Coull *et al.* (1998) herring spawning grounds, and overlapping areas of high herring larval abundance indicated by the IHLS herring larval abundance data. The sensitivity of herring to noise impacts is therefore considered to be **high**.

3.11.1.59 There are no specific criteria currently published in respect of shellfish species, however studies on lobsters have shown no effect on mortality, appendage loss or the ability of animals to regain normal posture after exposure to very high sound levels (>220 dB) (Payne *et al.* 2007). Similarly, studies of marine bivalves (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). All other fish and shellfish VERs within the study area are deemed to be of low vulnerability, medium recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be **medium**.

Significance of effect

3.11.1.60 Construction related underwater noise will represent a temporary, short to medium term duration (i.e. up to a 2.5-year piling phase) and intermittent impact, affecting a relatively small proportion of the habitats study area. In addition to this, taking into account the locations of herring spawning grounds relative to the piling locations of Hornsea Four (**Figure 3.3**), the magnitude of effect on herring from piling within the array area is assessed as being Minor, and due to the proximity of high intensity spawning grounds to the HVAC booster station, the magnitude of effect of piling at this location on herring is assessed as being Minor. Sandeel spawning habitats are located across the southern North Sea, and therefore the magnitude of impact in the context of the wider environment is considered small; taking this into account, the magnitude of effect of piling on sandeel at both the array area, and the HVAC booster station is assessed as being Minor.

3.11.1.61 Sandeel lack a swim bladder and are therefore considered less sensitive to underwater noise. Sandeel spawning and nursery habitats occur over a large area across the southern North Sea, including within the Hornsea Four array area and offshore Section of the ECC. Due to their demersal nature, sandeel were considered a stationary receptor to underwater noise in this assessment, and therefore would be exposed to underwater noise from construction. However, due to their reduced sensitivity, and small degree of disturbance to spawning grounds in the context of the wider habitat availability in the southern North Sea, the species were assessed as having Medium sensitivity to underwater noise during construction, and therefore the effect on sandeel at both the array and the HVAC booster station is predicted to be of **minor** significance (not significant in EIA terms).

3.11.1.62 Herring 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. Herring are demersal spawners, and were therefore considered stationary receptors in the assessment, increasing their exposure to underwater noise from the construction phase of the development. Due to their sensitivity to underwater noise, and likelihood of disturbance to spawning herring, the species were assessed as having High sensitivity to underwater noise during construction, and therefore the effect on herring is predicted to be of **minor** significance at both the array and the HVAC booster station (not significant in EIA terms).

3.11.1.63 The majority of other VERs in this assessment lack swim bladders and were therefore considered to be less sensitive to noise. Whilst some VERs have spawning and nursery grounds within the study area, they typically occur over a large area of the southern North Sea, any disturbance to spawning is considered small in the context of the wider habitat availability. Whiting and cod both have swim bladders involved in hearing. Both species have spawning and nursery grounds occurring over a large area across the wider southern North Sea, and therefore any disturbance from construction noise to spawning is considered small in the context of the wider habitat availability. Both species are considered mobile, and therefore would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. Taking all of this into account, all other VERs are assessed as having Medium sensitivity to underwater noise during construction, and therefore the effects on these species at the array and the HVAC booster station location are predicted to be of **minor** significance (not significant in EIA terms).

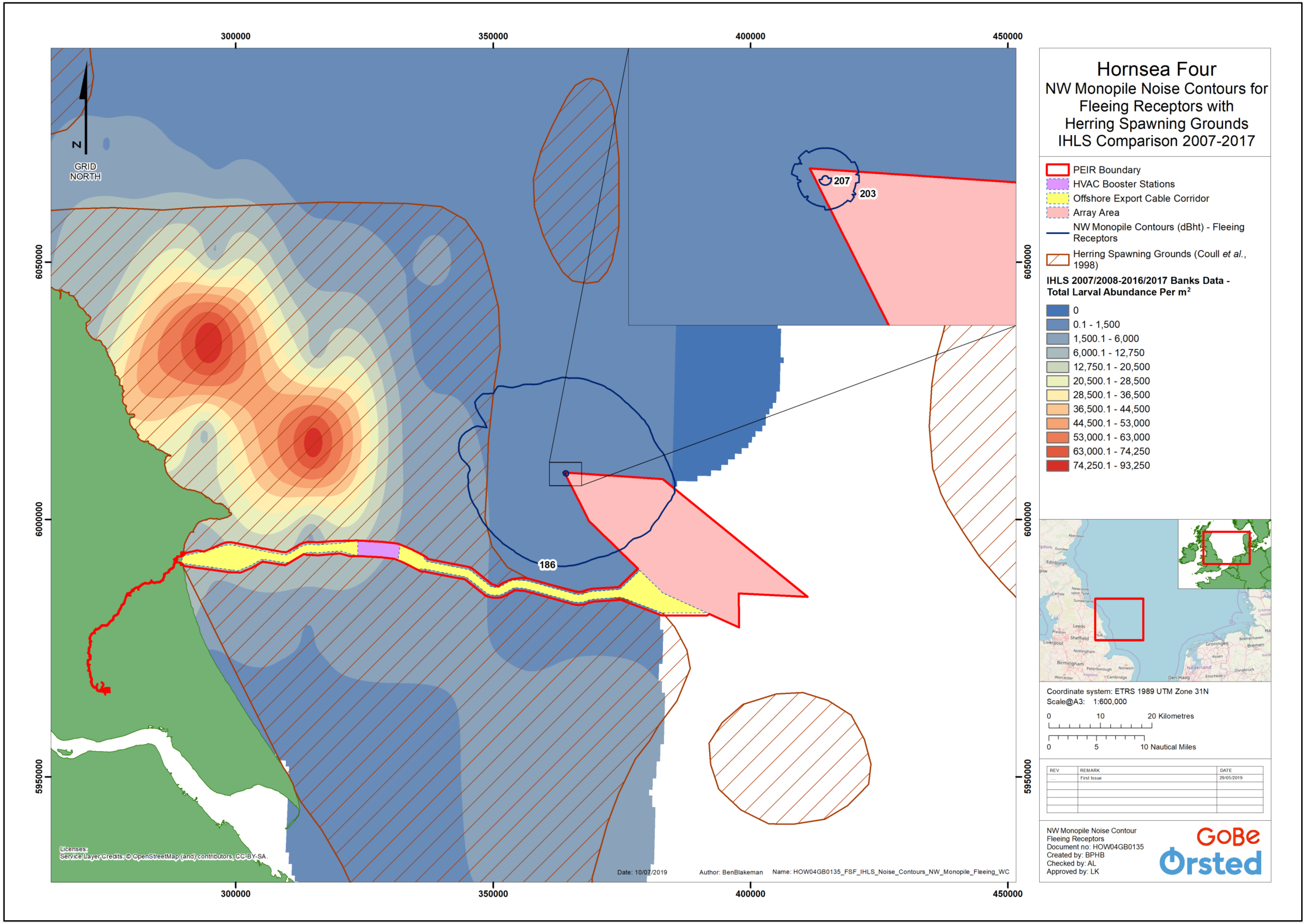

Figure 3.7: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the MDS piling scenario of monopile foundations (5,000 kJ hammer energy) at the Northwest modelling location of the array area (fleeing receptors at a rate of 1.5 ms^{-1}) (not to scale).

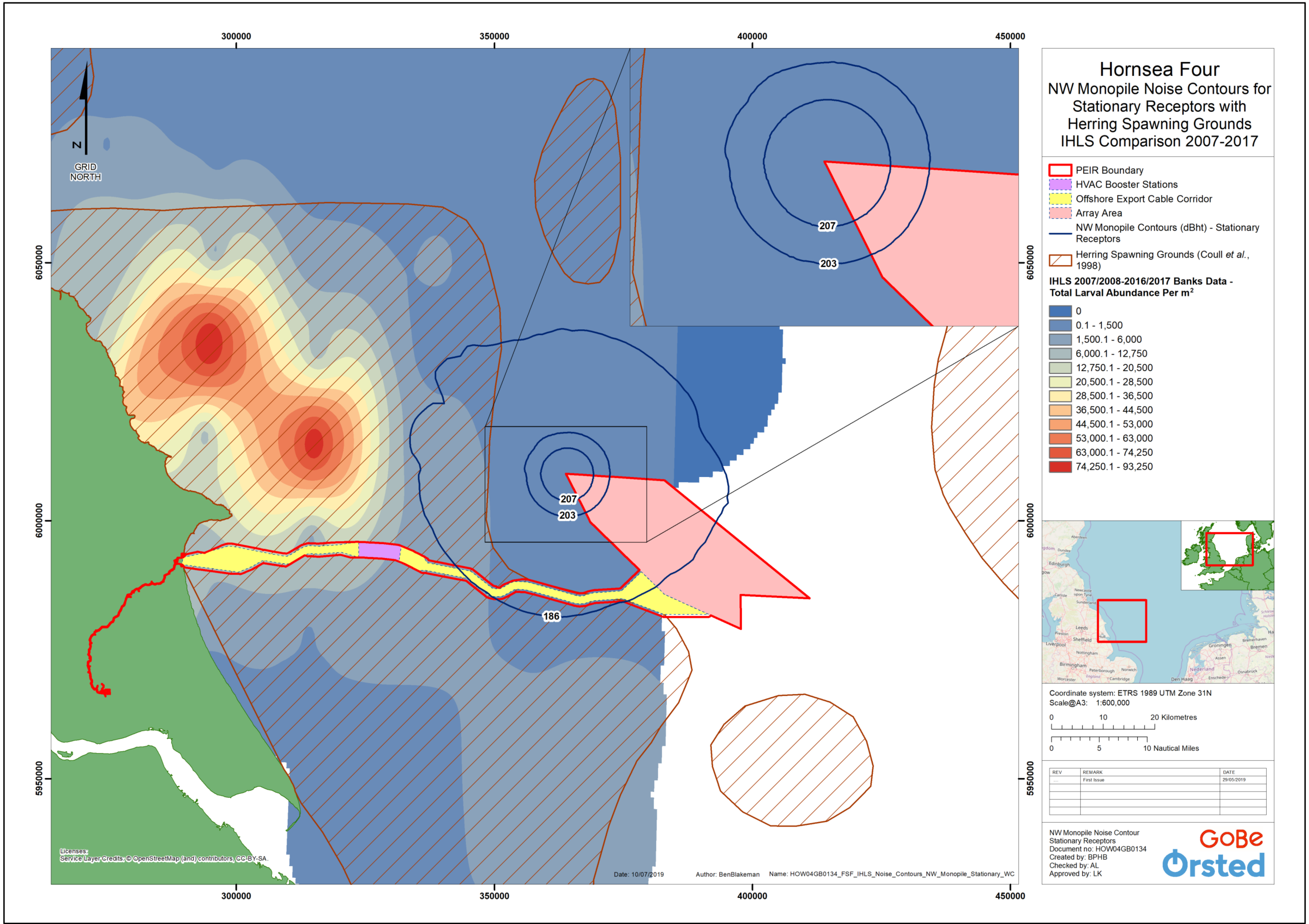

Figure 3.8: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the MDS piling scenario of monopile foundations (5,000 kJ hammer energy) at the Northwest modelling location of the array area (stationary receptors) (not to scale).

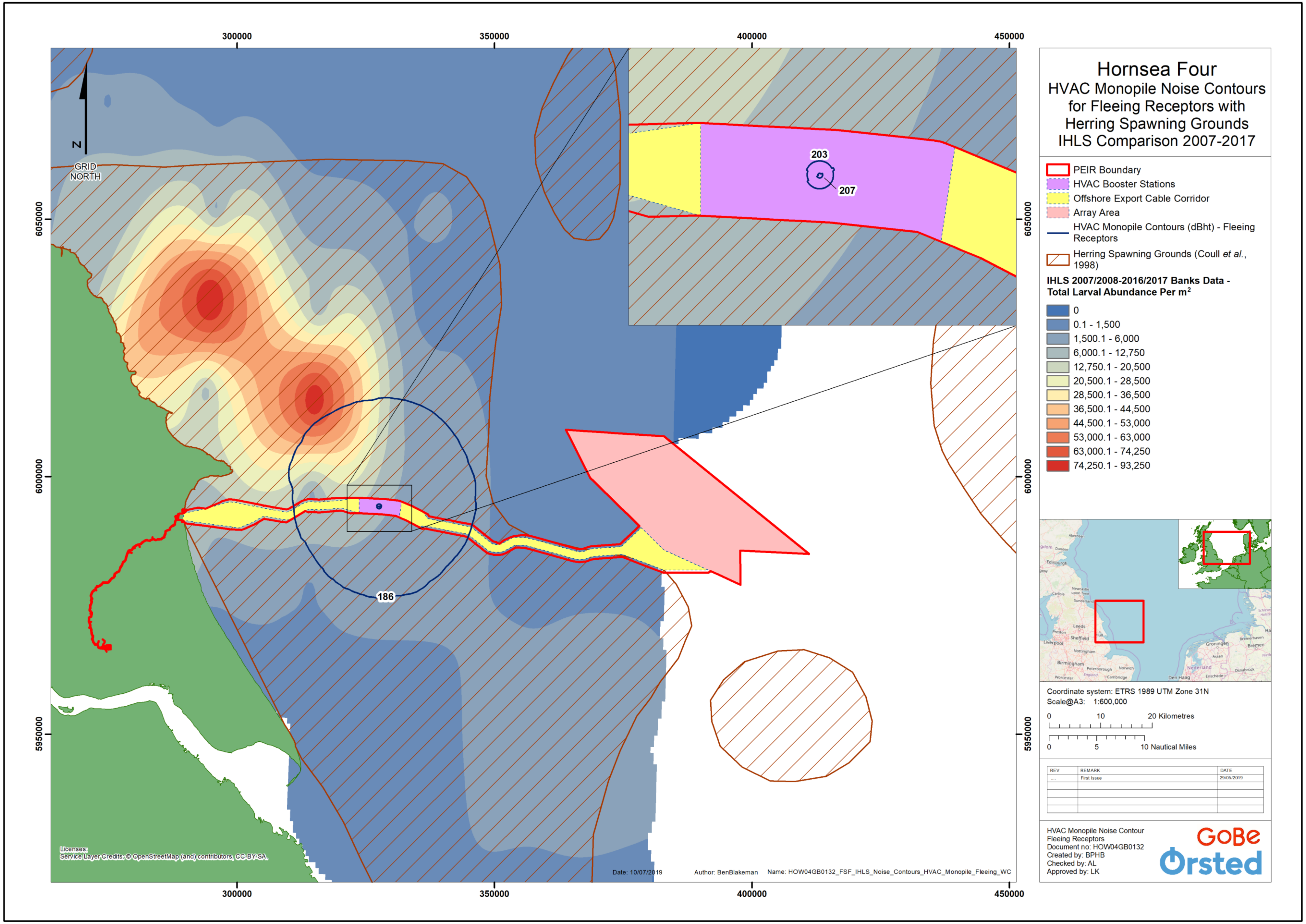

Figure 3.9: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the MDS piling scenario of monopile foundations (5,000 kJ hammer energy) at the HVAC booster station modelling location (fleeing receptors at a rate of 1.5 ms^{-1}) (not to scale).

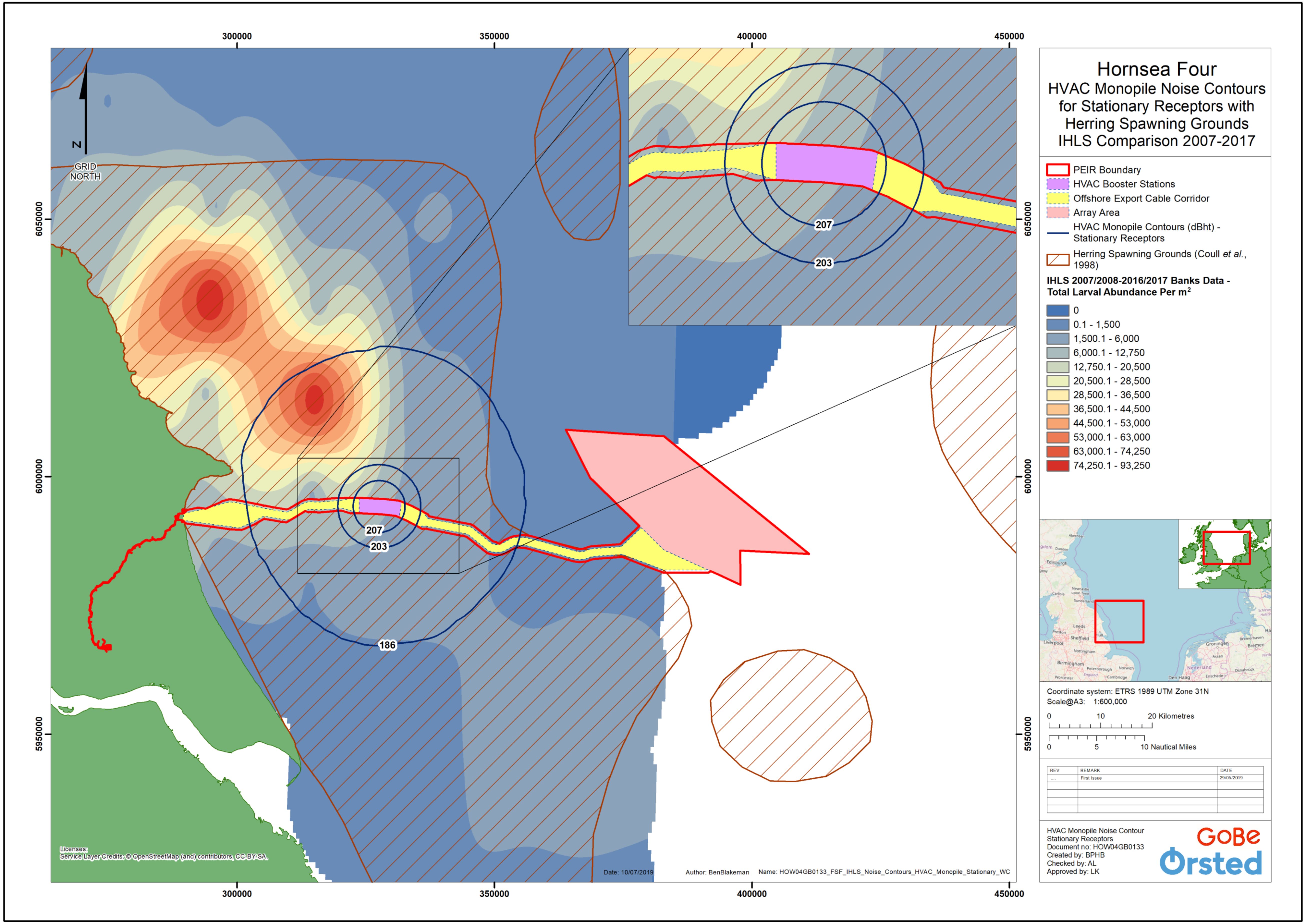

Figure 3.10: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the MDS piling scenario of monopile foundations (5,000 kJ hammer energy) at the HVAC booster station modelling location (stationary receptors) (not to scale).

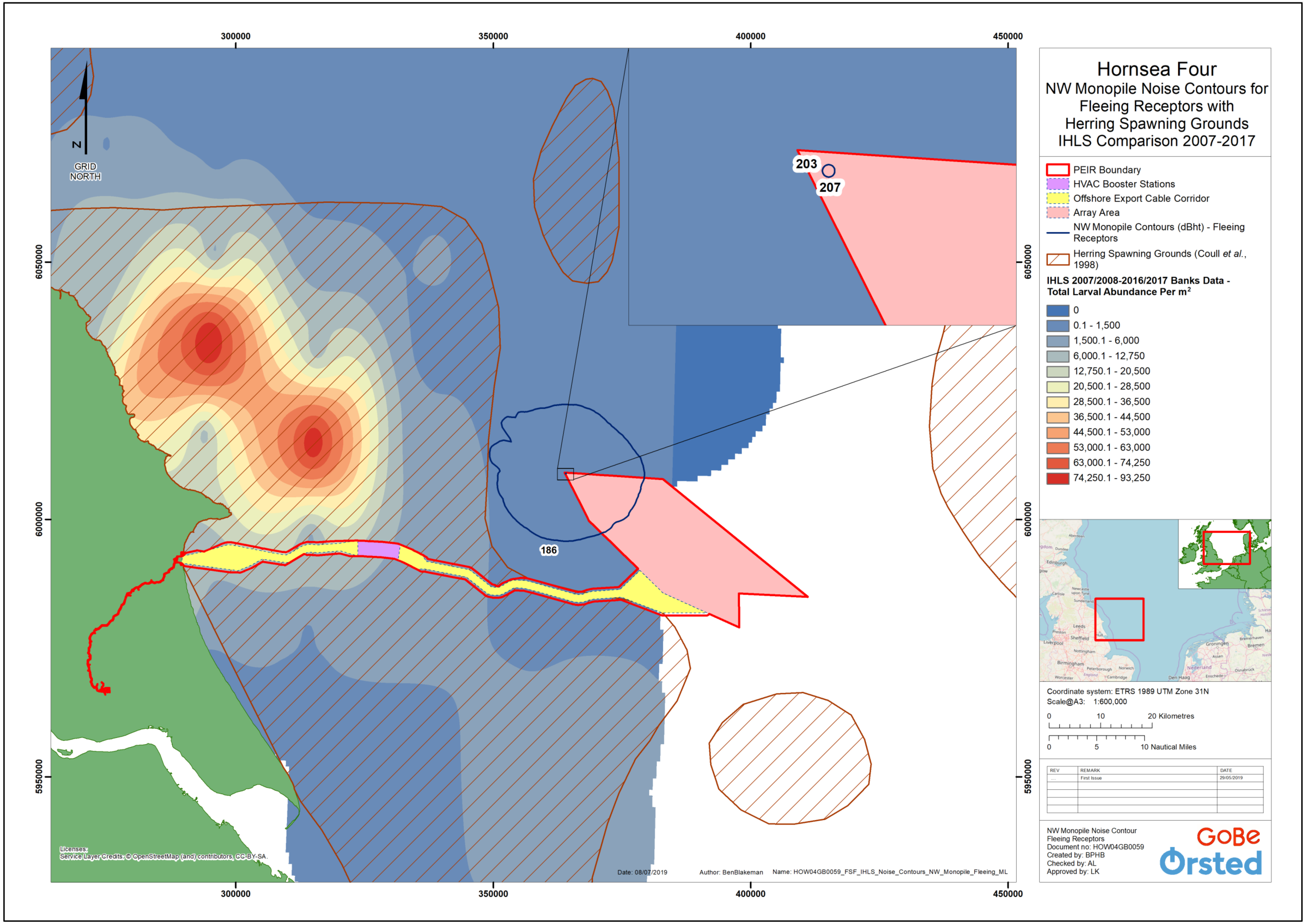

Figure 3.11: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the at the Northwest modelling location of the array area (fleeing receptors at a rate of 1.5 ms^{-1}) (not to scale).

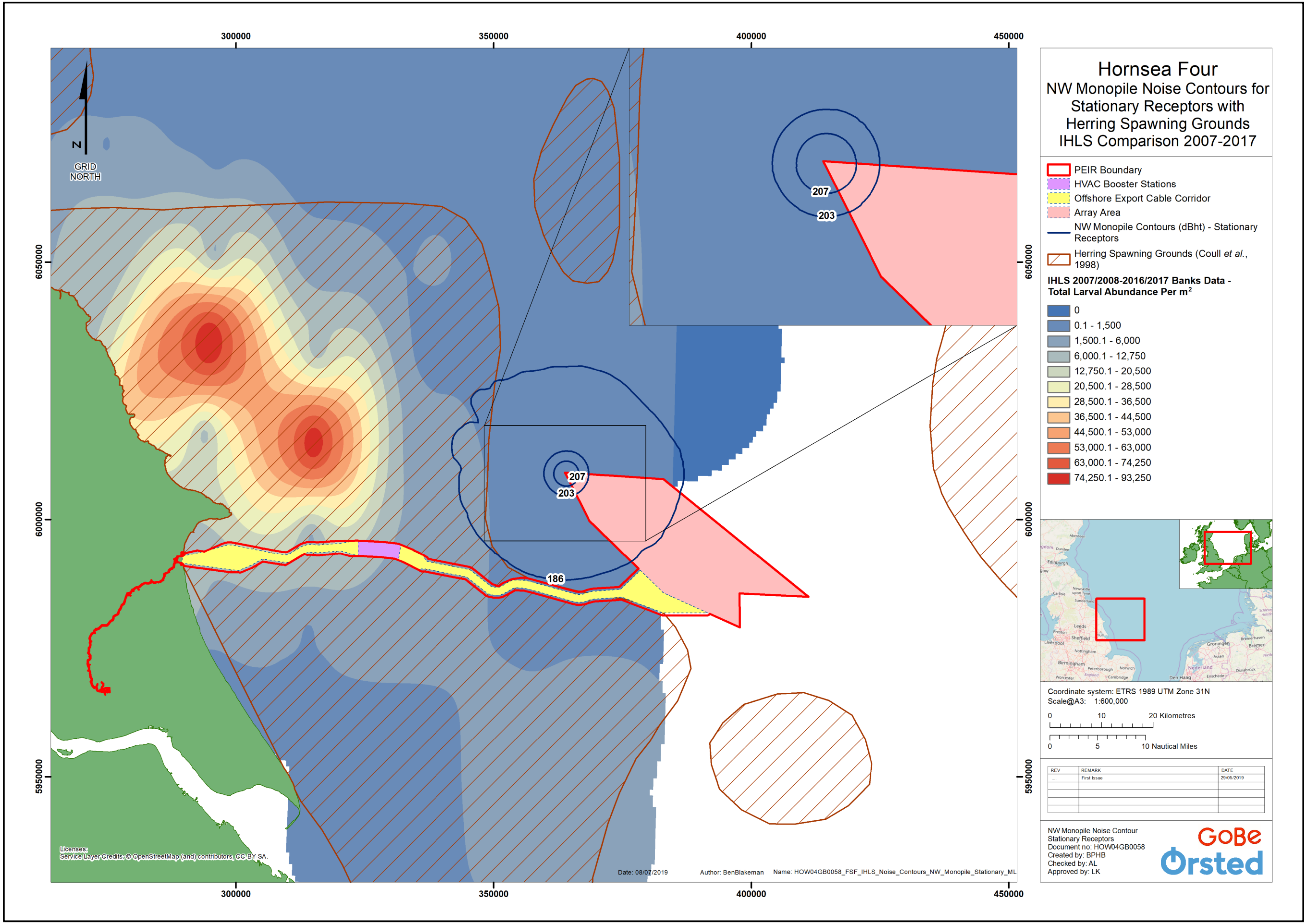

Figure 3.12: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the at the Northwest modelling location (stationary receptors) (not to scale).

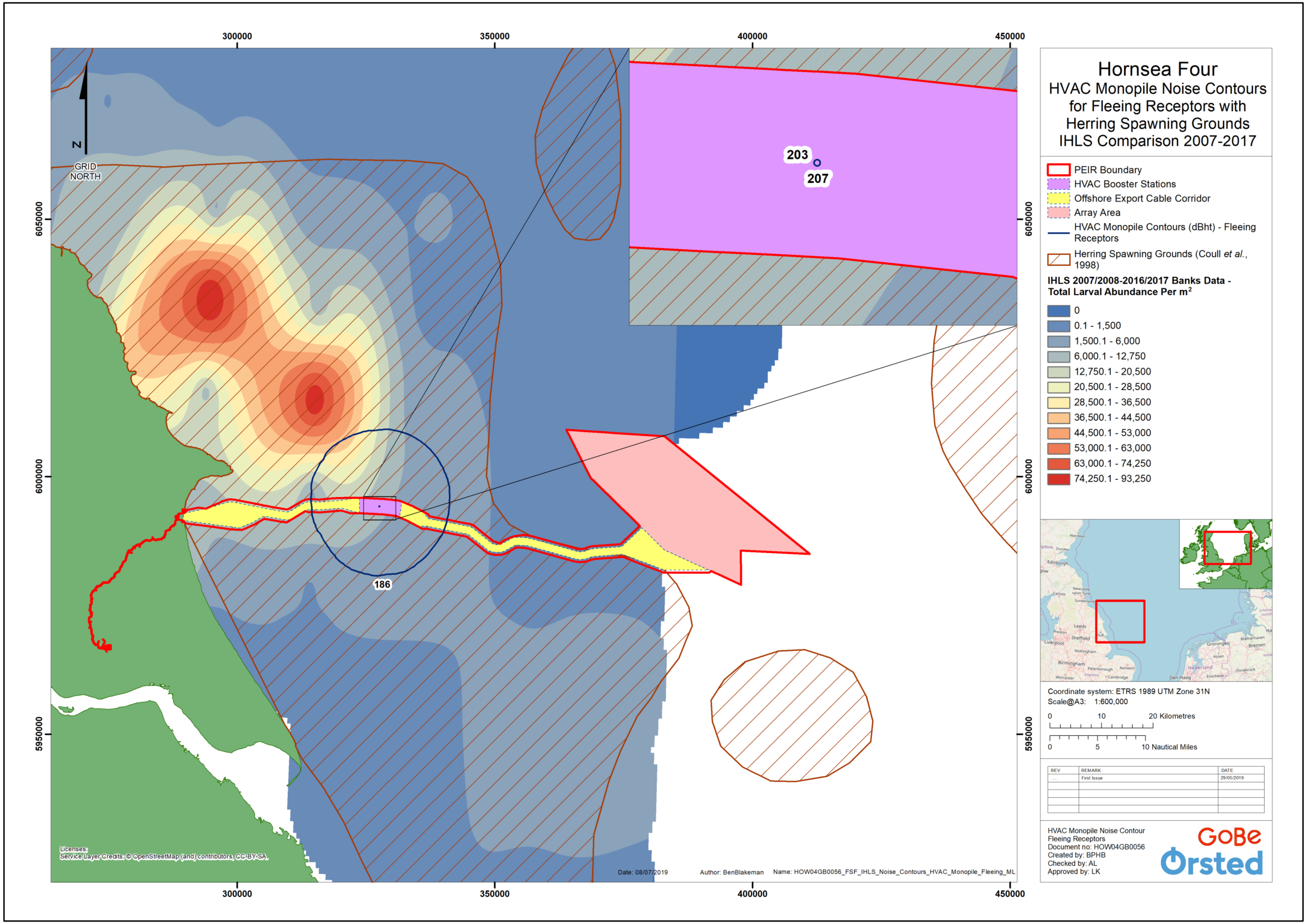

Figure 3.13: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the at the HVAC booster station modelling location (fleeing receptors at a rate of 1.5 ms^{-1}) (not to scale).

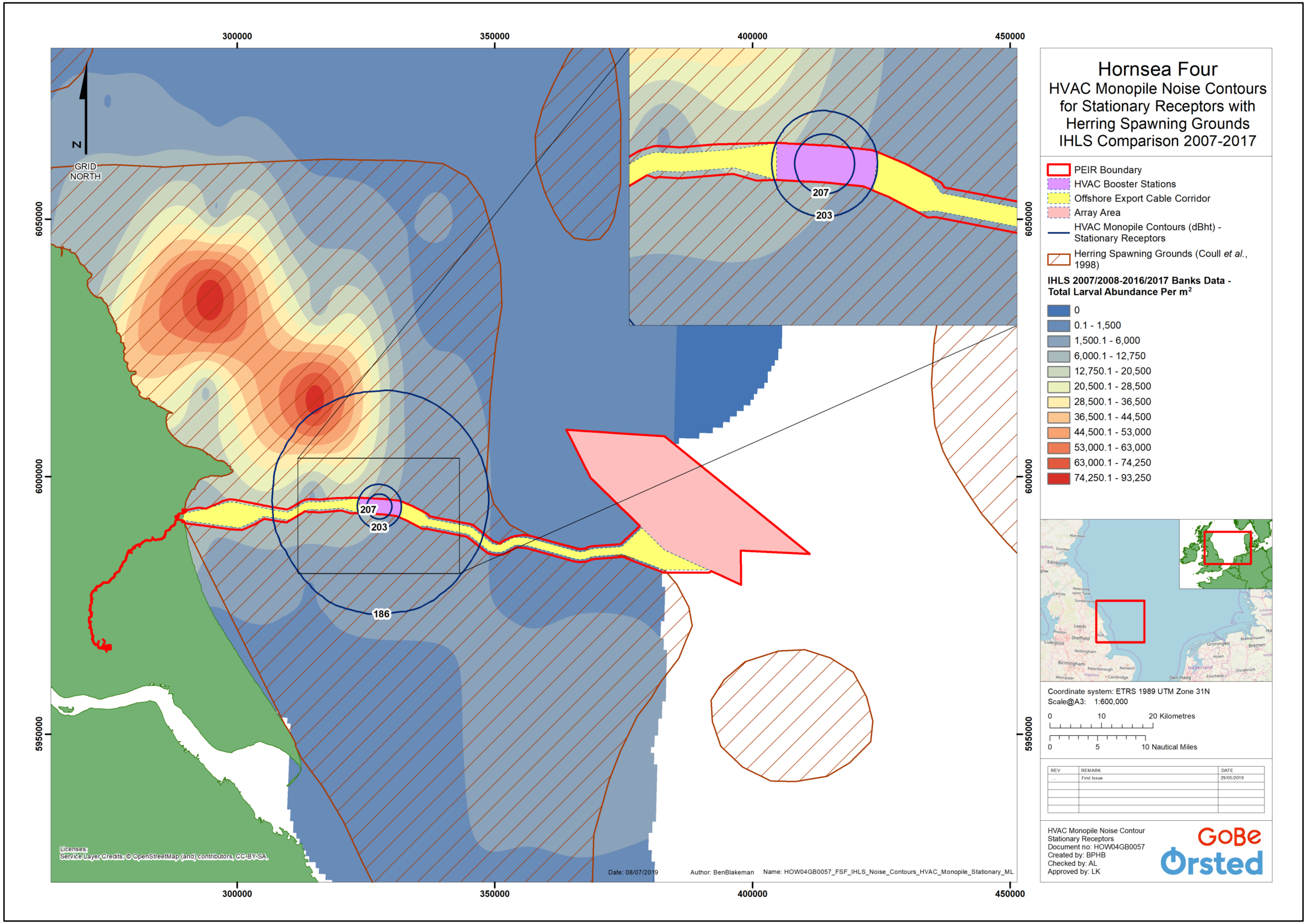

Figure 3.14: Herring spawning habitats (Coull *et al*, 1998) presented alongside IHLS (2014) dataset, with underwater noise contours (unweighted SEL $_{cum}$) associated with the most likely piling scenario of monopile foundations (4,000 kJ hammer energy) at the at the HVAC booster station modelling location (stationary receptors) (not to scale).

Noise and vibration arising from Unexploded Ordnance clearance

3.11.1.64 Prior to the start of construction activities at Hornsea Four, it will be necessary for the Applicant to provide the contractors undertaking the work with a certificate that confirms that the risk from unexploded ordnance (UXO) is as low as reasonably possible (ALARP). This will require UXO investigation works and potentially require the clearance of UXO in situ which will result in emission of underwater noise.

3.11.1.65 The Applicant is not applying for permission to undertake UXO clearance works as part of this 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.

3.11.1.66 UXO clearance activities are one of the loudest anthropogenic noise sources that occur underwater. 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 at 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.

3.11.1.67 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.

3.11.1.68 Due to the potential impacts from underwater noise from UXO clearance, bubble curtains are typically required, where oceanographic conditions are suitable for their deployment, 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, the bubble curtains will also result in a reduction of the impacts to fish and shellfish receptors as well.

3.11.1.69 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.

3.11.1.70 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 construction 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. **Volume 2, Chapter 1: Marine Geology, Oceanography and Physical Process** and **Volume 5, 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 PEIR chapter.

Magnitude of impact

3.11.2.3 **Table 3.10** presents the MDS associated with increases in SSC and deposition. MDS for SSC and deposition during the operation and maintenance phase of Hornsea Four is predicted to be the total release of 3,382,624 m^3 of sediment in the array area and offshore ECC.

3.11.2.4 Cable remedial burial and cable repairs are both predicted to cause sediment plumes. Plumes are expected to be restricted to well-within the tidal excursion from slack water to peak flows, with plumes expected to occur over a maximum distance of 2 km. An increase in SSC of 2 mg/l above background levels is predicted local to the source; these concentrations are expected to reduce with dispersion, with sediments remaining in suspension for up to three hours. 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.

3.11.2.5 Sediment deposition from the plume is predicted to occur up to 2 km from the source, with maximum depth of 2 mm from the deposition of finer sediments (silts and muds). Coarser sediments are predicted to be deposited local to the source.

3.11.2.6 The magnitude of the maximum potential increase in SSC resulting from construction activities is within the natural range of SSC (2 to 14 mg/l closer inshore, reducing offshore to around 2 to 3 mg/l.), within the region, with each event being discrete, short term, and of localised extent (within one tidal excursion). 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.** 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.**

Sensitivity

3.11.2.7 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 no recoverability and of regional importance, and therefore the sensitivity of the receptor is **high**.

3.11.2.8 Sandeel spawning grounds and preferred habitats (**Figure 3.4**) 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, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is **medium**.

Significance of effect

3.11.2.9 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 both herring and sandeel within both the array area and the ECC, with the sensitivity of herring being assessed as High**.** The significance of effect therefore is deemed **minor** for herring, which is not significant in EIA terms. The sensitivity of sandeel is assessed as Medium and therefore the effect is deemed to be of **minor** significance, which is also 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).

3.11.2.10 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

3.11.2.11 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 3,699,466 m^2, which represents 0.08% of the area within the Hornsea Four PEIR boundary. Comparable habitats are present and widespread within the wider area.

3.11.2.12 The impact is predicted to be of local spatial extent (i.e. within the Hornsea Four PEIR boundary), 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. Taking into consideration the localised nature of herring spawning grounds to Hornsea Four, the magnitude of impact from long term habitat loss, associated with construction within the array area on herring is assessed as **minor**, and the magnitude of impact on herring from construction within the HVAC booster station location is assessed as **minor**. 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 and the HVAC booster station is also considered to be **minor**.

Sensitivity

3.11.2.13 Herring and sandeel are reliant upon the presence of suitable sediment/ habitat for spawning and are therefore considered to be more vulnerable to change depending on the availability of habitat within the wider region.

3.11.2.14 The Hornsea Four nearshore section of the ECC is located proximal to main high intensity herring spawning grounds (**Figure 3.3** and **Figure 3.5**), with the ECC and the proposed location of the HVAC booster station directly overlapping areas of low intensity spawning. Due to the localised nature of the impact (within the Hornsea Four development boundary), and the small overlap with low intensity herring spawning grounds, any impacts on spawning grounds from habitat loss are expected to be low.

3.11.2.15 The Hornsea Four offshore section of the ECC and the array area are located within preferred sandeel spawning and nursery habitat (**Figure 3.4**), however the proportion of habitat affected within Hornsea Four is small in the context of known wider sandeel habitats in the area

3.11.2.16 Sandeel and herring are deemed to be of high vulnerability to permanent changes in substrate, with no ability for recovery, and are of regional importance are both considered to be of **high** sensitivity.

Significance of the effect

3.11.2.17 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 herring from the array area, and from the HVAC booster station. The magnitude of effect on sandeel was assessed as Minor from both locations. The sensitivity of both herring and sandeel are assessed as assessed as High. The significance of effect therefore is deemed **minor** for herring and sandeel from both locations, 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).

3.11.2.18 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 development site. 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

3.11.2.19 Up to 3,699,466 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. The potential impact is predicted to be of local spatial extent (within the Hornsea Four development boundary), 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** for herring from the array area and the booster station, and **minor** for sandeel at both locations.

Sensitivity

3.11.2.20 Herring preferred spawning grounds consist of coarse sediments, typically sandy, and gravelly sand. Sandeel preferred habitats and spawning areas are typically dominated by gravel, and sandy gravel. The nearshore Section of the Hornsea Four ECC and the HVAC booster station 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.

Significance of the effect

3.11.2.21 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 edible crab and lobster) would benefit from the introduction of hard substrates. Demersal spawners, herring and sandeel are considered to have increased sensitivity to the introduction of hard substrate, do to their specific habitat requirements.

3.11.2.22 Overall, the magnitude of the impact has been assessed as minor, with the sensitivity of herring and sandeel being assessed as high. The significance of effect therefore is deemed

minor for herring and sandeel from the array and the HVAC booster station, which is not significant in EIA terms.

Underwater noise as a result of operational turbines (FSE-O-8).

3.11.2.23 Underwater noise is predicted to occur as a result of the operation and maintenance of up to 180 turbines within the Hornsea Four array area, although at considerably lower levels compared to those of the construction phase. Underwater noise from operational turbines mainly originates from the gearbox and the generator and has tonal characteristics (Madsen *et al*. 2005; Tougaard *et al*. 2009). The radiated levels are low and the spatial extent of the potential impact of the operational wind farm noise on marine receptors is generally estimated to be small and therefore unlikely to result in any injury to fish (Wahlberg and Westerberg, 2005). Besides the sound source level, the potential for impact will also depend on the propagation environment, the receptors hearing ability and the ambient sound levels.

3.11.2.24 Marine animals may perceive the radiated tonal components where these exist above the ambient noise levels, which may result in a behavioural response of the receptor or lead to a reduced detection of other sounds due to masking. Previous studies have shown that behavioural responses of fish are only likely at close ranges from the turbine (i.e. a few metres; Wahlberg and Westerberg, 2005).

3.11.2.25 Although effects on fish are difficult to establish given the lack of information available in the scientific literature, there is indicative evidence that fish would be unlikely to show significant avoidance to the noise levels radiating from the turbine. Studies of very low frequency sound have indicated that consistent deterrence from the source is only likely to occur at particle accelerations equivalent to a free-field SPL of 160 dB re 1 μPa (RMS) (Sand *et al*. 2001). Particle acceleration resulting from an operational wind turbine has also been measured by Sigray *et al*. (2011) with the resultant levels being considered too low to be of concern for behavioural reactions from fish. Furthermore, the particle acceleration levels measured at 10 m from the turbine were comparable with hearing thresholds. Whilst limited, the available data provides an indicator that operational wind turbines are unlikely to result in disturbance of fish except within very close proximity of the turbine structure, as postulated by Wahlberg and Westerberg (2005). Any potential avoidance reactions (should they occur) would be limited to a short distance from the operational turbine with the potential for acclimatisation occurring over the lifetime of the project.

3.11.2.26 The impact is predicted to be of a highly localised spatial extent (in the immediate vicinity of the operational turbines), long-term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact will affect the fish and shellfish receptors indirectly. Due to the extremely localised spatial extent, the magnitude is **negligible** for both herring and sandeel from the array area and the HVAC booster station; therefore, this impact is not considered further as it will always lead to a not significant effect.

Potentially reduced fishing pressure within the Hornsea Four array area and increases fishing pressure outside the array area due to displacement (FSE-O-12).

3.11.2.27 During the operational phase of Hornsea Four, the presence of infrastructure within the array area is predicted to lead to a localised loss in access to fishing grounds, and therefore a reduced intensity in fishing activities (including trawling and potting) (**Volume 2, Chapter 7: Commercial Fisheries**).This has the potential to enhance fish and shellfish populations by providing refuge from fishing activities for certain species targeted by commercial fisheries. Conversely, this also has the potential to increase the intensity of fishing activity outside of the array area as fishing activity is displaced, to the detriment of fish populations there.

3.11.2.28 As all fish and shellfish receptors will be exposed to the same pressure and are considered to have the same sensitivity to fishing pressures in the area, all receptors are assessed as one for this impact.

Reduced fishing pressure within the Hornsea Four array area

3.11.2.29 Fishing activity may be reduced within Hornsea Four as a result of the physical presence of the infrastructure within the array area, and if Hornsea Four apply for a 500 m safety zone around manned infrastructure. There would be no safety zones around turbines after construction, however a 50 m safe working distance is assumed, and a 500 m safety zone would be implemented during major maintenance activities.

Magnitude of impact

3.11.2.30 A range of species are targeted by commercial fisheries in the area. these species are likely to observe the greatest benefit from a reduction in fishing effort within the Hornsea Four array area, although non-target fish caught as by-catch are also likely to benefit due to a reduction in fishing mortality.

3.11.2.31 The habitat protected from trawling may also become a refuge for young and spawning fish, thus providing benefits to fish populations beyond the immediate exclusion area (Byrne Ó Cléirigh *et al.* 2000). However, many of the commercially important fish species in the area are highly mobile and therefore may not significantly benefit from a reduction in fishing pressure.

3.11.2.32 Trawling can damage the seabed and its marine life (Hart *et al.* 2004). Therefore, the potential reduction in trawl fishing within the Hornsea Four array area may benefit shellfish communities that were historically disturbed by trawling activity.

3.11.2.33 The impact is predicted to be of a local spatial extent (within the array area), long-term duration, continuous and irreversible (during the lifetime of the project, design life of 35 years). It is predicted that the impact will both herring and sandeel directly. The magnitude is therefore considered to be **negligible** beneficial for both herring and sandeel, and is not considered further in this assessment, as it will not lead to a significant effect.

Increased fishing pressure outside the array area

3.11.2.34 Receptors likely to be affected by an increase in fishing pressure outside the Hornsea Four array area include demersal fish species targeted by commercial fisheries occurring within Hornsea Four (e.g. plaice and sole). It would not be expected that any changes in fishing activities in this area (should these effects occur at all) would lead to changes in populations of these species.

3.11.2.35 A reduction in fishing pressure within Hornsea Four array area may mean increased fishing pressure in areas adjacent to Hornsea Four. However, it is expected that any such increase would have a localised effect on fish populations in the wider study area, with any population level effects minimised by fisheries management measures (e.g. quotas, days at sea etc.).

3.11.2.36 The impact is predicted to be of a local spatial extent, long-term duration, continuous and irreversible (within the lifetime of the project). It is predicted that the impact will affect both herring and sandeel directly. The magnitude is therefore considered to be **negligible** beneficial for both herring and sandeel, and is not considered further in this assessment, as it will not lead to a significant effect.

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.**

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

3.11.3.2 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 3.11.1.2** *et seq.*

3.11.3.3 The magnitude of the impact has been assessed as **minor**, with the maximum sensitivity of the receptors being **high**. Therefore, 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 **minor** significance of effect, which is not significant in EIA terms.

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

3.11.3.4 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 3.11.1.14** *et seq.*

3.11.3.5 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** for both herring and sandeel and is therefore not considered further in this assessment.

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

3.11.3.6 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 1, Chapter 4: Project Description**, 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 3.11.1.15** *et seq*).

3.11.3.7 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**, and therefore this impact is 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 4,**

Annex 5.3: Offshore Cumulative Effects and are presented in a series of maps within **Volume 4, Annex 5.4: Location of Offshore Cumulative Schemes**.

3.12.1.3 The cumulative effect assessment (CEA) methodology undertaken is detailed in **Volume 4, 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 3.15** below.

Table 3.15: 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 4, 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 15 km range around the offshore ECC (**Figure 3.15**), representing the tidal ellipse distance. 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 3.16** below, and shown in **Figure 3.15** (tidal ellipse buffer) and **Figure 3.16** (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 4, Annex 5.3: Offshore Cumulative Effects**.

Table 3.16: 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	>50	27.75	2.10	Part of the baseline but has an ongoing impact and is therefore considered relevant to the cumulative impact assessment
1	Hornsea Project One Offshore Wind Farm	Under construction (2019)	5.08	21.32	82.50	Potential cumulative impact exists. Development not included as part of baseline, and therefore to be considered in cumulative assessment.
1	Hornsea Project Two Offshore Wind Farm	Consented 2019, with construction 2020-2022	0.00	5.84	66.43	Potential cumulative impact exists. Development not included as part of baseline, and therefore to be considered in cumulative assessment.
1	Hornsea Three Offshore Wind Farm	In planning 2019-2023, with construction 2024-2031.	36.34	55.47	116.1	Potential cumulative impact exists. Temporal overlap, with construction occurring in 2026.
1	Sofia Offshore Wind Farm	In planning 2019-2021, with construction 2023-2026.	97.75	113.14	143.26	Potential cumulative impact exists. Temporal overlap, with construction occurring 2026-2028.

3.12.1.6 The cumulative maximum design scenarios described in **Table 3.17** 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): the potential significance of the impact from Hornsea Four alone has been assessed as negligible;
- Underwater noise as a result of operational turbines (operational phase): the potential significance of the impact from Hornsea Four alone has been assessed as negligible;
- Increased fishing pressure outside of the array area (operational phase): the potential significance of the impact from Hornsea Four alone has been assessed as negligible; and
- Reduced fishing pressure within the Hornsea Four array area (operation phase): the potential significance of the impact from Hornsea Four alone has been assessed as negligible.

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 and operation and maintenance phase);
- Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (construction phase);
- Long term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (operation phase); and
- Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection (operation phase).

3.12.1.10 The projects considered in this cumulative impact assessment are illustrated in **Figure 3.15** and **Figure 3.16** below.

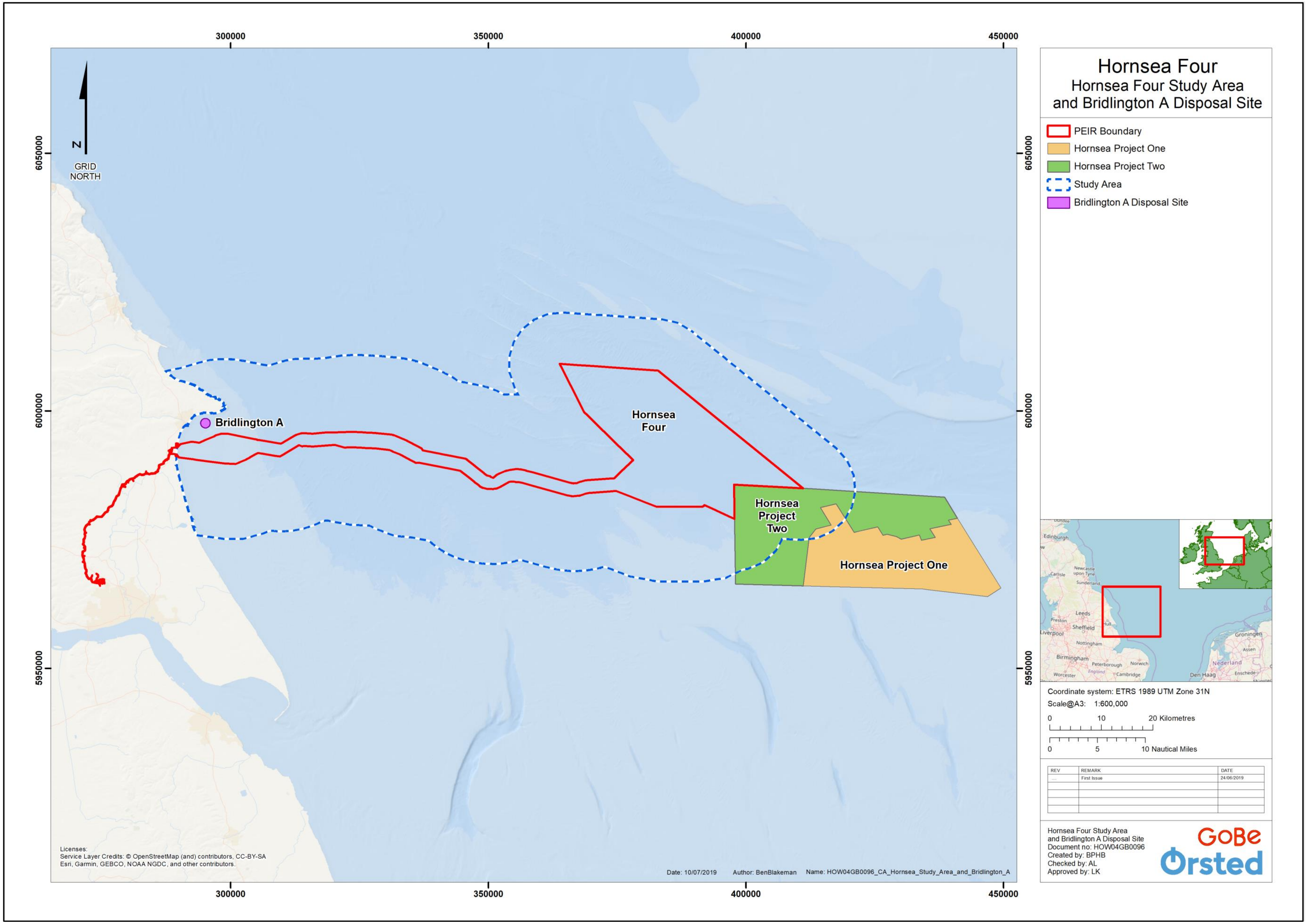

Figure 3.15: The projects screened into the cumulative impact assessment within the tidal ellipse buffer (10 km surrounding the array, and 15 km around the ECC) (not to scale).

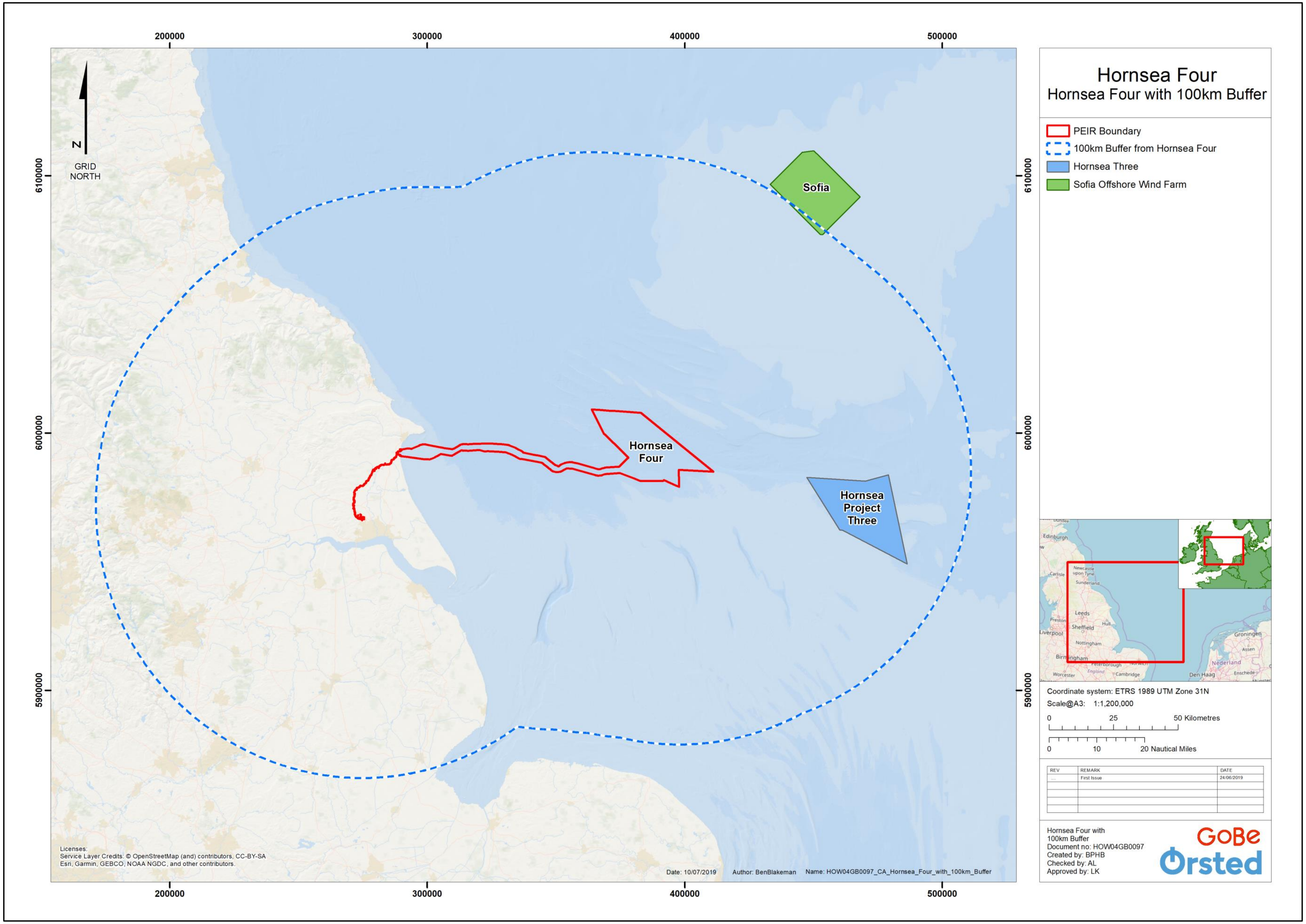

Figure 3.16 The projects screened into the cumulative impact assessment within a 100 km buffer of Hornsea Four for consideration of underwater noise impacts (not to scale).

Table 3.17: Cumulative Maximum Design Scenario.

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); Consented wind farm project (Hornsea Project Two); and Wind farm projects under construction (Hornsea Project One) **Tier 2:** No Tier 2 projects identified. ***Tier 3:*** No Tier 3 projects identified.	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 (Sofia, and Hornsea Three), **Tier 2:** No Tier 2 projects identified. ***Tier 3:*** No Tier 3 projects identified.	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:** Disposal site (Bridlington A); Consented wind farm project (Hornsea Project Two); and Wind farm projects under construction (Hornsea Project One) **Tier 2:** No Tier 2 projects identified. ***Tier 3:*** No Tier 3 projects identified.	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.
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:** Consented wind farm project (Hornsea Project Two); and Wind farm projects under construction (Hornsea Project One). **Tier 2:** No Tier 2 projects identified. ***Tier 3:*** No Tier 3 projects identified.	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.

Project Phase	Potential Impact	Maximum Design Scenario	Justification
Operation	Increased hard substrate and structural complexity as a result of the introduction 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:** Consented wind farm project (Hornsea Project Two); and Wind farm projects under construction (Hornsea Project One). **Tier 2:** No Tier 2 projects identified. ***Tier 3:*** No Tier 3 projects identified.	Maximum cumulative increase in hard substrate and structural complexity 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.

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 (FSE-C-2).

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 3.16**). For the purposes of this PEIR, this additive impact has been assessed within 10 km of the Hornsea Four array area, and 15 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 only projects identified in this Tier are the Bridlington A disposal site, the Hornsea Project One offshore windfarm, and the Hornsea Project Two offshore windfarm. There are no Tier 2 of Tier 3 projects.

3.12.2.2 The Bridlington A disposal site (HU015) is located 2.1 km west of the HVAC booster station, and adjacent to 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 Hornsea Four. However, if Hornsea Four is discharging overspill of fine silts and sands in the nearshore from cable trenching by MFE 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 The Hornsea Project One offshore windfarm is located 5.08 km from the Hornsea Four array area. The maximum volume of material displaced from Hornsea Project One foundations installation will be approximately 2,000,000 m^3 (maximum adverse scenario for increased SSC), from the installation of gravity base foundations. The Hornsea Project Two offshore windfarm is located adjacent to the eastern side of the Hornsea Four array area. The maximum volume of material displaced from Hornsea Project Two construction will be approximately 2,770,021 m^3 (maximum adverse scenario for increased SSC). Cumulatively with Hornsea Four, this may result in the disturbance and deposition of up to 11,920,818 m^3 of sediment. However, this will not happen concurrently; Hornsea Project One is under construction until 2019, and Hornsea Project Two commencing construction in 2020, with completion in 2022. The construction of the Hornsea Four offshore windfarm is not proposed is not scheduled for construction until 2026. Therefore, it is determined that there will be no temporal overlap of the construction between Hornsea Projects One and Two, and Hornsea Four, and consequently limited integration between the sediment deposition from the different projects.

3.12.2.5 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.

3.12.2.6 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**.

3.12.2.7 Full discussion of the sensitivity of fish and shellfish to increased SSC and sediment deposition is discussed in **paragraphs 3.11.1.8** *et seq.* which conclude that most 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. Therefore, 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 One, and Hornsea Project Two is **minor**, which is not significant in EIA terms.

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

Tier 1

3.12.2.8 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 3.16**). For the purposes of this PEIR, 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 their PEIR assessment, detailed in **Section 3.11.1**.

3.12.2.9 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 at other offshore wind farm sites within 100 km of Hornsea Four. Injury or mortality of fish from piling noise 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.

3.12.2.10 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. 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 3.16**, are indicative and subject to change.

3.12.2.11 For the purposes of this assessment the full length of the construction periods for all cumulative projects (i.e. 2023 to 2031 or 9 years) have been considered for potential cumulative effects due to a lack of data or information regarding the piling timescales for the Sofia Offshore Windfarm, and Hornsea Three. Based on the MDS for piling duration at Hornsea Four and the MDS piling duration for Sofia Offshore Windfarm, and Hornsea Three (**Table 3.18**), piling activities will occur over a maximum of 507 days, over 9 years, equating to approximately 15 % 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 Windfarm and the Hornsea Three offshore windfarm are also likely to include the combination of onshore and offshore construction periods and as such projects the project may, in reality not overlap temporally with the construction period of Hornsea Four.

Table 3.18: 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	720	Total piling duration based on 180 turbines, and 4-hour piling duration (**Volume 1, Chapter 4: Project Description**).
Hornsea Three	7,392	Total piling duration taken from ES (Ørsted, 2018) based on a maximum of 300 turbines.
Sofia Offshore Windfarm	4,056	Total piling duration taken from ES (Forewind, 2014) based on maximum of 200 turbines.
Total Tier 1	12,168 hours	

3.12.2.12 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.

3.12.2.13 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. 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.

3.12.2.14 The Hornsea Project Three offshore windfarm assessment (Ørsted, 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 4 hours per foundation. The spatial 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.

3.12.2.15 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 nine years), intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be **minor**.

3.12.2.16 Sensitivities of fish and shellfish receptors to underwater noise are fully detailed in **paragraph 3.11.1.20** *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.

3.12.2.17 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.

3.12.2.18 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.

3.12.2.19 Herring and sandeel are considered to be of high vulnerability, with no recoverability and of regional importance. The sensitivity of these receptors is therefore considered to be **high**.

3.12.2.20 Overall, the magnitude of the cumulative impact is deemed to be Minor, the sensitivity of herring and sandeel were assessed as High, and therefore the effect will be of **minor** significance, which is not significant in EIA terms. For those species of Medium sensitivity, the effect is also predicted to be of **minor** adverse significance and therefore not significant in EIA terms.

3.12.3 Operation Phase

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

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 the operation of other projects (**Table 3.16**). As detailed in **paragraph 3.12.2.1** *et seq* cumulative impacts from additional sources have been assessed within the maximum tidal ellipse. Projects identified in this Tier are the Bridlington A disposal site, the Hornsea Project One offshore windfarm, and the Hornsea Project Two offshore windfarm. 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 The cumulative impacts of temporary localised increases in SSC and associated sediment deposition are predicted to have the potential to result from maintenance activities (cable remedial cable burial and cable repairs) of Hornsea Project One, Hornsea Project Two and Hornsea Four, as all sites are predicted to be operational simultaneously. However, cable maintenance activities undertaken on the sites are undertaken intermittently and are therefore considered unlikely to have a temporal overlap.

3.12.3.4 The MDS for increases in SSC and deposition during the operation and maintenance phase of Hornsea Four results from the use of MFE 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.

3.12.3.5 **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 MFE for maintenance activities, resulting in the total release of 3,382,624 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 2 km from the site, with a maximum deposition of 2 mm of fine sediments. 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.

3.12.3.6 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**. Full discussion of the sensitivity of fish and shellfish to increased SSC and sediment deposition is discussed in **paragraphs 3.11.1.8** *et seq.* which conclude that most species have relatively high vulnerability to increased SSC and deposition. The maximum sensitivity of receptors in to these impacts are assessed as **high**, and the magnitude has been assessed as Minor. Therefore, 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 One, and Hornsea Project Two is **minor**, 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).

Tier 1

3.12.3.7 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 15 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 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.

3.12.3.8 The predicted cumulative long-term habitat loss from all Tier 1 projects is estimated to be 13.54 km^2 which equates to 0.28% of the total area of subtidal habitat within a representative 15 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 5, Annex 3.1: Fish and Shellfish Technical Report**) so this loss is not predicted to diminish regional ecosystem functions.

Table 3.19: Cumulative temporary 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 (km^2)	Source
Tier 1 offshore wind farms		
Hornsea Four	3.7	**Volume 1, Chapter 1: Project Description**
Hornsea Project One	4.23	Total habitat loss taken from ES (SmartWind, 2013).

Project	Total predicted long-term habitat loss (km^2)	Source
Tier 1 offshore wind farms		
Hornsea Project Two	5.45	Total habitat loss taken from ES (SmartWind, 2015).
Total Tier 1	13.54 km^2	

3.12.3.9 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**.

3.12.3.10 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**.

3.12.3.11 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 and therefore for those fish and shellfish receptors which have low sensitivity to this impact, the effect will be of minor adverse significance, which is not significant in EIA terms. For those species with medium sensitivity to this impact, it is also predicted that the effect will be of **minor** significance and therefore 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).

Tier 1

3.12.3.12 As discussed in **paragraphs 3.11.2.18** *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 decommissioning activities within a representative 15 km buffer of the Hornsea Four ECC, and 10 km buffer of the array area (see **Table 3.17** and **Figure 3.15**). Effects may result from the physical presence of foundations, scour protection and cable/pipeline protection.

3.12.3.13 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.

3.12.3.14 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 3.17**). 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 872 turbines may be constructed from all projects included within Tier 1 (**Table 3.20**). 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 3.20: Cumulative habitat creation for Hornsea Four and offshore wind farms in the Tier 1 assessment within the Hornsea Four study area.

Project	MDS scenario for number of turbines	Total predicted habitat creation (m^2)	Source
Tier 1 offshore wind farms			
Hornsea Four	180	3,707,730	Volume 1, Chapter 1: Project Description
Hornsea Project One	332	4,860,136	Total habitat creation taken from ES (SmartWind, 2013).
Hornsea Project Two	360	6,239,991	Total habitat creation taken from ES (SmartWind, 2015).
Total Tier 1	14,807,857 m^2		

3.12.3.15 The total cumulative habitat creation is estimated to be approximately 14,807,857 m^2 for all Tier 1 projects within a 15 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 smaller turbines than those assumed for the Hornsea Four assessment will be installed for the other OWFs, and 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 14,807,857 m^2.

3.12.3.16 The impact will extend over the regional area but will be highly localised within each of the offshore wind farm arrays and cable routes, 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**.

3.12.3.17 Shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of medium vulnerability and of local to regional value in the southern North Sea fish and shellfish study area (recoverability is not relevant to this impact). The sensitivity of the receptor is therefore considered to be **medium**.

3.12.3.18 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 the magnitude of the cumulative impact is predicted to be **minor**. The effect will, therefore, be of **minor** beneficial significance, which is not significant in EIA terms.

3.12.3.19 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 the Report to Inform Appropriate Assessment.

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 K 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 (84 km form 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 effect was therefore considered to be a maximum of moderate significance, which is considered significant in EIA terms; the mitigation to reduce the impact of underwater noise on sensitive species is within **Table 3.22**.

3.13.1.3 Effects of increases in SSC are predicted to be limited in extent to a number of kilometres of 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 3.21**. 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 1, Chapter 5: Environmental Impact Assessment Methodology.**

Table 3.21: 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 being of minor significance.	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 Negligible to Minor significance, which are not significant in EIA terms.
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 being of minor significance for herring and sandeel in the construction and decommissioning phases.	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 Minor 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	

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
		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 SCC 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. Spawning herring local to the HVAC booster station 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 3.22**.

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 negligible, minor adverse or minor beneficial 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 and aggregate extraction, concluded that the effects of any cumulative impacts would generally be of minor 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 European Economic Area (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, these impacts were not predicted to have significant effects on fish and shellfish populations of other EEA States.

Table 3.22: Summary of potential impacts assessed for fish and shellfish ecology.

Impact and Phase	Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
Construction						
Temporary localised increases in SSC and smothering (FSE-C-2).	Herring	Array: Minor HVAC: Minor	High	Minor Minor	None	Minor
	Sandeel	Array: Minor HVAC: Minor	Medium	Minor Minor	None	Minor
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-C-3-).	Herring Sandeel	Negligible		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.		
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-C-4).	Herring	Array: Minor HVAC: Minor	High	Minor Minor	None	Minor
	Sandeel	Array: Minor HVAC: Minor	Medium	Minor Minor	None	Minor
	All other fish/shellfish	Array: Minor HVAC: Minor	Medium	Minor Minor	None	Minor
Operation and Maintenance						
Temporary localised increases in SSC and smothering (FSE-O-18).	Herring	Array: Minor	High	Minor	None	None
	Sandeel	ECC: Minor	Medium	Minor	None	None
Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection (FSE-O-16).	Herring	Array: Minor HVAC: Minor	High	Minor Minor	None	Minor

Impact and Phase	Receptor	Magnitude	Sensitivity	Significance	Mitigation beyond existing commitments	Residual impact
	Sandeel	Array: Minor	High	Minor	None	Minor
		HVAC: Minor		Minor		
Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection (FSE-O-7).	Herring	Array: Minor	High	Minor	None	Minor
		HVAC: Minor		Minor		
	Sandeel	Array: Minor	High	Minor	None	Minor
		HVAC: Minor		Minor		
Underwater noise as a result of operational turbines (FSE-O-8).	Herring	Negligible		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					
	All other fish/shellfish					
Potentially reduced fishing pressure within the Hornsea Four array area and increases fishing pressure outside the array area due to displacement (FSE-O-12). *Reduced fishing pressure within the Hornsea Four array area*	All fish/shellfish receptors	Negligible		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.		
Increased fishing pressure outside the array area	All fish/shellfish receptors					

Decommissioning						
Temporary localised increases in SSC and smothering (FSE-D-14).	Herring	Array: Minor HVAC: Minor	High	Minor Minor	None	Minor
	Sandeel	Array: Minor HVAC: Minor	Medium	Minor Minor	None	Minor
Direct and indirect seabed disturbances leading to the release of sediment contaminants (FSE-D-15).	Herring	Negligible		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					
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration (FSE-D-16).	Herring	Negligible		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					
	All other fish/shellfish					

3.16 References

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Appendix A

Table 3.23: Mean worst-case noise impact ranges for fleeing (f) fish (1.5 ms-1) and stationary (s) fish at the modelled locations and noise levels for monopile (MP) installation (5,000 kJ hammer energy), and pin pile (PP) installation (2,500 kJ hammer energy) surrounding the array. Where the maximum/minimum differs from the mean, these values are indicated in brackets.

Receptor	Criteria	Noise level (dB re 1 μPa SPL/ dB re 1 μPa2 s SEL)	Distance (m) from modelling locations surrounding the array *			
			NW			
			MP (f)	MP (s)	PP (f)	PP (s)
Mortality and potentially mortal injury						
Group 1	SPL_{peak}	213	430	430	260 (250-260)	260 (250-260)
	SEL_{cum}	219	< 100	760 (750-760)	< 100	460 (450-460)
Group 2	SPL_{peak}	207	1300	1300	770 (760-770)	770 (760-770)
	SEL_{cum}	210	< 100	3300 (3300-3400)	< 100	2200
Group 3	SPL_{peak}	207	1300	1300	770 (760-770)	770 (760-770)
	SEL_{cum}	207	< 100	5100 (5000-5200)	< 100	3500
Eggs and larvae	SPL_{peak}	207	1300	1300	770 (760-770)	770 (760-770)
	SEL_{cum}	210	< 100	3300 (3300-3400)	< 100	2200
Recoverable injury						
Group 1	SPL_{peak}	213	430	430	260 (250-260)	260 (250-260)
	SEL_{cum}	216	< 100	1300	< 100	780 (770-790)
Group 2	SPL_{peak}	207	1300	1300	770 (760-770)	770 (760-770)
	SEL_{cum}	203	460 (360 – 550)	8200 (7900-8500)	< 100	5900 (5800-6000)
Group 3	SPL_{peak}	207	1300	1300	770 (760-770)	770 (760-770)

Receptor	Criteria	Noise level (dB re 1 µPa SPL/ dB re 1 µPa2 s SEL)	Distance (m) from modelling locations surrounding the array *			
			NW			
			MP (f)	MP (s)	PP (f)	PP (s)
	SEL$_{cum}$	203	460 (360 – 550)	8200 (7900-8500	< 100	5900 (5800-6000)
TTS						
Group 1	SEL$_{cum}$	186	19000 (17000 – 23000)	29000 (27000-33000)	15000 (14000-18000)	25000 (23000-27000)
Group 2	SEL$_{cum}$	186	19000 (17000 – 23000)	29000 (27000-33000)	15000 (14000-18000)	25000 (23000-27000)
Group 3	SEL$_{cum}$	186	19000 (17000 – 23000)	29000 (27000-33000)	15000 (14000-18000)	25000 (23000-27000)

*Note: f = fleeing receptor, S = stationary receptor, MP = monopile, PP= pin pile.

Table 3.24: Mean worst-case noise impact ranges for fleeing (f) fish (1.5 ms-1) and stationary (s) fish at the HVAC booster station modelled location and noise levels for monopile (MP) installation (5,000 kJ hammer energy, and pin pile (PP) installation (2,500 kJ hammer energy). Where the maximum/minimum differs from the mean, these values are indicated in brackets.

Receptor	Criteria	Noise level (dB re 1 µPa SPL/ dB re 1 µPa2 s SEL)	Distance (m) from modelling locations surrounding the array *			
			HVAC MP (f)	HVAC MP (s)	HVAC PP (f)	HVAC PP (s)
Mortality and potentially mortal injury						
Group1	SPL_{peak}	213	430	430	250	250
	SEL_{cum}	219	< 100	760 (750-760)	< 100	460 (450-460)
Group 2	SPL_{peak}	207	1200	1200	760	760
	SEL_{cum}	210	< 100	3300	< 100	2100 (2100-2200)
Group 3	SPL_{peak}	207	1200	1200	760	760
	SEL_{cum}	207	< 100	5000 (5000-5100)	< 100	3400 (3400-3500)
Eggs and Larvae	SPL_{peak}	207	1200	1200	760	760
	SEL_{cum}	210	< 100	3300	< 100	2100 (2100-2200)
Recoverable injury						
Group 1	SPL_{peak}	213	430	430	250	250
	SEL_{cum}	216	< 100	1300	< 100	780 (770-780)
Group 2	SPL_{peak}	207	1200	1200	760	760
	SEL_{cum}	203	410 (390 – 440)	8100 (8000-8200)	< 100	5800 (5800-5900)
Group 3	SPL_{peak}	207	1200	1200	760	760
	SEL_{cum}	203	410 (390 – 440)	8100 (8000-8200)	< 100	5800 (5800-5900)
TTS						
Group 1	SEL_{cum}	186	19000 (16000 – 21000)	28000 (25000-31000)	15000 (13000-17000)	24000 (22000-26000)
Group 2	SEL_{cum}	186	19000 (16000 – 21000)	28000 (25000-31000)	15000 (13000-17000)	24000 (22000-26000)
Group 3	SEL_{cum}	186	19000 (16000 – 21000)	28000 (25000-31000)	15000 (13000-17000)	24000 (22000-26000)

*Note: f = fleeing receptor, S = stationary receptor, M = monopile, PP= pin pile

Table 3.25: Mean most likely noise impact ranges for fleeing (f) fish (1.5 ms-1) and stationary (s) fish at the modelled locations and noise levels for monopile installation (4,000 kJ hammer energy), and pin pile installation (1,750 kJ hammer energy) surrounding the array. Where the maximum/minimum range differs from the mean, these values are indicated in brackets.

Receptor	Criteria	Noise level (dB re 1 μPa SPL/ dB re 1 μPa2 s SEL)	NW			
			MP (f)	MP (s)	PP (f)	PP (s)
Mortality and potentially mortal injury						
Group 1	SPL_{peak}	213	370	370	180	180
	SEL_{cum}	219	< 100	300 (290-300)	< 100	150 (140-150)
Group 2	SPL_{peak}	207	1100	1100	550	550
	SEL_{cum}	210	< 100	1500	< 100	760 (750-760)
Group 3	SPL_{peak}	207	1100	1100	550	550
	SEL_{cum}	207	< 100	2400	< 100	1300
Eggs and Larvae	SPL_{peak}	207	1100	1100	550	550
	SEL_{cum}	210	< 100	1500	< 100	760 (750-760)
Recoverable injury						
Group 1	SPL_{peak}	213	370	370	180	180
	SEL_{cum}	216	< 100	520 (510-520)	< 100	260 (250-260)
Group 2	SPL_{peak}	207	1100	1100	550	550
	SEL_{cum}	203	< 100	4400 (4300-4400)	< 100	2500 (2500-2600)
Group 3	SPL_{peak}	207	1100	1100	550	550
	SEL_{cum}	203	< 100	4400 (4300-4400)	< 100	2500 (2500-2600)

TTS						
Group 1	SELcum	186	14000 (12000-16000)	21000 (20000-24000)	9000 (8200-11000)	16000 (16000-18000)
Group 2	SELcum	186	14000 (12000-16000)	21000 (20000-24000)	9000 (8200-11000)	16000 (16000-18000)
Group 3	SELcum	186	14000 (12000-16000)	21000 (20000-24000)	9000 (8200-11000)	16000 (16000-18000)

*Note: f = fleeing receptor, S = stationary receptor, M = monopile, PP= pin pile.

Table 3.26: Mean most likely noise impact ranges for fleeing (f) fish (1.5 ms-1) and stationary (s) fish at the HVAC booster station modelled location and noise levels for monopile (MP) installation (4,000 kJ hammer energy), and pin pile (PP) installation (1,750 kJ hammer energy). Where the maximum/minimum range differs from the mean, these values are indicated in brackets.

Receptor	Criteria	Noise level (dB re 1 µPa SPL/ dB re 1 µPa2 s SEL)	Distance (m) from modelling locations surrounding the array *			
			HVAC MP (f)	HVAC MP (s)	HVAC PP (f)	HVAC PP (s)
Mortality and potentially mortal injury						
Group1	SPLpeak	213	370	370	180	180
	SELcum	219	< 100	300 (290-300)	< 100	150 (140-150)
Group 2	SPLpeak	207	1100	1100	550	550
	SELcum	210	< 100	1500	< 100	760 (750-760)
Group 3	SPLpeak	207	1100	1100	550	550
	SELcum	207	< 100	2400	< 100	1300
Eggs and Larvae	SPLpeak	207	1100	1100	550	550
	SELcum	210	< 100	1500	< 100	760 (750-760)
Recoverable injury						
Group 1	SPLpeak	213	370	370	180	180
	SELcum	216	< 100	1500	< 100	260 (250-260)
Group 2	SPLpeak	207	1100	1100	550	550
	SELcum	203	< 100	510 (500-510)	< 100	2500
Group 3	SPLpeak	207	1100	1100	550	550
	SELcum	203	< 100	4300	< 100	2500

TTS						
Group 1	SEL_{cum}	186	14000 (12000-15000)	21000 (20000-23000)	9100 (8700-9600)	17000 (16000-17000)
Group 2	SEL_{cum}	186	14000 (12000-15000)	21000 (20000-23000)	9100 (8700-9600)	17000 (16000-17000)
Group 3	SEL_{cum}	186	14000 (12000-15000)	21000 (20000-23000)	9100 (8700-9600)	17000 (16000-17000)