Hornsea Project Three
Offshore Wind Farm

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Preliminary Environmental Information Report: Chapter 3 – Fish and Shellfish Ecology

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 2

Chapter 3 – Fish and Shellfish Ecology

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Front cover picture: Kite surfer near one of DONG Energy's UK offshore wind farms © DONG Energy Hornsea Project Three (UK) Ltd., 2016.

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Glossary

Term	Definition
Benthic ecology	Benthic ecology encompasses the study of the organisms living in and on the sea floor, the interactions between them and impacts on the surrounding environment.
Crustacea	Arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp, or barnacle.
Demersal	Relating to the seabed and area close to it. Demersal spawning species are those which deposit eggs onto the seabed.
Epibenthic	Organisms living on the surface of the seabed.
Epifauna	Animals living on the surface of the seabed.
Intertidal	An area of a seashore that is covered at high tide and uncovered at low tide.
Mollusc	Invertebrate animal belonging to the phylum mollusca that includes the snails, clams, chitons, tooth shells, and octopi.
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.
Plankton	Small and microscopic organisms drifting or floating in the sea or fresh water, consisting chiefly of diatoms, protozoans, small crustaceans, and the eggs and larval stages of larger animals.
Planktivorous	Feeding on plankton
Spawning	The release or deposition of eggs and sperm, usually into water, by aquatic animals.
Swim bladder	Internal gas-filled organ that contributes to the ability of many bony fish to control buoyancy.
Zooplankton	Plankton consisting of animals (e.g. small crustaceans or immature stages of larger animals)

Acronyms

Acronym	Description
AC	Alternating Current
ASA	Acoustical Society of America
B field	Magnetic field
BEIS	Department of Business, Energy and Industrial Strategy
CBD	Convention on Biological Diversity
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CEA	Cumulative Effects Assessment
CIEEM	Chartered Institute for Ecology and Environmental Management
CoCP	Code of Construction Practice
CPA	Coast Protection Act
DC	Direct Current
DCO	Development Consent Order
Defra	Department for Environment, Food and Rural Affairs
DECC	Department of Energy and Climate Change
DP	Dynamically Positioned
E field	Electrical field
EA	Environment Agency
EEA	European Economic Area
EIA	Environmental Impact Assessment
EIFCA	Eastern Inshore Fisheries and Conservation Authority
EMF	Electro-Magnetic Fields
EQS	Environmental Quality Standard
ESFJC	Eastern Sea Fisheries Joint Committee
EU	European Union
EUNIS	European Nature Information System
EWG	Expert Working Group
FEPA	Food and Environment Protection Act
GES	Good Environmental Status
GBF	Gravity Base Foundation
GSI	Gonadal Somatic Index
HRA	Habitats Regulations Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICES	International Council of the Exploration of the Sea
iE field	Induced Electrical field
IHLS	International Herring Larvae Survey
INNS	Invasive and Non-Native Species
IPC	Infrastructure Planning Commission
IBTS	International Bottom Trawl Survey
IUCN	International Union for the Conservation of Nature
JNCC	Joint Nature Conservation Committee
MAREA	Marine Aggregates Regional Environmental Assessment
MCA	Maritime and Coastguard Agency
MCZ	Marine Conservation Zone
MHWS	Mean High Water Springs
MNA	Marine Natural Area
MMO	Marine Management Organisation
MSFD	Marine Strategy Framework Directive
NIMF	Nationally Important Marine Features
NPS	National Policy Statement
NSIPs	Nationally Significant Infrastructure Projects
OESEA	Offshore Energy Strategic Environmental Assessment
OSPAR	Oslo Paris Convention (also known as Convention for the Protection of the Marine Environment of the North-East Atlantic)
PAH	Polycyclic Aromatic Hydrocarbon

Acronym	Description
PEIR	Preliminary Environmental Information Report
PEMMP	Project Environmental Management and Monitoring Plan
PINS	Planning Inspectorate
PSA	Particle Size Analysis
rMCZ	Recommended Marine Conservation Zone
RMS	Root Mean Square
SAC	Special Area of Conservation
SCI	Site of Community Importance
SEA	Strategic Environmental Assessment
SEL	Sound Exposure Level
SELcum (i.e.	Cumulative Sound Exposure Level
SPL	Sound Pressure Level
SSC	Suspended Sediment Concentrations
SSSI	Sites of Special Scientific Interest
TKOWFL	Triton Knoll Offshore Wind Limited
TWT	The Wildlife Trust
UNEP	United Nations Environment Programme
UK BAP	United Kingdom Biodiversity Action Plan
VER	Valued Ecological Receptor
ZoI	Zone of Impact

Units

Unit	Description
cm	centimetre
dB	Decibel
kg	Kilogram
km	Kilometre
kV	Kilovolt (electrical potential)
l	Litre
m	Metre
mm	Millimetre
MW	Megawatt (power)
m2	Metres squared
m3	Metres cubed
nm	Nautical mile
T	Tesla
V	Volt
μPa	Micropascal
μT	Microtesla
μV	Microvolt

3. Fish and Shellfish Ecology

3.1 Introduction

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

3.1.1.2 The detailed technical information which underpins the impact assessments presented within this chapter is contained within 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 Three 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 Three array area, and includes information on fish and shellfish species of ecological importance and of commercial and conservation value. For the purposes of this assessment, shellfish is considered a generic term to define molluscs and crustaceans.

3.2 Purpose of this chapter

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

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

3.2.1.3 In particular, this PEIR chapter:

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

3.3 Study area

3.3.1.1 For the purposes of the fish and shellfish ecology characterisation, two study areas were defined:

- The Hornsea Three fish and shellfish study area – this was defined as the area encompassing Hornsea Three array area, the offshore cable corridor and the area in the immediate vicinity of the landfall. The Hornsea Three fish and shellfish study area also included much of the former Hornsea Zone, extending from the eastern boundary of the former zone (i.e. approximately 10 km east of Hornsea Three), to the western section of the former zone (i.e. approximately 70 km west of Hornsea Three) and a 4 km buffer to the north and south of the boundary (including Hornsea Three). This is the zone of influence for the majority of impacts on fish and shellfish receptors. This study area was also the area in which survey data were, or are to be, collected, including historic trawl surveys undertaken across the former Hornsea zone and site-specific survey data along the offshore cable corridor (Figure 3.1); and
- The southern North Sea fish and shellfish study area – this is the regional fish and shellfish study area and was defined as the southern North Sea region which coincides with the southern North Sea Marine Natural Area (MNA; Jones *et al*., 2004; Figure 3.2). This study area also included areas within territorial waters of Netherlands, Germany and Denmark, broadly following the 50 m depth contour which separates the southern North Sea fish and shellfish communities from those of the central and northern North Sea (Teal, 2011; see section 3.7.1). This study area provided a wider context for the data from the Hornsea Three fish and shellfish study area and formed the area covered by the desktop review and informed assessments of those impacts affecting fish and shellfish receptors over a larger scale (e.g. underwater noise).

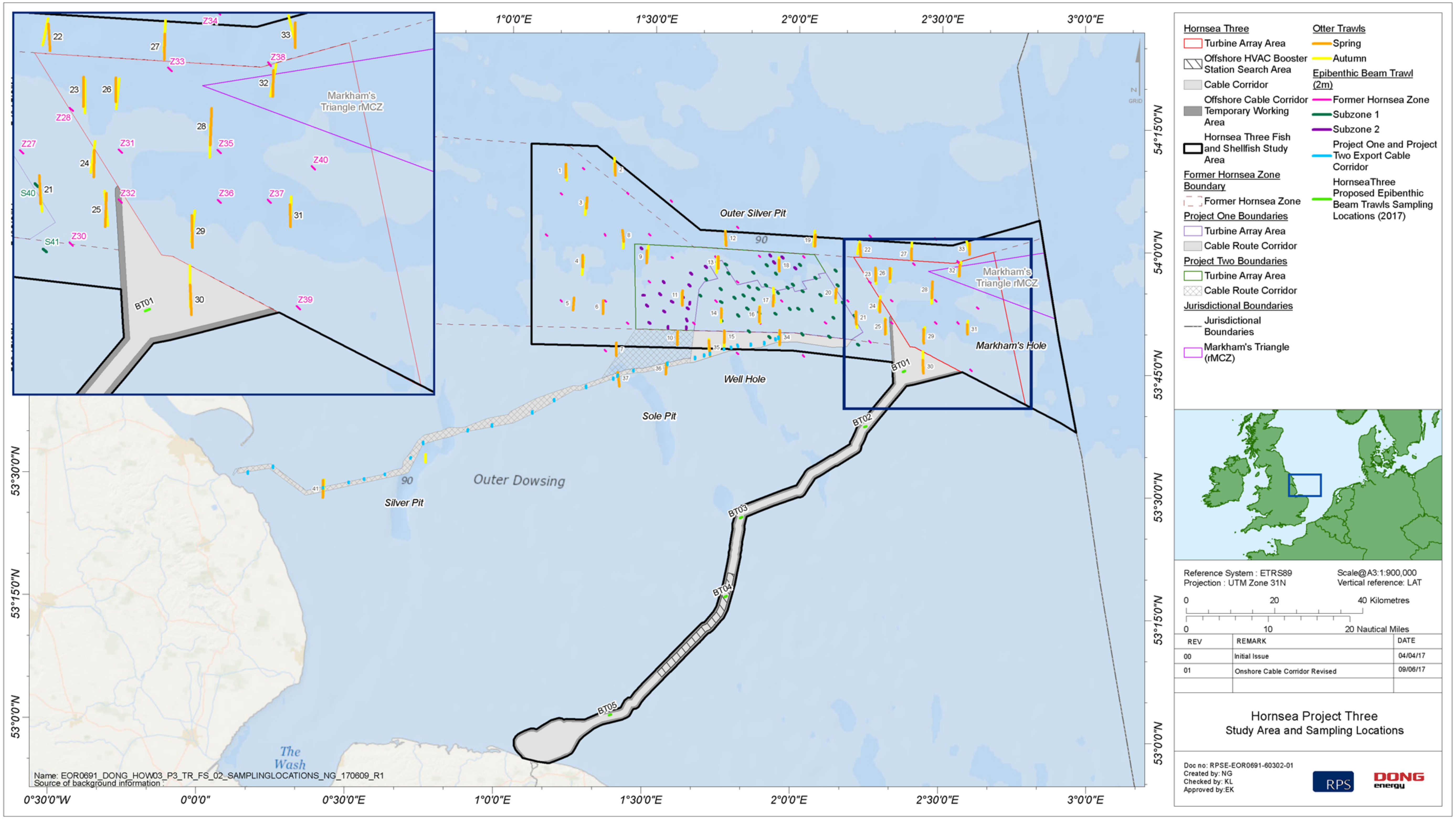

Figure 3.1: Historic otter trawl and epibenthic beam trawl sampling locations from across the former Hornsea Zone, used to inform the characterisation of fish and shellfish ecology within the Hornsea Three fish and shellfish study area. Figure also shows proposed site specific epibenthic beam trawl sampling locations.

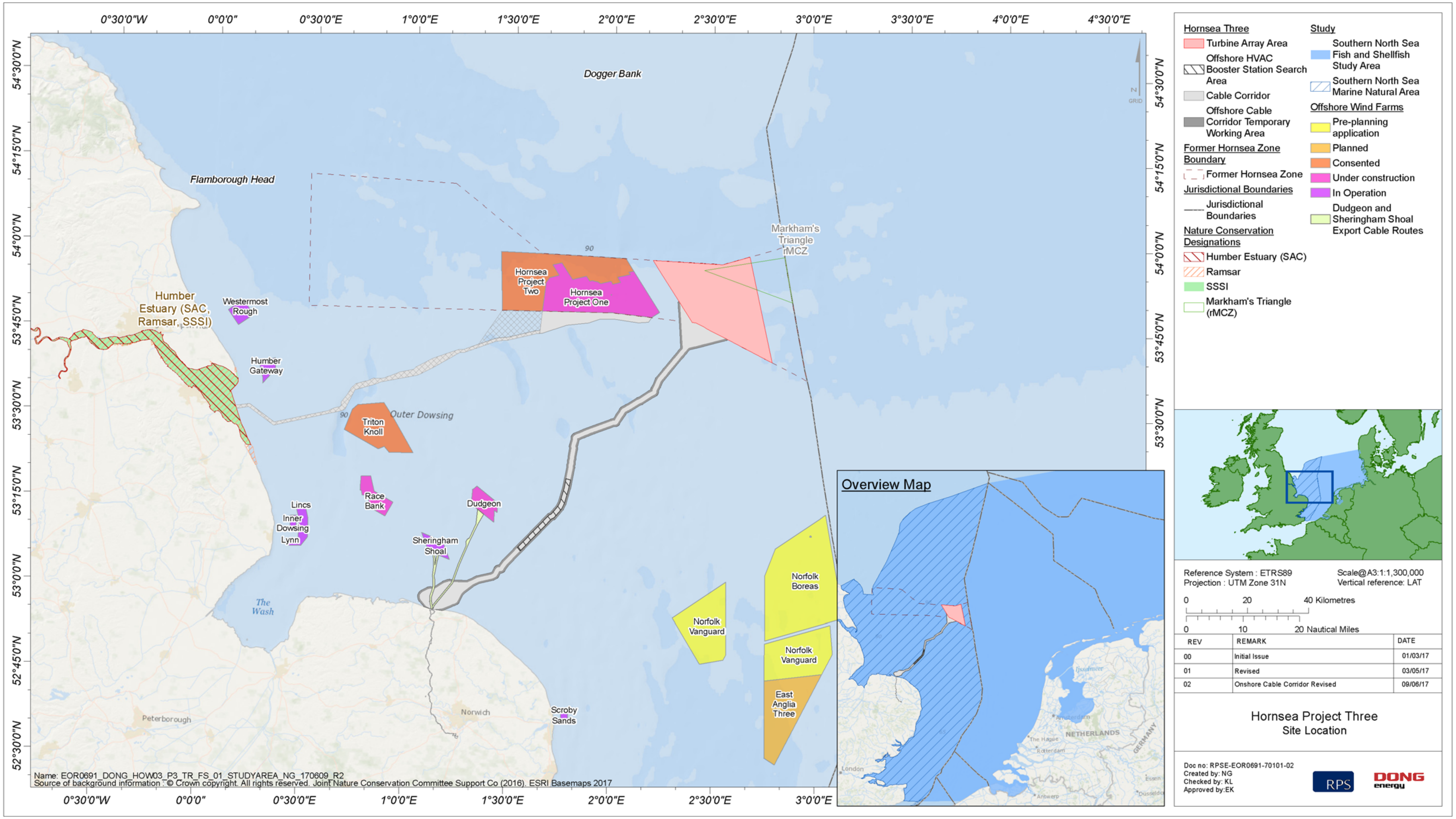

Figure 3.2: Location of Hornsea Three and the former Hornsea Zone, UK nature conservation designations with fish and shellfish features and other offshore wind farm sites in the southern North Sea fish and shellfish study area.

3.4 Planning policy context

3.4.1.1 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 (NPS EN-1; DECC, 2011a), the NPS for Renewable Energy Infrastructure (NPS EN-3, DECC, 2011b) and the Marine Policy Statement (MPS). The MPS notes that marine planning authorities should be mindful of the high-level marine objectives set out by the UK in order to ensure due consideration of marine ecology and biodiversity interests. It also recognises the role of conservation of ecologically sensitive areas throughout the planning process and mitigation or compensatory actions where significant harm cannot be avoided (paragraph 2.6.1 of the MPS).

3.4.1.2 NPS EN-3 and NPS EN-1 include guidance on what matters are to be considered in the assessment. These are summarised in Table 3.1 and Table 3.2, respectively.

3.4.1.3 NPS EN-3 also highlights a number of factors relating to the determination of an application and in relation to mitigation. These are summarised in Table 3.3 below.

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

Summary of NPS EN-3 policy relevant to the assessment of fish and shellfish ecology	How and where considered within the Hornsea Three assessment
Biodiversity	
Applicants should assess the effects on the offshore ecology and biodiversity for all stages of the lifespan of the proposed offshore wind farm (paragraph 2.6.64 of NPS EN-3).	Construction, operation and decommissioning phases of Hornsea Three have been assessed (see section 3.11).
Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate (paragraph 2.6.65 of NPS EN-3).	Consultation with relevant statutory and non-statutory stakeholders has been carried out from the early stages of Hornsea Three (see section 3.5).
Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore wind farms should be referred to where appropriate (paragraph 2.6.66 of NPS EN-3).	Relevant data collected as part of post-construction monitoring from other offshore wind farm developments has informed the assessment of Hornsea Three (section 3.11).
Applicants should assess the potential for the scheme to have both positive and negative effects on marine ecology and biodiversity (paragraph 2.6.67 of NPS EN-3).	Both the positive and negative effects have been assessed for Hornsea Three (see section 3.11).
Fish and shellfish ecology	
Impacts arising from construction and decommissioning at the seabed with consequential effects on fish communities, migration routes, spawning activities and nursery areas for particular species (paragraph 2.6.73 of NPS EN-3).	The Hornsea Three assessment has considered all phases of the Hornsea Three development on fish and shellfish species with key life stages in the vicinity of the development (see section 3.11).
In addition, there are potential noise impacts, which could affect fish during construction and decommissioning and to a lesser extent during operation (paragraph 2.6.73 of NPS EN-3).	The Hornsea Three assessment has considered noise effects on fish and shellfish species arising from construction (piling; see paragraphs 3.11.1.43 *et seq.*) and operational noise (see paragraphs 3.11.2.15 *et seq.*) as well as throughout decommissioning (see paragraphs 3.11.3.16 *et seq.*).
The applicant should identify fish species that are the most likely receptors of impacts with respect to feeding areas; spawning grounds; nursery grounds; and migration routes (paragraph 2.6.74 of NPS EN-3).	Particular attention has been given to impacts on fish (and shellfish) species at key life stages, such as during spawning or on known nursery habitats (see section 3.7).

Table 3.2: Summary of NPS EN-1 policy relevant to fish and shellfish ecology and consideration of the Hornsea Three assessment.

Summary of NPS EN-1 policy relevant to the assessment of fish and shellfish ecology	How and where considered within the Hornsea Three assessment
Biodiversity	
Where the development is subject to EIA the applicant should ensure that the Environmental Statement clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance, on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity. The applicant should provide environmental information proportionate to the infrastructure where EIA is not required to help the IPC consider thoroughly the potential effects of a proposed project.	Effects on fish and shellfish ecology, including species of conservation importance, including those listed as features of designated sites, are fully considered in sections 3.11.1 (construction phase), 3.11.2 (operation and maintenance phase) and 3.11.3 (decommissioning phase). Baseline information on these receptors is presented in section 3.7, with valuation of these receptors in the context of their conservation importance considered in section 3.7.6.
The most important sites for biodiversity are those identified through international conventions and European Directives. The Habitats Regulations provide statutory protection for these sites but do not provide statutory protection for potential Special Protection Areas (pSPAs) before they have been classified as a Special Protection Area. For the purposes of considering development proposals affecting them, as a matter of policy the Government wishes pSPAs to be considered in the same way as if they had already been classified. Listed Ramsar sites should, also as a matter of policy, receive the same protection	Effects on benthic features of designated sites are fully considered in sections 3.11.1 (construction phase), 3.11.2 (operation and maintenance phase) and 3.11.3 (decommissioning phase). These effects have also been assessed within the Draft Report to Inform the Appropriate Assessment (DONG Energy, 2017a) for Natura 2000 sites.
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 (paragraph 5.3.10 of NPS EN-1). 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 (paragraph 5.3.11 of NPS EN-1).	For SSSIs, where these are within European sites, the SSSI has been considered as part of that site in this environmental assessment. Where SSSIs are not within European sites these would be considered individually within this chapter, although no such SSSIs with fish features were identified (see paragraph 3.6.3.1).
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 (paragraph 5.3.12 in NPS EN-1).	Of the original list of rMCZs that were identified within the vicinity of the Hornsea Three fish and shellfish study area, none have fish or shellfish features (see section 3.7.5).
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.	Designed-in measures to be adopted as part of the Hornsea Three project are presented in section 3.10.
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 IPC (now PINS) should ensure that these species and habitats are protected from the adverse effects of development by using requirements or planning obligations.	All species receptors, including those of principal importance for the conservation of biodiversity in England are summarised in section 3.7 (full description in volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report), with valuation of these receptors in the context of their conservation importance considered in section 3.7.6.
The applicant should include appropriate mitigation measures as an integral part of the proposed development. In particular, the applicant should demonstrate that: • During construction, they will seek to ensure that activities will be confined to the minimum areas required for the works; • During construction and operation best practice will be followed to ensure that risk of disturbance or damage to species or habitats is minimised, including as a consequence of transport access arrangements; • Habitats will, where practicable, be restored after construction works have finished; and opportunities will be taken to enhance existing habitats and, where practicable, to create new habitats of value within the site landscaping proposals.	Mitigation measures proposed for Hornsea Three are presented in section 3.10.

Table 3.3 Summary of NPS EN-3 policy on decision making with regard to fish and shellfish ecology and consideration in the Hornsea Three assessment.

Summary of NPS EN-3 policy on decision making (and mitigation) in relation to fish and shellfish ecology	How considered within the Hornsea Three assessment
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).	This impact assessment (section 3.11) considers the effects of Hornsea Three on fish and shellfish ecology with other marine ecological receptors considered in other chapters (i.e. chapter 2: Benthic Ecology, chapter 4: Marine Mammals and chapter 5: Ornithology).
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).	European sites have been considered during the assessment (see section 3.7.5).
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).	Mitigation has been considered during the Hornsea Three assessment (see section 3.10).
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, with proposed monitoring detailed in paragraphs 3.11.1.85, 3.11.2.99 and 3.11.3.43.
Fish and shellfish ecology	
Where mitigation measures are applied to offshore export cables to reduce electromagnetic fields (EMF) the effects on sensitive species during operation are unlikely to be a reason for the Infrastructure Planning Commission (IPC) [now PINS] to have to refuse to grant consent. 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 effects (including cable design and installation) are considered within the Hornsea Three (see Table 3.11 and paragraphs 3.11.2.43 *et seq*.).
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).	Mitigation of EMF through cable burial and cable protection has been considered within the Hornsea Three assessment (see paragraphs 3.11.2.43 *et seq*.).
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).	The duration of the proposed construction works has been considered within the Hornsea Three assessment process (section 3.11 and Table 3.11).

3.4.1.4 The assessment of potential changes to benthic ecology has also been made with consideration to the specific policies set out in the East Inshore and East Offshore Coast Marine Plans (MMO, 2014). Key provisions are set out in Table 3.4 along with details as to how these have been addressed within the assessment.

Table 3.4: East Marine Plan Policies of relevance to this chapter.

Policy	Key provisions	How and where considered in the PEIR
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 3.13.
East Inshore and East Offshore Marine Plans – MPA1	Any impacts on the overall marine protected area (MPA) network must be taken account of in strategic level measures and assessments, with due regard given to any current agreed advice on an ecologically coherent network.	Designated nature conservation sites within the Hornsea Three and CEA benthic ecology study area have been described in volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report. The predicted changes to fish ecology have been considered in sections 3.11 and 3.13.

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

3.4.1.6 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 Three are listed in Table 3.5, including a brief description of how and where these have been addressed in the Hornsea Three assessment.

3.4.1.7 Further advice in relation specifically to the Hornsea Three development, has been sought through consultation with the statutory authorities and from the PINS scoping opinion (PINS, 2016) (section 3.5 and Table 3.6).

Table 3.5: 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 Three assessment.

Summary of MSFD high level descriptors of GES relevant to fish and shellfish ecology	How considered within the Hornsea Three assessment
Descriptor 1: Biological diversity: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	The effects on biological diversity has been described and considered within the assessment for Hornsea Three alone and in the cumulative effects assessment (CEA) (see sections 3.11 and 3.13, respectively).
Descriptor 2: Non-indigenous species: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.	The effects of non-indigenous species on fish and shellfish ecology within the Hornsea Three fish and shellfish ecology study area has been assessed in paragraphs 3.11.2.28 *et seq.*, with a detailed assessment of the potential effects of introduction of non-indigenous species considered in chapter 2: Benthic Ecology.
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 Three alone and in the CEA, (see sections 3.11 and 3.13, respectively).
Descriptor 6: Sea floor integrity: Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	The effects on fish and shellfish ecology has been described and considered within the assessment for Hornsea Three alone and in the CEA (see sections 3.11 and 3.13, respectively).
Descriptor 8: Contaminants: Concentrations of contaminants are at levels not giving rise to pollution effects.	The effects of contaminants on fish and shellfish species and populations have been assessed in paragraphs 3.11.1.41 *et seq.*, 3.11.1.72 *et seq.*, 3.11.2.72 *et seq.*, 3.11.3.15 *et seq.* and 3.11.3.40 *et seq.*
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 species and populations have been assessed in paragraphs 3.11.1.41 *et seq.*, 3.11.1.72 *et seq.*, 3.11.2.72 *et seq.*, 3.11.3.15 *et seq.* and 3.11.3.40 *et seq.*
Descriptor 10: Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	A Code of Construction Practice (CoCP) will be developed and implemented to cover the construction phase and an appropriate Project Environmental Management and Monitoring Plan (PEMMP) will be produced and followed to cover the operation and maintenance phase of Hornsea Three. The latter will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details (e.g. the Environmental Agency (EA), Natural England and Maritime and Coastguard Agency (MCA)). A Decommissioning Programme will be developed to cover the decommissioning phase (see section 3.10).
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 3.11.1.43 *et seq.* (construction), paragraphs 3.11.2.15 *et seq.* (operation) and paragraphs 3.13.2.35 *et seq.* (decommissioning).

3.5 Consultation

3.5.1.1 A summary of the key issues raised during consultation specific to fish and shellfish ecology is outlined below, together with how these issues have been considered in the production of this PEIR.

3.5.2 Hornsea Project One and Hornsea Project Two consultation

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

3.5.3 Hornsea Three consultation

3.5.3.1 Table 3.6 below summarises the issues raised relevant to fish and shellfish ecology, which have been identified during consultation activities undertaken to date. Table 3.6 also indicates either how these issues have been addressed within this PEIR or how the Applicant has had regard to them.

3.5.1 Evidence Plan

3.5.1.1 The purpose of the Evidence Plan process (see Draft Evidence Plan; DONG Energy 2017) is to agree the information Hornsea Three needs to supply to PINS, as part of a DCO application for Hornsea Three. The Evidence Plan seeks to ensure compliance with the Habitat Regulations Assessment (HRA) and EIA.

3.5.1.2 As part of the Evidence Plan process, the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology Expert Working Group (EWG) was established with representatives from the key regulatory bodies and their advisors and statutory nature conservation bodies, including the MMO, Cefas and Natural England. Representatives from the Wildlife Trust (TWT), who were not part of the EWG at the start, joined the EWG from February 2017. Between June 2016 and publication of this PEIR, a number of EWG meetings were held that included discussion of key issues with regard to the fish and shellfish ecology elements of Hornsea Three, including characterisation of the baseline environment and the impacts to be considered within the impact assessment. The identification of key issues was informed by consultation on Hornsea Project One and Project Two, where appropriate. Matters raised during EWG meetings have been included in Table 3.6 below.

Table 3.6: Summary of key consultation issues raised during consultation activities undertaken for Hornsea Three relevant to fish and shellfish ecology.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
6 December 2016	PINS - Scoping Opinion	Identification of the Humber Estuary Special Area of Conservation (SAC)/Ramsar site, Humber Estuary SSSI and Markham's Triangle MCZ as being located within the surrounding area and relevant to the project in terms of fish and shellfish ecology.	These nature conservation designations are considered in section 3.7.5 and volume 5, annex 3.1: Fish and Shellfish Technical Report.
		The Secretary of State does not agree that effects from remobilisation of sediment bound contaminants during construction and decommissioning should be scoped out.	This is considered in paragraphs 3.11.1.41 and 3.11.3.15 for the Hornsea Three offshore cable corridor only. Effects from remobilisation of sediment bound contaminants were scoped out of the assessment as agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG (see section 3.8.2).
		The Secretary of State does not agree that effects from changes in fishing pressure within and outside the array during operation should be scoped out. I	This impact has not been scoped out and is considered in full in paragraph 3.11.2.83 *et seq*.
		Offshore Energy Strategic Environmental Assessment 3 (OESEA3) to be reviewed by Applicant.	Comment acknowledged, information from the OESEA3 has been considered within the baseline characterisation (volume 5, annex 3.1: Fish and Shellfish Technical Report).
		Request for pre-application agreement with the MMO and SNCBs in respect of the baseline for fish and shellfish ecology, including any requirement for further surveys.	Agreement on the information used to support the baseline characterisation has been reached through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology (EWG; see below.
		Potential impacts scoped into the impact assessment for fish and shellfish ecology are appropriate. However, the Applicant's attention is drawn to the MMO response, which queries whether the construction impacts to be considered relate to both fish and shellfish receptors, or only fish receptors.	Both fish and shellfish receptors are considered for all impacts assessed.
25 November 2016	MMO - Scoping Opinion	The MMO considers that the most relevant impacts to fish and shellfish ecology have been scoped into the EIA process and that data sources appear to be appropriate.	No response required.
		MMO currently unable to confirm the sufficiency of the information used to support the baseline characterisation and the proposed approach, but has been provided further information through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG.	Agreement of the information used to support the baseline characterisation has been agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG; see below.
		It is not clear whether the impacts of construction activities will be considered for both fish and shellfish or just fish (both receptors will be assessed for the other phases). The EIA should consider key shellfish receptors during the construction and other phases. Applicant is encouraged to review existing peer-reviewed literature on effects of noise on invertebrates (e.g. Wale *et al*., 2013a, 2013b, Solan *et al*., 2016).	Both fish and shellfish receptors are considered for all impacts assessed., and include assessment of noise impacts.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
25 November 2016	Natural England - Scoping Opinion	Request to use the available data or any additional modelling and assess any impacts on stratification and in particular the Flamborough Front.	Effects on the Flamborough Front have the potential to affect a number of ecological receptors, including a number of fish and shellfish receptors in the southern North Sea fish and shellfish study area. An assessment of the potential effects of Hornsea Three on the Flamborough Front has been presented within chapter 1: Marine Processes and volume 5, annex 1.1: Marine Processes Technical Report. This assessment predicted that minor decreases in the strength of water column stratification may occur within the Hornsea Three array area. Only a small proportion of water passing through the Hornsea Three array area would interact with individual foundations, causing only partial and localised mixing of any stratification. Numerous repeat passes through the Hornsea Three array area would be needed for an initially stratified body of water to become mixed, although, this is unlikely to happen due to displacement of the water body out of the Hornsea Three array area over shorter time periods by residual tidal currents. It is therefore unlikely that water which is stratified entering the Hornsea Three array area will become fully mixed. Regional scale patterns of stratification in the North Sea will be unaffected and will continue to be subject to natural processes and variability. The location and physical characteristics of the Flamborough Front are therefore unlikely to be measurably affected and will remain within the range of natural variability. On the basis of the assessment presented in chapter 1: Marine Processes, no impact on fish and shellfish receptors (and other ecological receptors) are predicted.
		Aspects of the baseline characterisation for fish and shellfish ecology are still under discussion with Cefas and Natural England through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG and have yet to be formally signed off.	Agreement of the information used to support the baseline characterisation has been agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish EWG; see below.
6 June 2016	Marine Processes, Benthic Ecology and Fish and Shellfish EWG meeting (DONG Energy, 2017b).	Discussion of baseline characterisation and assessments for Hornsea Project One and Project Two.	No response required.
		Discussion of information to support the Hornsea Three baseline characterisation, including information to support sandeel characterisation. Cefas required further information on sandeel habitats.	No response required.
		Agreement that due to low levels of sediment contamination recorded during surveys across the former Hornsea Zone, these represent a low risk to marine ecology and therefore it is unlikely that a pathway exists for impacts from contaminated sediments within the Hornsea Three array.	No response necessary. This has been scoped out for the Hornsea Three array area in section 3.8.2. Potential effects of release of sediment contamination on the offshore cable corridor are considered in paragraphs 3.11.1.41 and 3.11.3.15.
12 July 2016	Marine Processes, Benthic Ecology and Fish and Shellfish EWG meeting (DONG Energy, 2017b).	Discussion of key data sources to be used to characterise the proposed offshore cable corridor.	No response required.
		Agreement on the designated conservation sites to be considered in the impact assessment.	Nature conservation designations are considered in section 3.7.5 and volume 5, annex 3.1: Fish and Shellfish Technical Report
		Agreement on the relevant construction/operation/decommissioning impacts, their applicability to HOW03, the data gaps identified and the approach to fill the data gaps.	No response required.
		Key assessment issues from Hornsea Project One and Hornsea Project Two may be applicable to Hornsea Three. No specific Hornsea Three issues identified.	Key issues raised during Hornsea Project One and Hornsea Project Two are summarised in volume 4, annex 1.1: Hornsea Project One and Hornsea Project Two Consultation of Relevance to Hornsea Three.
		Discussion on key receptors and availability of data sources to inform assessment.	No response required.
		Construction methodologies along Hornsea Three offshore cable corridor. Cefas stated that construction is acceptable provided substrate is left in a suitable state after cable installation.	Effects of cable burial and placement of cable protection on fish and shellfish receptors are considered in including paragraphs 3.11.1.3 *et seq*. (temporary habitat loss) and paragraphs 3.11.2.3 *et seq*. (long term habitat loss).

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
		Electromagnetic fields: Cefas noted that a lot of research into EMF is generally inconclusive and that burial depth is considered an appropriate mitigation. EMF is generally not considered to be an issue, with appropriate burial.	EMF effects on fish and shellfish receptors have been considered in paragraphs 3.11.2.43 *et seq*. and paragraphs 3.13.3.30 *et seq*.
17 November 2016	Marine Processes, Benthic Ecology and Fish and Shellfish EWG meeting (DONG Energy, 2017b).	Discussions on potential for displacement of commercial fisheries.	Effects on commercial fisheries are assessed in chapter 6: Commercial Fisheries. Effects on fish and shellfish receptors are considered in paragraph 3.11.2.83 *et seq*.
2 February 2017	Marine Processes, Benthic Ecology and Fish and Shellfish EWG meeting (DONG Energy, 2017b).	Discussion of adequacy of fish ecology data to inform impact assessment, including provision of further information on sandeel characterisation.	Further information requested by Cefas provided, with confirmation of adequacy of information to support the baseline characterisation in post meeting correspondence.
24 February 2017		Post meeting correspondence: Confirmation from Cefas of adequacy of information to support fish ecology characterisation, including sandeel for Hornsea Three array and offshore cable corridor.	
10 April 2017		Post meeting correspondence: Comments from Cefas shellfish team regarding importance of inshore section of the Hornsea three offshore cable corridor for shellfish species, including brown crab *Cancer pagurus* and European lobster *Homarus gammarus*.	Characterisation of shellfish populations is summarised in section 3.7.4 and presented in full in volume 5, annex 3.1: Fish and Shellfish Technical Report. Effects on shellfish populations are considered throughout the impact assessment, including paragraphs 3.11.1.3 *et seq*. (temporary habitat loss) and paragraphs 3.11.2.3 *et seq*. (long term habitat loss).

3.6 Methodology to inform the baseline

3.6.1 Overview

3.6.1.1 The approach proposed by Hornsea Three for the purposes of characterising the fish and shellfish communities within the two fish and shellfish ecology study areas defined in paragraph 3.3.1.1, was an evidence based approach to the EIA, which involves utilising existing data and information from sufficiently similar or analogous studies to inform the baseline understanding (and/or impact assessments) for a new proposed development. In this way, the evidence based approach does not necessarily require new data to be collected, or new modelling studies to be undertaken, to characterise potential impacts with sufficient confidence for the purposes of EIA (see volume 1, chapter 5: Environmental Impact Assessment Methodology).

3.6.1.2 Hornsea Three is located within the former Hornsea Zone, for which extensive data and knowledge regarding fish and shellfish ecology is already available. This data/knowledge has been acquired through zonal studies and from the surveys and characterisations undertaken for Hornsea Project One and Hornsea Project Two. It was therefore proposed that the Hornsea Three fish and shellfish characterisation be completed using a combination of desktop data and information sources, and survey data collected as part of the characterisations of the Hornsea Project One and Hornsea Project Two offshore wind farms and the former Hornsea Zone. Over the series of EWG meetings conducted between June 2016 and publication of this PEIR, it was agreed that this approach (further detailed in the sections below) was appropriate and sufficient for the purposes of characterising the fish and shellfish ecology of Hornsea Three.

3.6.1.3 As agreed with the EWG, further Hornsea Three specific survey data, collected during the benthic ecology surveys of the Hornsea Three array area and the Hornsea Three offshore cable corridor, will also be incorporated into the baseline characterisation assessment. This includes grab sample data to characterise the suitability of sediments as sandeel (i.e. lesser sandeel *Ammodytes* sp. and greater sandeel *Hyperoplus lanceolatus*) and herring *Clupea harengus* spawning habitats and epibenthic beam trawl data within the Hornsea Three offshore cable corridor to provide further site-specific data on fish communities, to supplement desk based information (see Table 3.8).

3.6.2 Desktop study

3.6.2.1 Information on fish and shellfish ecology within the southern North Sea was collected through a detailed desktop review of existing studies and datasets. The key data sources are summarised in Table 3.7 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. While these data sources span a wide range of dates, with some of these reports dating back to the 1990s, up to date data and information have been used to ensure these sources are still valid, including data from International Council of the Exploration of the Sea (ICES; e.g. the most recent International Bottom Trawl Survey (IBTS) or International Herring Larvae Survey (IHLS) datasets) and commercial fisheries information. These data sources ensure that historic datasets can be validated to ensure an up-to-date baseline appropriate to inform the impact assessment.

Table 3.7: Summary of key desktop reports.

Title	Source	Year	Author
Technical Reports for the Offshore Oil and Gas Strategic Environmental Assessment (SEA) Areas 2 and 3	UK Government, Department of Energy and Climate Change (DECC)	2001 2002	Cefas Rogers and Stocks DTI
UK Offshore Energy SEA 3 (OESEA3)	UK Government, DECC (now Department of Business, Energy and Industrial Strategy; BEIS)	2016	DECC
Southern North Sea Marine Natural Area Profile	Natural England, Open Source	2004	Jones *et al.*
The distribution and abundance of young fish on the east and south coast of England (1981 to 1997)	Cefas Science Series Technical Reports	1998	Rogers *et al.*
The North Sea fish community: past, present and future	Wettelijke Onderzoekstaken Natuur and Milieu, Wagengingen	2011	Teal
Diversity and community structure of epibenthic invertebrates and fish in the North Sea	ICES Journal of Marine Science	2002	Callaway *et al.*
Spatial patterns of infauna, epifauna, and demersal fish communities in the North Sea	ICES Journal of Marine Science	2013	Reiss *et al.*
International Council of the Exploration of the Sea (ICES) FishMap	ICES; http://www.ices.dk/marine-data/maps/Pages/ICES-FishMap.aspx	2005	ICES
International Herring Larvae Survey (IHLS)	ICES; http://www.ices.dk/marine-data/data-portals/Pages/Eggs-and-larvae.aspx	2015	ICES
International Bottom Trawl Surveys	ICES; http://datras.ices.dk/home/descriptions.aspx	2017	ICES

Title	Source	Year	Author
Spawning and nursery grounds of selected fish species in UK waters	Cefas Scientific Series Technical Report	2012	Ellis *et al.*
Fisheries Sensitivity Maps in British Waters	UKOOA Ltd: Aberdeen	1998	Coull *et al.*
Triton Knoll offshore wind farm Environmental Statement	Triton Knoll Offshore Wind Farm Ltd.	2011	RPS
Dudgeon offshore wind farm Environmental Statement	Dudgeon Offshore Wind Limited	2009	Dudgeon Offshore Wind Limited, 2009
Sheringham Shoal offshore wind farm Environmental Statement and pre-construction survey data.	Scira Offshore Energy	2006 2009	Scira Offshore Energy; Brown and May
Marine Aggregates Regional Environmental Assessment (MAREA) of the Humber and the Outer Wash Region	Humber Aggregate Dredging Association (HADA)	2012	ERM
Eastern Sea Fisheries Joint Committee Research Report	Eastern Sea Fisheries Joint Committee (ESFJC)	2007	Jessop *et al.*
Fisheries Mapping Project	Eastern Inshore Fisheries and Conservation Authority (EIFCA); http://www.eastern-ifca.gov.uk/about/fisheries/fisheries-mapping-project/	2010	ESFJC
Crab and lobster stock assessments	EIFCA Cefas	2015 2014	EIFCA Cefas

3.6.3 Designated sites

3.6.3.1 All designated sites within the southern North Sea fish and shellfish study area that could be affected by the construction, operation and maintenance, and decommissioning of Hornsea Three for fish and shellfish ecology, were identified using the three step process described below:

- Step 1: All designated sites of international, national and local importance within the southern North Sea fish and shellfish ecology study area were identified using a number of sources. These included the JNCC's website, the European Site European Nature Information System (EUNIS) database for international designations, and the Final Recommendations Reports of the Net Gain project for rMCZs (Net Gain, 2011). National and local designations including NNRs, SSSIs and LNRs were identified using the Department for Environment, Food and Rural Affairs (Defra) MAGIC interactive map applications (http://magic.defra.gov.uk/).
- Step 2: Information was compiled on the relevant qualifying fish features for each of these sites as follows:
    - The known occurrence of species within Hornsea Three was based on the results of the Hornsea Three fish and shellfish ecology surveys which are presented in this chapter and relevant desktop information on the fish communities of the southern North Sea fish and shellfish study area.
- Step 3: Using the above information and expert judgement, sites were included for further consideration if:
    - A designated site directly overlaps with Hornsea Three including the offshore export cable route corridor (up to Mean High Water Springs (MHWS));
    - Sites and associated features were located within the potential Zone of Impact (ZoI) for impacts associated with Hornsea Three (e.g. habitat loss/disturbance, increase in suspended sediments and deposition);
    - Species of a designated site were either recorded as present during historic surveys across the former Hornsea zone, or identified in the desktop study as having the potential to occur in Hornsea Three and listed as either a primary reason for site selection or listed as a qualifying feature;
    - Where national and locally designated sites (i.e. SSSIs, rMCZs, NNRs and LNRs) fall within the boundaries of an internationally designated site (e.g. SAC and SCI), only the international site has been considered, as potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken). In some cases, however where a national site forms a component of an international site, but the latter designation does not list a qualifying feature that is present on the SSSI citation, the individual SSSI will be taken forward for further assessment for that particular feature or the species;
    - Where a national site falls outside of an international site, but within the Hornsea Three fish and shellfish study area, the national site will be taken forward for further assessment for a particular feature; and
    - For rMCZs, only those which have been designated in the first two tranches of designations in 2013 and 2016 have been considered. This is in line with guidance issued by the MMO regarding the lack of a need for formal assessment for MCZ sites identified as possible candidates for designation in future tranches (MMO, 2013).

3.6.4 Historic and site specific surveys

3.6.4.1 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, Benthic Ecology and Fish and Shellfish EWG (see section 3.6.4). A summary of these surveys and proposed Hornsea Three site specific surveys is outlined in Table 3.8 below.

Table 3.8: Summary of survey data collected across the former Zone and proposed site specific surveys.

Title	Extent of survey	Overview of survey	Survey contractor	Year	Reference to further information
Seasonal otter trawl sampling	41 trawls undertaken across the former Hornsea Zone with a 4 km buffer to the north and south. Twelve of these trawls were undertaken within or in the immediate vicinity to the Hornsea Three array area (see Figure 3.1).	Seasonal otter trawl surveys undertaken in spring and autumn 2011 across the former Hornsea Zone, which is now encompassed within the Hornsea Three fish and shellfish study area. The vessel used to conduct these surveys was a commercial fishing vessel fitted with a high-opening 5 m otter trawl and 40 mm cod-end allowing for both demersal and semi-pelagic species to be caught. A total of 41 trawls, of 30 minute duration, were completed (Figure 3.1), after which time the catch was recovered on board and sorted to species level using relevant identification keys. The entire catch was then enumerated and measured to the nearest millimetre. All mature herring captured during the autumn survey were analysed to determine their spawning condition. The gonads were examined and compared to the established International ICES Gonadal Somatic Index (GSI) criteria and the fish grouped into one of seven maturity stages (Bucholtz *et al*., 2008).	EMU	2011	Volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report
Epibenthic beam trawl sampling	102 beam trawl samples were collected across the former Hornsea Zone to support the zonal characterisation and baseline characterisations for Hornsea Projects One and Two. Nine of these were undertaken within the Hornsea Three array area (see Figure 3.1).	Epibenthic beam trawl surveys between 2010 and 2012 across the former Hornsea Zone, which is now encompassed within the Hornsea Three fish and shellfish study area. The beam trawls, each lasting ten minutes, were carried out using a standard Cefas 2 m 'Jennings' beam trawl fitted with a 5 mm cod-end. The total catch for each trawl was sorted to species level using the relevant keys and then enumerated and measured within species groups.	EMU	2010 and 2012	Volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report Volume 5, annex 2.1: Benthic Ecology Technical Report
Proposed epibenthic beam trawl sampling of Hornsea Three offshore cable corridor	Five epibenthic beam trawls to be undertaken across the Hornsea Three offshore cable corridor (see Figure 3.1).	During the Evidence Plan process (section 3.5; DONG Energy, 2017b), it was agreed that no further trawl samples would be collected to characterise the Hornsea Three array. In order to further characterise the Hornsea Three offshore cable corridor, DE proposed a further five locations to be sampled 2017 as part of the benthic ecology survey of the offshore cable corridor. Due to the timing of this survey, these data are not included within the PEIR (i.e. this report), but will be incorporated into the fish and shellfish technical report to be submitted as part of the DCO application.	To be confirmed	2017	Volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report

3.7 Baseline environment

3.7.1 Fish populations

3.7.1.1 A detailed characterisation of the fish and shellfish communities within the Hornsea Three and southern North Sea fish and shellfish study areas is presented in volume 5, annex 3.1, with a summary provided here. This PEIR chapter should therefore be read alongside this detailed fish and shellfish ecology characterisation annex.

3.7.1.2 The fish communities characterising the Hornsea Three fish and shellfish study area were found to comprise mainly demersal fish species such as whiting, dab, plaice, solenette and grey gurnard, all of which were recorded in abundance during trawl surveys. The Hornsea Three fish and shellfish study area was also found to be characterised by other demersal species such as lemon sole, common sole and cod. Small demersal species including the short spined sea scorpion *Myoxocephalus scorpius*, lesser weaver *Echiichthys vipera*, dragonet and scaldfish *Arnoglossus laterna* were also recorded in surveys across the former Hornsea Zone including the Hornsea Three array area.

3.7.1.3 Spatial variability was also noted in the trawl datasets with depth identified as an important factor influencing communities. Offshore areas, including the Hornsea Three array area and the rest of the former Hornsea Zone, were generally consistent spatially, primarily being characterised by demersal species including whiting, dab, plaice, solenette and grey gurnard, with subtle differences in the communities in deeper areas (e.g. increased abundances of whiting). By contrast, communities recorded in shallow, inshore areas were characterised by lower abundances of species like dab (which were abundant elsewhere) and high abundances of crustaceans (discussed in section 3.7.4 below).

3.7.1.4 Pelagic species recorded in the Hornsea Three fish and shellfish study area included sprat, herring and mackerel *Scomber scombrus* with sprat and herring identified as being two of the key characterising species within the Hornsea Three fish and shellfish study area. Mackerel was found to have seasonal variability and appeared to be more abundant in autumn with very low numbers occurring in spring. Sprat showed strong seasonal patterns in abundance, with notably higher abundances in spring than autumn. The high abundances recorded during the spring (April) otter trawl survey may coincide with the start of the peak spawning period for this species (May to June; Coull *et al*., 1998). As with sprat, herring also showed a strong seasonal pattern, with high abundances recorded during the spring survey in inshore areas close to the Humber Estuary and lower abundances in autumn.

3.7.1.5 Two sandeel species were recorded in trawl surveys within the Hornsea Three fish and shellfish study area: lesser sandeel *Ammodytes tobianus* and greater sandeel which are hereafter referred to collectively as sandeel. These species were generally recorded at low abundances during trawl surveys, particularly during otter trawl surveys, compared to many of the other characterising species. Sandeel were also recorded during epibenthic beam trawls and at generally higher abundances than in otter trawls, however, abundances were still lower than for many other key species such as solenette, dab and scaldfish. 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 former Hornsea Zone were generally found to be highest to the west of the Hornsea Three array area. Sandeel habitats in the North Sea have been mapped using data collected from fishing vessels targeting sandeel (Jensen *et al*., 2010) and therefore give an indication of the distribution of sandeel habitats *across* the North Sea (although it should be noted that these do not represent all the sandeel habitats in the North Sea). Sandeel habitats *were shown to* occur throughout the southern North Sea fish and shellfish study area, including *across the former Hornsea Zone,* the Hornsea Three offshore cable corridor (i.e. North Norfolk sandbanks), to the northwest of the former Hornsea Zone and Dogger Bank (see Jensen *et al*., 2010 and Figure 3.22 of volume 5, annex 3.1: Fish and Shellfish Technical Report).

3.7.1.6 Potential sandeel habitats were also mapped using particle size analysis (PSA) data (collected as part of the Benthic Ecology characterisation; see volume 5 annex 2.1: Benthic Ecology Technical Report) and broadscale SeaZone HydroSpatial sediment data, 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 Three and wider southern North Sea fish and shellfish study areas (full details of these methodologies are presented in volume 5, annex 3.1: Fish and Shellfish Technical Report). The results of these analyses (see Figure 3.23 of volume 5, annex 3.1: Fish and Shellfish Technical Report) largely reflected the patterns detected in trawl surveys discussed above, with sandeel habitats considered to be "preferred" across most of the Hornsea Three fish and shellfish study area, including the Hornsea Three array area, although these were most extensive to the west of the Hornsea Three array area. These habitats were also recorded along the Hornsea Three offshore cable corridor in the vicinity of the North Norfolk Sandbanks, with "marginal" areas in coarse, gravelly areas, including the nearshore sections of the Hornsea Three offshore cable corridor.

3.7.1.7 Elasmobranchs including thornback ray *Raja clavata* and spotted ray *Raja montagui* were recorded in surveys across the former Hornsea Zone but at very low abundances in the Hornsea Three fish and shellfish study area. Ray species have also been recorded and tagged in proximity to the nearshore section of the Hornsea Three offshore cable corridor (i.e. offshore of Wells-next-the-Sea) in a recent tagging study by Cefas (McCully *et al*., 2013). This study showed catches dominated by thornback ray, with proportionally more large females recorded here than other nearshore areas surveyed (e.g. off of Southwold and Lowestoft). Other elasmobranch species such as the smooth hound *Mustelus mustelus* and tope shark *Galeorhinus galeus* have been reported to occur in the southern North Sea fish and shellfish study area and although these species were not recorded during surveys across the former Hornsea Zone, it is thought that spawning and/or nursery habitats may potentially occur in inshore areas of the Hornsea Three fish and shellfish study area (ERM, 2012).

3.7.2 Fish spawning and nursery habitats

3.7.2.1 Spawning and nursery habitats present in the Hornsea Three fish and shellfish study area are summarised in Table 3.9 for all species for which data exist. Nursery and spawning habitats 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). These spawning and nursery habitats (including mapping of these relative to Hornsea Three) are fully discussed in volume 5, annex 3.1: Fish and Shellfish Technical Report.

3.7.3 Migratory fish species

3.7.3.1 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 have the potential to occur in a number of rivers in the southern North Sea fish and shellfish study area, including those flowing into the Wash, although the most important river for these species on the east coast of England is the Humber Estuary (Perez-Dominguez, 2008; Allen *et al*., 2003; Proctor et al., 2000; Proctor and Musk, 2001). These species are fully discussed in volume 5, annex 3.1: Fish and Shellfish Technical Report, including their likely occurrence in the Hornsea Three project area and in coastal and estuarine habitats in the southern North Sea fish and shellfish study area.

3.7.4 Shellfish species

3.7.4.1 The shellfish ecology of the Hornsea Three fish and shellfish study area was found to be primarily characterised by four commercial species: brown crab, European lobster, *Nephrops* and common whelk. Of these species, brown crab were found to be by far the most abundant species in the Hornsea Three fish and shellfish study area, especially along the nearshore section of the Hornsea Three offshore cable corridor where it is targeted by commercial fisheries along the north Norfolk coast. Lobster were also present along the Hornsea Three offshore cable corridor though at much lower abundances. Both of these species are particularly important to commercial fisheries in the southern North Sea. Whelk are also targeted by commercial fisheries along the Hornsea Three offshore cable corridor, with increasing importance to commercial fisheries in recent times. *Nephrops*, in contrast, were recorded consistently in deep water, sandy mud habitats within the Hornsea Three array area and in the deep waters to the north and northwest of it. *Nephrops* within the Hornsea Three array area and the deeper areas to the north (e.g. Outer Silver Pit) are targeted by commercial fishing fleets from the UK, Belgium and Netherlands. Overwintering, spawning and/or nursery habitats for brown crab and *Nephrops* are expected to coincide with the Hornsea Three fish and shellfish study area (see volume 5, annex 3.1: Fish and Shellfish Technical Report for further discussion).

Table 3.9: Summary of spawning and nursery habitats within the Hornsea Three and southern North Sea fish and shellfish study areas from data presented in Coull *et al.* (1998), Ellis *et al*. (2010), Rogers *et al*. (1998), ERM (2012) and surveys across the former Hornsea Zone. Note: Distances should be interpreted with caution as boundaries drawn by Coull *et al*. (1998) and Ellis *et al*. (2010) should be considered guidelines rather than definitive boundaries (see volume 5, annex 3.1: Fish and Shellfish Technical Report).

Species		Spawning Habitats		Nursery Habitats	
		Description	Distance to Hornsea Three (km)	Description	Distance to Hornsea Three (km)
Whiting	*Merlangius merlangus*	Low intensity spawning habitat coinciding with the Hornsea Three fish and shellfish study area, including inshore sections of the Hornsea Three offshore cable corridor. Spawns February to June.	0	High intensity nursery habitat across most of the Hornsea Three fish and shellfish study area. Low intensity nursery habitat in inshore sections of the Hornsea Three offshore cable corridor.	0
Cod	*Gadus morhua*	Low intensity spawning habitat coinciding with the Hornsea Three fish and shellfish study area. Spawns January to April.	0	Low intensity nursery habitat coinciding with Hornsea Three (array area and offshore cable corridor); high intensity nursery habitat to the west of former Hornsea Zone.	0
Dab	*Limanda limanda*	No data.	No data.	Juvenile dab recorded in sandy coastal habitats, including the Wash and inshore along the north Norfolk coast.	No data.
Plaice	*Pleuronectes platessa*	High intensity spawning habitat coinciding with the Hornsea Three fish and shellfish study area. Spawns January to March.	0	Low intensity nursery habitat coinciding with inshore sections of the Hornsea Three offshore cable corridor.	0
Lemon sole	*Microstomus kitt*	Spawning grounds coinciding with the Hornsea Three offshore cable corridor, though not the Hornsea Three array area. Spawns April to September.	0	Nursery habitat coinciding with the Hornsea Three offshore cable corridor.	0
Common sole	*Solea solea*	Low intensity spawning habitat coinciding with the inshore sections of the Hornsea Three offshore cable corridor and to the north of the Hornsea Three array area. Spawns March to May.	0	Low intensity nursery habitat coinciding with inshore sections of the Hornsea Three offshore cable corridor.	0
Sprat	*Sprattus sprattus*	Spawning habitat coinciding with Hornsea Three, excluding much of the Hornsea Three offshore cable corridor. Spawns May to August.	0	Nursery habitats coinciding with Hornsea Three (array area and offshore cable corridor), though not inshore sections of the Hornsea Three offshore cable corridor.	0
Herring	*Clupea harengus*	Autumn spawning (September to October) habitat to the west of the Hornsea Three array area, with spring (April) spawning population in the Wash.	Hornsea Three array area: 83[a] Hornsea Three offshore cable corridor: 52[a]	Low intensity nursery habitat coinciding with Hornsea Three (array area and offshore cable corridor), with high intensity nursery habitat further west in the Wash.	0
Mackerel	*Scomber scombrus*	Spawning habitat coinciding with the Hornsea Three array area and much of the Hornsea Three offshore cable corridor. Spawns May to August.	0	Low intensity nursery habitats coinciding with Hornsea Three (array area and offshore cable corridor).	0
Thornback ray	*Raja clavata*	Spawning females recorded off Wells-next-the-Sea indicating the waters off the north Norfolk coast and the Greater Wash (i.e. the nearshore sections of the Hornsea Three offshore cable corridor) represent spawning habitat for this species (McCully *et al*., 2013). Reported to spawn in summer months, with records above made in June and July.	No data.	Low intensity nursery habitat in inshore section of the Hornsea Three offshore cable corridor and to the west within and around the Wash.	0
Spotted ray	*Raja montagui*	Spawning in the southern North Sea fish and shellfish study area. Lay egg cases in April to July.	No data.	Nursery habitat within the southern North Sea fish and shellfish study area.	No data.
Sandeel	*Ammodytes spp.* and *Hyperoplus lanceolatus*	High intensity spawning grounds to the north of the Hornsea Three array area, with low intensity spawning grounds coinciding with Hornsea Three (array area and offshore cable corridor). Spawns November to February.	0	Low intensity nursery habitats coinciding with Hornsea Three (array area and offshore cable corridor).	0

Species		Spawning Habitats		Nursery Habitats	
Anglerfish	*Lophius spp.*	No data.	No data.	Low intensity nursery habitat coinciding with the Hornsea Three array area and offshore section of the Hornsea Three offshore cable corridor. Hornsea Three lies at the southern extent of anglerfish nursery habitats in the North Sea.	0
Spurdog	*Squalus acanthias*	Females give birth in coastal waters in the southern North Sea fish and shellfish study area between August and December.	No data.	Low intensity nursery habitat coinciding with the Hornsea Three array area and offshore section of the Hornsea Three offshore cable corridor. Hornsea Three lies at the southern extent of spurdog nursery habitats in the North Sea.	0
Tope shark	*Galeorhinus galeus*	Spawning in the southern North Sea fish and shellfish study area during the summer months.	No data.	Low intensity nursery habitat coinciding with the Hornsea Three array area and offshore section of the Hornsea Three offshore cable corridor. Hornsea Three lies at the eastern extent of tope nursery habitat in the southern North Sea.	0
Smooth hound	*Mustelus mustelus*	Mating and birth in the southern North Sea fish and shellfish study area in summer.	No data.	No data.	No data.
Starry smooth hound	*Mustelus asterias*	Mating and birth in the southern North Sea fish and shellfish study area in summer.	No data.	No data.	No data.
Lesser spotted dogfish	*Scyliorhinus canicula*	Spawning within the southern North Sea fish and shellfish study area in spring and early summer, though little is known about where eggs are deposited.	No data.	No data.	No data.
Blue whiting	*Micromesistius poutassou*	No known spawning habitats in the Hornsea Three fish and shellfish study area.	N/A	Low intensity nursery habitat immediately to the north of the Hornsea Three array area. Hornsea Three lies at the southern extent of blue whiting nursery habitats in the North Sea.	0
Ling	*Molva molva*	No known spawning habitats in the Hornsea Three fish and shellfish study area.	N/A	Low intensity nursery habitat immediately to the north of the Hornsea Three array area. Hornsea Three lies at the southern extent of ling nursery habitats in the North Sea.	0
Hake	*Merluccius merluccius*	No known spawning habitats in the Hornsea Three fish and shellfish study area.	N/A	Low intensity nursery habitat immediately to the north of the Hornsea Three array area. Hornsea Three lies at the southern extent of hake nursery habitats in the North Sea.	0
Haddock	*Melanogrammus aeglefinus*	No known spawning habitats in the Hornsea Three fish and shellfish study area.	N/A	Nursery habitats located far to the northwest of Hornsea Three array area.	168

a: Distance to herring spawning ground as mapped using IHLS data 2001-2015 (see Figure 3.33 of volume 5, annex 3.1).

3.7.5 Designated sites

3.7.5.1 Designated sites, with fish species as listed features, within close proximity to Hornsea Three and therefore most likely to be potentially affected by activities associated with it, are described here and discussed in full in volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report.

3.7.5.2 A number of the fish species which were recorded during historic surveys across the former Hornsea Zone (see Table 3.8 and Figure 3.1), or identified as having the potential to be present within the Hornsea Three fish and shellfish study area, are listed under conservation legislation with five of these species listed as Annex II species under the EU Habitats Directive. This includes sea lamprey and river lamprey which are listed as qualifying features of the Humber Estuary SAC, but not primary reasons for site selection. These two species are also listed on the Humber Estuary Ramsar and Humber Estuary SSSI. There is currently limited understanding of how these species use the Humber Estuary (e.g. during migration), although these species are known to migrate through the Humber Estuary to freshwater spawning habitats, including in the River Derwent SAC, a tributary of the Humber Estuary which lists river and sea lamprey as qualifying features, with river lamprey listed a primary feature for selection of this site. A number of other Natura 2000 sites within the southern North Sea fish and shellfish study area, though outside UK waters, list these Annex II fish species as features. These are presented relative to Hornsea Three in Figure 3.3 and include:

- Vlakte van de Raan Site of Community Importance (SCI; Belgium; twaite shad and sea lamprey);
- Bokrum-Riffgrund SCI (twaite shad);
- Hamburgisches Wattenmeer SCI (twaite shad, sea lamprey and river lamprey);
- Unterelbe SCI (twaite shad, Atlantic salmon, sea lamprey and river lamprey);
- NTP S-H Wattenmeer un angrenzende Küstengebiete SCI (sea lamprey and river lamprey);
- Sylt Outer Reef SCI (twaite shad and river lamprey);
- Vlakte van de Raan SAC (Netherlands; twaite shad, river lamprey, sea lamprey);
- Waddenzee SAC (twaite shad, river lamprey, sea lamprey);
- Noordzeekustzone SAC (twaite shad, river lamprey, sea lamprey); and
- Noordzeekustzone II SCI (allis shad, twaite shad, river lamprey, sea lamprey).

3.7.5.3 The Net Gain Marine Conservation Zone (MCZ) Project made recommendations to the UK government in 2011 on the designation of MCZs within the southern North Sea (coinciding with the UK portion of the southern North Sea fish and shellfish study area) and the southern part of the northern North Sea (Net Gain, 2011). European eel and European smelt are both listed as features under the MCZ Project, with European eel reported as being recorded in the Markham's Triangle rMCZ (see Figure 3.3), although it was not proposed as a feature for designation due to uncertainties regarding the importance of this species to this site (Net Gain, 2011).

3.7.6 Valued Ecological Receptors

3.7.6.1 The value of ecological features 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 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 fully presented in volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report, a number of VERs were identified within the southern North Sea fish and shellfish study area. Table 3.10 provides a summary of these VERs and a valuation of their importance within the southern North Sea fish and shellfish study area based the criteria detailed in volume 5, annex 3.1: Fish and Shellfish Technical Report, including:

- Populations present within the southern North Sea fish and shellfish study area;
- Spawning, nursery and migratory behaviour within the southern North Sea 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).

3.7.6.2 In some cases, a number of fish or shellfish species may be grouped (e.g. migratory fish species, elasmobranchs) as their distribution across the Hornsea Three and southern North Sea fish and shellfish study areas show similarities across a number of species. These may also be grouped based on the relative risks that the Hornsea Three project poses to these species, e.g. similarities in sensitivities (i.e. elasmobranchs) or distances to key habitats for these species (e.g. estuaries for migratory fish species). A detailed justification of how these valuations were assigned is presented in volume 5, annex 3.1: Fish and Shellfish Ecology Technical Report and further information on commercially important species is provided in chapter 6: Commercial Fisheries.

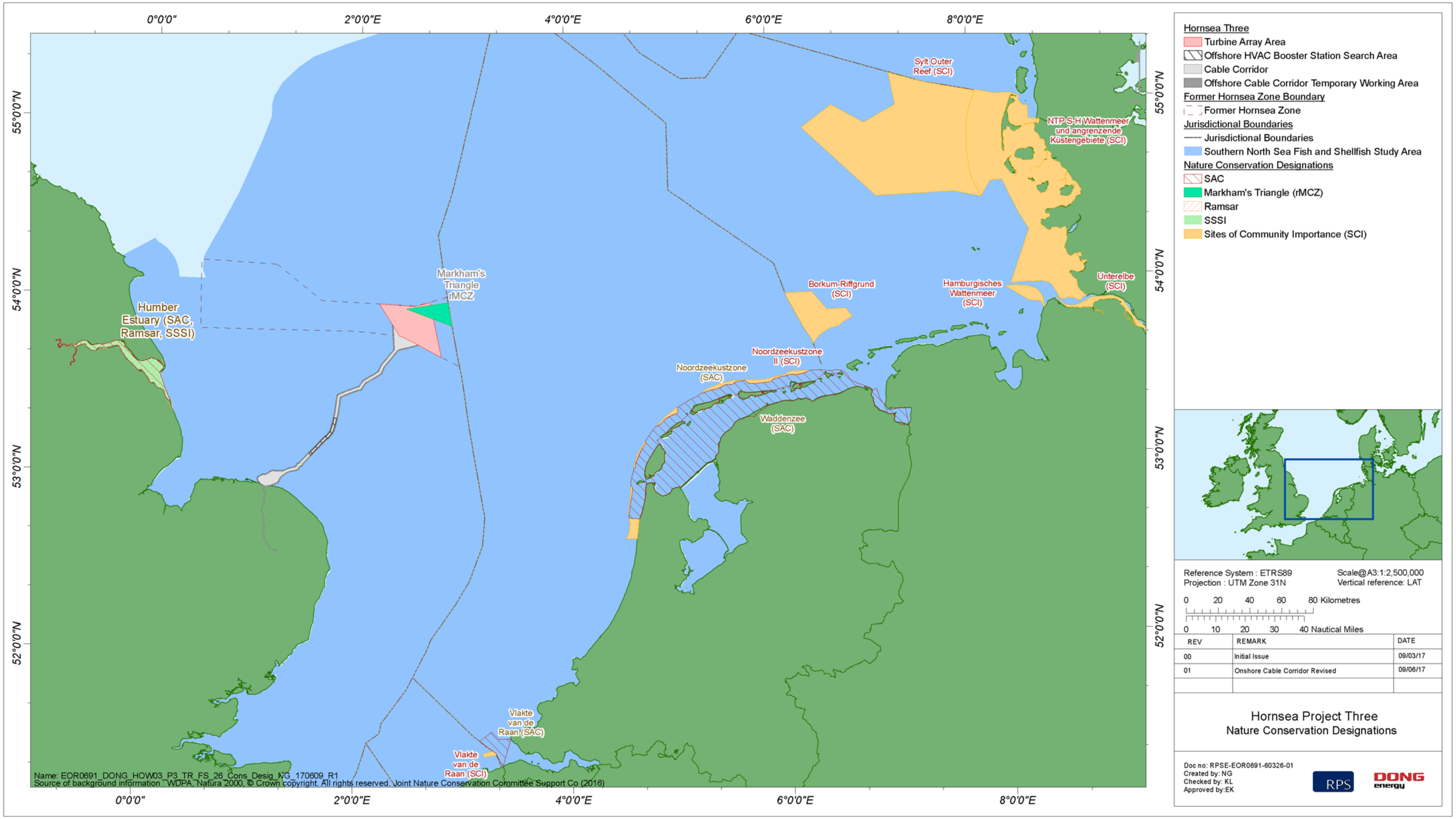

Figure 3.3: Nature conservation designations within the southern North Sea fish and shellfish study area with Annex II fish species listed as qualifying features.

Table 3.10: Fish and Shellfish Valued Ecological Receptors (VERs) within the southern North Sea fish and shellfish study area and their value/importance within the Hornsea Three fish and shellfish study area.

VER	Valuation	Importance within the Hornsea Three fish and shellfish study area and justification
Demersal Fish Species		
Whiting	Regional	Most abundantly recorded and widely distributed species across the Hornsea Three fish and shellfish study area. Low intensity spawning and high to low intensity nursery habitats. Commercially important fish species in the region and a key prey species for other marine species (particularly harbour porpoise).
Cod	Regional	Recorded at low abundances throughout the Hornsea Three fish and shellfish study area. Low intensity spawning and nursery habitats, with high intensity nursery to the west of the former Hornsea Zone. Commercially important species. UK Biodiversity Action Plan (BAP) priority species, listed by OSPAR as threatened and/or declining and listed as vulnerable on the International Union for Conservation of Nature (IUCN) Red List.
Dab	Regional	Abundantly recorded throughout the Hornsea Three fish and shellfish study area and one of the key characterising species. Fished commercially, though usually as by-catch.
Plaice	Regional	Recorded at moderate abundances throughout the Hornsea Three fish and shellfish study area and one of the key characterising species. High intensity spawning habitats with low intensity nursery habitats in inshore areas. Commercially important species. UK BAP priority species.
Lemon sole	Local	Recorded at low abundances. Spawning and nursery habitats coinciding with the Hornsea Three fish and shellfish study area. Targeted by commercial fishing vessels.
Common sole	Local	Recorded at very low abundances within the Hornsea Three fish and shellfish study area. Low intensity spawning and nursery grounds, though likely to be at the northern extent of the main spawning and nursery areas. Commercially important species. UK BAP priority species.
Other demersal species	Local	Includes grey gurnard and solenette (key characterising species of the fish assemblage) and small demersal species such as common dragonet, short spined sea scorpion and gobies. No information on spawning or nursery habitats. Little or no commercial importance. Not listed under nature conservation legislation. Likely prey items for fish, bird and marine mammal species.
Elasmobranchs	Local	Species include thornback, spotted, blonde and cuckoo ray, spurdog, starry smooth hound, basking shark and lesser spotted dogfish. All recorded at low abundances. Spawning and nursery habitats for thornback ray in inshore sections of the Hornsea Three offshore cable corridor and low intensity nursery for spurdog and tope. Low commercial value in the southern North Sea. Many elasmobranch species listed as UK BAP species or listed by OSPAR as threatened and/or declining.
Pelagic Fish Species		
Herring	Regional	Recorded at moderate abundances. Nursery habitats likely to occur throughout the Hornsea Three fish and shellfish study area. Autumn spawning ground located to the west of the former Hornsea Zone, off Flamborough Head. UK BAP species and nationally important marine feature (NIMF) although populations in Hornsea Three fish and shellfish study area not nationally important. Prey species for birds and marine mammals. Important commercial fish species.
Sprat	Regional	Abundantly recorded throughout the Hornsea Three fish and shellfish study area and a key characterising species in the fish assemblage. Spawning and nursery habitats present. Important prey species for bird and marine mammal species. Commercially important species.
Mackerel	Local	Seasonally abundant, with relatively high abundances in autumn within the Hornsea Three fish and shellfish study area. Spawning and nursery habitats (low intensity) present. UK BAP species and NIMF. Commercially important species.
Bentho-pelagic Fish Species		
Sandeel	Regional	Greater and lesser sandeel recorded throughout the Hornsea Three fish and shellfish study area. Low intensity spawning and nursery habitats occur across the Hornsea Three fish and shellfish study area, high intensity spawning grounds immediately to the north of the Hornsea Three array area. Important prey species for fish, birds and marine mammals. Commercially important species. UK BAP species and a NIMF, although populations in Hornsea Three fish and shellfish study area not nationally important.
Migratory Fish Species		
River lamprey, sea lamprey, Atlantic salmon, twaite shad, allis shad, sea trout, European eel and European smelt	Regional to International	Likely to undertake migratory movements through the Humber Estuary and other SACs/SCIs in the southern North Sea fish and shellfish study area. Atlantic salmon and twaite shad recorded during historic surveys across the former Hornsea Zone, or close to the Humber Estuary, albeit at very low abundances. River and sea lamprey, Atlantic salmon and allis and twaite shad are Annex II species and are listed as qualifying features of a number of SACs/SCIs within the southern North Sea fish and shellfish study area. As such these are considered to be of international importance. Sea trout, European eel and European smelt are all listed as UK BAP priority species and European eel is also listed as critically endangered on the IUCN Red List and these species are therefore considered to be of regional importance.

VER	Valuation	Importance within the Hornsea Three fish and shellfish study area and justification
Shellfish Species		
Brown (Edible) crab	Regional	Most important commercial shellfish species in the Hornsea Three fish and shellfish study area, particularly along the Hornsea Three offshore cable corridor. Targeted by north Norfolk commercial fisheries. Likely to overwinter within the Hornsea Three fish and shellfish study area and potential nursery habitat in inshore areas.
European lobster	Regional	Considerably less abundant than brown crab but high commercial value and therefore important species to local fisheries.
Nephrops	Regional	Recorded primarily in deep water within the Hornsea Three array area and to the north of it, coinciding with known spawning and nursery habitats. Commercially important in the Hornsea Three fish and shellfish study area.
Common whelk	Local	Present within the nearshore section of the Hornsea Three offshore cable corridor and of increasing commercial importance to north Norfolk fisheries.
Other shellfish species	Local	Species include velvet swimming crab, brown and pink shrimp in the nearshore section of the Hornsea Three offshore cable corridor and are targeted by commercial fishing fleets in the southern North Sea fish and shellfish study area. European common squid recorded throughout the Hornsea Three fish and shellfish study area though of limited value to commercial fisheries.

3.7.7 Future baseline scenario

3.7.7.1 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, 2016a). 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. 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).

3.7.7.2 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).

3.7.7.3 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 species having specific habitat requirements which are not available in these deep water areas. This may include sandeel, which are less 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. Climate change may also affect key life history stages of fish and shellfish species, including the timing of spawning migrations. 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 Three project.

3.7.7.4 In addition to climate change, overfishing subjects many fish species to considerable pressure, reducing 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. 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 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 and ICES advice suggesting that some of the stocks are recovering, with increased quotas for several species in 2016. 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.

3.7.7.5 The Hornsea Three 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.

3.7.8 Data limitations

3.7.8.1 Mobile species, such as fish, exhibit varying spatial and temporal patterns. All surveys across the former Hornsea Zone (i.e. otter and epibenthic beam trawls) provide a semi-seasonal description of the fish and shellfish assemblages within the Hornsea Three fish and shellfish study area. However, the data collected during these surveys represent snapshots of the fish and shellfish assemblage within the Hornsea Three fish and shellfish study area at the time of sampling and the fish and shellfish assemblages may vary considerably both seasonally and annually. Furthermore, the efficiency of the survey methods employed at collecting particular species will vary depending on the nature of the survey methods used and the species recorded. For example, the semi-pelagic otter trawl would not collect pelagic species (e.g. herring and sprat *Sprattus sprattus*) as efficiently as a pelagic trawl and the 2 m scientific beam trawl would not be as efficient at collecting sandeel and shellfish species as other methods used commercially in the Hornsea Three fish and shellfish study area (e.g. sandeel or shrimp trawls and shellfish potting).

3.7.8.2 In order to control for these limitations, the survey data have been discussed in the context of literature reviewed for the wider southern North Sea fish and shellfish study area, including commercial fisheries consultation work undertaken as part of the commercial fisheries baseline characterisation (volume 5, annex 6.1: Commercial Fisheries Technical Report), which provides a broader picture of the fish assemblages occurring across the area to ensure a robust characterisation for the purposes of the EIA. Specific data limitations with respect to the success of historic sampling across the former Hornsea Zone are presented in section 2.6 of volume 5, annex 3.1.

3.7.8.3 As discussed in section 2.2, the approach to data collection, including the use of survey data from across the former Hornsea Zone, Hornsea Project One and Hornsea Project Two, was agreed with the EWG, including representatives from the MMO, Cefas and Natural England.

3.8 Key parameters for assessment

3.8.1 Maximum design scenario

3.8.1.1 The maximum design scenarios identified in Table 3.11 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in the project description (volume 1, chapter 3: Project Description). Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope (e.g. different turbine layout), to that assessed here be taken forward in the final design scheme.

3.8.2 Impacts scoped out of the assessment

3.8.2.1 On the basis of the baseline environment and the project description outlined in volume 1, chapter 3: Project Description, a number of impacts have been scoped out of the assessment for fish and shellfish ecology as agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG. These impacts are outlined, together with a justification for scoping them out, in Table 3.11.

Table 3.11: Maximum design scenario considered for the assessment of potential impacts on fish and shellfish ecology..

Potential impact	Maximum design scenario	Justification
Construction phase		
Temporary habitat loss/disturbance from construction operations including foundation installation (e.g. jack-up operations and seabed preparation works) and cable laying operations (including anchor placement) may affect fish ecology.	Total subtidal temporary habitat loss of up to 31,728,118 m² comprising the following: *Hornsea Three array area - Foundations* 736,440 m² temporary loss due to jack-up barge deployments for foundations for up to 361 structures (maximum design scenario assumes up to 342 7 MW turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations and up to three offshore accommodation platforms) assuming six spud cans per barge, 170 m² seabed area affected per spud can and two jack up operations per turbine (361 foundations x six spud cans x 170 m² per spud can x two jack ups); Up to a total of 4,351,094 m² of spoil from placement of coarse dredged material to a uniform thickness of 0.5 m (see justification, right) as a result of seabed preparation works prior to the installation of all GBFs. Comprising: • 1,289,682 m³ (3,771 m³ x 342) from up 342 WTG foundation installation (2,579,364 m²); • 735,000 m³ (61,250 m³ x 12) from up to 12 HVAC collector substations (1,470,000 m²); • 139,552 m³ (34,888 m³ x 4) from up to four HVDC substations (279,104 m²); and • 11,313 m³ (3,771 m³ x 3) from up to three accommodation platforms (22,626 m²). *Hornsea Three array area - Cables* 8,500,000 m² from burial of up to 850 km of inter-array cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m wide corridor). 2,250,000 m² from burial of up to 225 km of substation interconnector cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m corridor). Up to a total of 163,222 m² from sandwave clearance activities for inter array and substation interconnector cables (30 m wide corridor in these areas). Up to a total of 336,650 m² from placement of coarse dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance within the Hornsea Three array, assuming a volume of up to 168,325 m³, placed on the seabed within the array. 215,000 m² from cable barge anchor placement associated with inter array and substation interconnector cable laying assuming: one anchor (footprint 100 m²) repositioned every 500 m ((850,000 m + 225,000) x one x 100 m² / 500 m =215,000 m²). *Hornsea Three offshore cable corridor - Subtidal* 14,460,000 m² from burial of up to 1,038 km of export cable (up to six trenches of 173 km length) by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development augmented by mobile sediment clearance and cable protection installation; up to 10 m width of seabed or 30 m for the 34 km of sandwaves along the offshore cable corridor). Up to a total of 364,112 m² from placement of coarse, dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance on the offshore cable corridor, assuming a volume of up to 182,056 m³, placed on the seabed within the Hornsea Three offshore cable corridor. 351,600 m² from cable barge anchor placement associated with cable laying for all subtidal export cables broken down as follows: • First 20 km of the Hornsea Three offshore cable corridor: Up to seven anchors (footprint of 100 m² each) repositioned every 500 m for up to six export cables (20,000 m x seven x 100 m² x six / 500 m = 168,000 m²); and • Export cables beyond 20 km: one anchor (footprint of 100 m²) repositioned every 500 m for up to six export cables ((173,000 m – 20,000) x one x 100 m² x six / 500 m = 183,600 m²). Construction phase lasting up to 11 years over two phases, with a gap of up to six years between the same activity between phases.	The maximum design scenario presented is associated with HVDC transmission due to the larger foundation sizes associated with the offshore HVDC substations compared to the HVAC booster substations. Seabed preparation works prior to gravity base installation represents the maximum design scenario, with respect to spatial extent, for temporary habitat loss, compared to the temporary habitat loss associated with drill arisings resulting from jacket foundation installation. The area predicted to be affected by the placement of material as a result of seabed preparation and sandwave clearance has been calculated based on the maximum volume of sediment predicted to be placed across the entire Hornsea Three array, assuming all this sediment is coarse material and therefore is placed on the seabed (i.e. is not dispersed through tidal currents; see "Temporary increases in suspended sediment concentrations" impact assessment below). The total area of seabed affected was calculated assuming a mound of uniform thickness of 0.5 m height. As detailed in volume 5, annex 1.1: Marine Processes Technical Report, the area of seabed affected by this scenario broadly aligns with the scenario of a cone shaped mound of 1.7 m maximum height (see Table 4.24 of volume 5, annex 1.1). Temporary loss of benthic habitat is assumed beneath this within the Hornsea Three array. The maximum design scenario for temporary habitat loss has considered the burial of all subtidal cables, except where the necessary burial depth cannot be achieved and cable protection is required (this is considered long term habitat loss; see below).

Potential impact	Maximum design scenario	Justification
Increased suspended sediment concentrations (SSC) and associated deposition as a result of foundation installation, cable installation and seabed preparation resulting in potential effects on fish and shellfish receptors.	*Drilling operations for foundation installation: Greatest sediment disturbance from a single foundation location* Total sediment volume of 581,611 m^3 (113,104 + 253,338 + 193,962 + 21,207), comprising: 113,104 m^3 total spoil volume, from largest turbine monopile foundations (up to 160 monopiles), associated diameter 15 m, drilling to 40 m penetration depth, spoil volume per foundation 7,069 m^3, up to 10% of foundations may be drilled (160 x 10% x 7,069 m^3 = 113,104 m^3). 253,338 m^3 total spoil volume from largest offshore High Voltage Alternating Current (HVAC) collector substation piled jacket foundations (up to 12 foundations), 24 piles per foundation (six legs, four piles per leg), 4 m diameter, drilling to 70m penetration depth, spoil volume per foundation 21,112 m^3, up to 100% of foundations may be drilled (12 x 21,112 m^3 = 253,338 m^3). 193,962 m^3 total spoil volume from the largest offshore High Voltage Direct Current (HVDC) converter substation piled jacket foundations (up to four foundations), 72 piles per foundation (18 legs, four piles per leg), 3.5 m diameter, drilling to 70m penetration depth, spoil volume per foundation 48,490 m^3, up to 100% of foundations may be drilled (4 x 48,490 m^3 = 193,962 m^3). 21,207 m^3 total spoil volume from the largest offshore accommodation platform monopile foundations (up to three monopiles), associated diameter 15 m, drilling to 40 m penetration depth, spoil volume per foundation 7,069 m^3, up to 100% of foundations may be drilled (3 x 7,069 m^3 = 21,207 m^3). Up to two foundations may be simultaneously drilled, minimum spacing 1,000 m. Disposal of drill arisings at water surface. Construction phase lasting up to 11 years over two phases, with a gap of up to six years between the same activity between phases.	Drilling of individual turbine monopile foundations results in the release of relatively larger volumes of relatively fine sediment, at relatively lower rates (e.g. potentially leading to SSC effects over a wider area or longer duration), than similar potential impacts for bed preparation via dredging for individual gravity base foundations (which are separately assessed). The greatest volume of sediment disturbance by drilling, for both individual foundations and for the array as a whole, is associated with the largest diameter monopile and piled jacket foundations for substations in the array area. The volume of sediment released through drilling of other turbine and offshore accommodation platform foundation types (e.g. piled jackets) is smaller than for monopiles. The HVDC transmission system option (up to12 offshore HVAC collector substations and up to four offshore HVDC converter substations) results in the largest number of offshore substation foundations and the largest total volume of associated sediment disturbance in the array area compared to the HVAC transmission system option.
	Dredging for seabed preparation for foundation installation: Greatest sediment disturbance from a single foundation location Total sediment volume of 1,827,287 m^3 (935,200 + 735,000 + 139,552 + 17,535), comprising: 935,000 m^3 total spoil volume from largest turbine gravity base foundation (up to 160 gravity base foundations), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m), spoil volume per foundation 5,845 m^3 (160 x 5,845 = 935,000 m^3). 735,000 m^3 total spoil volume from largest offshore HVAC collector substation gravity base foundation (up to 12 gravity base foundations), associated base dimensions 75 m, associated bed preparation area dimensions 175 m, average depth 2 m, spoil volume per foundation 61,250 m^3 (12 x 61,250 m^3 = 935,000 m^3). 139,552 m^3 total spoil volume from largest offshore HVDC converter substation gravity base foundation (up to four gravity base foundations), associated base dimensions 90 x 170 m, associated bed preparation area dimensions 98 x 178 m, average depth 2 m, spoil volume per foundation 34,888 m^3 (4 x 34,888 m^3 = 935,000 m^3). 17,535 m^3 total spoil volume from largest offshore accommodation platform gravity base foundation (up to three gravity base foundations), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m), spoil volume per foundation 5,845 m^3 (3 x 5,845 m^3 = 17,535 m^3). Disposal of material on the seabed within Hornsea Three. Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 hopper capacity with split bottom for spoil disposal). Up to two dredgers to be working simultaneously, minimum spacing 1,000 m. Construction phase lasting up to 11 years over two phases, with a gap of up to six years between the same activity between phases.	Dredging as part of seabed preparation for individual gravity base foundation foundations results in the release of relatively smaller overall volumes of relatively coarser sediment, at relatively higher rates (e.g. leading to higher concentrations over a more restricted area), than similar potential impacts for drilling of individual monopile or piled jacket foundations (which are separately assessed above). The greatest sediment disturbance from a single gravity base foundation location is associated with the largest diameter or dimension gravity base foundation, which results in the greatest volume of spoil from a single foundation. Due to differences in both scale and number, gravity base foundations for turbines, electrical substations and offshore accommodation platforms are separately considered. The HVDC transmission system option (up to12 offshore HVAC collector substations and up to four offshore HVDC converter substations) results in the largest number of offshore substation foundations and the largest total volume of associated sediment disturbance in the array area compared to the HVAC transmission system option. Note: this assessment considers effects on benthic ecology from a passive plume (i.e. sediments transported via tidal currents) during dredging and disposal operations for foundation installation. Placements of coarse dredged materials during dredge disposal are considered in temporary habitat loss.

Potential impact	Maximum design scenario	Justification
	Cable Installation Total sediment volume of 13,026,381 m³ 5,100,000 + 168,325 + 1,350,000 + 6,226,000 + 182,056), comprising: Array cables • Installation method: mass flow excavator; • Total length 850 km; • 5,100,000 m³ total spoil volume from installation of up to 850 km cables in a V-shape trench of width = 6 m and depth =2 m (850 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 5,100,000 m³); and • 168,325 m³ total spoil volume from sand wave clearance by dredging or mass flow excavation within the Hornsea Three array area (based on the Hornsea Three array area geophysical survey data combined with cable installation design specifications). Substation interconnector cables • Installation method: mass flow excavator; • 15 in-project cables, total length 225 km; and • 1,350,000 m³ total spoil volume from installation of up to 225 km cables in a V-shape trench of width = 6 m and depth =2 m (225 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 1,350,000 m³). Export cables • Up to six cable trenches; each 173 km in length (1,038 km in total); • Installation method: mass flow excavator; • 6,226,000 m³ total spoil volume from installation of up to 225 km cables in a V-shape trench of width = 6 m and depth =2 m (6 x 173 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 6,226,000 m³); and • 182,056 m³ total spoil volume from sandwave clearance via either a dredger or mass flow excavator within the Hornsea Three offshore cable corridor (based on the Hornsea Three offshore cable corridor geophysical survey data combined with cable installation design specifications). Construction phase lasting up to 11 years over two phases, with a gap of up to six years between the same activity between phases.	Cable installation may involve ploughing, trenching, jetting, rock-cutting, surface laying with post lay burial, and/or surface laying installation techniques. Of these, mass flow excavation will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to be the maximum design scenario for sediment dispersion. The volume of material to be cleared from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data, the bedforms requiring clearance are likely to be in the range 1 to 2 m height in the array or 1 to 6 m in height in the offshore cable corridor. Sandwave clearance may involve dredging or mass flow excavation tools. Of these, mass flow excavation will most energetically disturb sediment in the clearance profile and as such is considered to be the maximum design scenario for sediment dispersion causing elevated SSC over more than a very short period of time. Dredging will result in a potentially greater instantaneous local effect in terms of SSC and potentially a greater local thickness of sediment deposition, but likely of a shorter duration and smaller extent, respectively. Note: this assessment considers effects on benthic ecology from a passive plume (i.e. sediments transported via tidal currents) during dredging and disposal operations. Placements of coarse dredged materials during dredge disposal are considered in temporary habitat loss.
Seabed disturbances within the Hornsea Three offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology.	Seabed disturbance arising from installation of foundations and cables as described above for temporary increases in SSC (Hornsea Three offshore cable corridor only).	This scenario represents the maximum design scenario for the Hornsea Three offshore cable corridor installation and therefore the maximum amount of contaminated sediment that may be released into the water column during construction activities. Potential impacts of release of contaminants were scoped out for the Hornsea Three array area (see Table 3.12).

Potential impact	Maximum design scenario	Justification
Underwater noise as a result of foundation installation (i.e. piling) and other construction activities (e.g. cable installation) resulting in potential effects on fish and shellfish receptors	*Maximum design scenario – Spatial extent: monopile foundations with concurrent piling* Up to 361 monopiles (342 turbine foundations and 19 foundations for other infrastructure and platform foundations) • Piling of up to 342 monopile foundations of 7 m diameter; • Piling of up to 19 monopile foundations, 15 m diameter, for substations and platforms including: o Three offshore accommodation platforms; o Twelve offshore HVAC collector substations; and o Four offshore HVAC booster stations (on the Hornsea Three offshore cable route corridor). • Absolute maximum hammer energy of up to 5,000 kJ, although typically the maximum hammer energy will be considerably less than this and the absolute maximum hammer energy (i.e. up to 5,000 kJ) would not be required at all locations; • Maximum four hours piling duration per monopile (including 30 minute soft start) within a 24 hour period; • Maximum total duration of actual piling is 1,444 hours (four x 361); • Piling within Hornsea Three array area could occur as single vessel scenario or two concurrent vessels (at opposite ends of the site) although maximum design spatial scenario is for concurrent piling. Concurrent piling will occur only within the Hornsea Three array area and not within the Hornsea Three offshore cable corridor; • Assumed that one monopile could be installed in each 24 hours period for single piling or up to two monopiles installed for concurrent piling, plus a 20% contingency allowance. • Number of days (concurrent vessel scenario) on which piling could occur is 219 days, which consists of: o Hornsea Three array area = 214.2 days (178.5 days piling for 342 turbines + three accommodation platforms + 12 offshore HVAC collector substations * 20% contingency); and o Hornsea Three offshore cable corridor = 4.8 days (four days piling for four offshore HVAC booster stations * 20% contingency). Note that offshore HVAC booster stations will not be concurrently piled. • Foundation installation could occur over 2.5 years in up to two phases (i.e. of ~1.25 years each phase) with a gap of up to six years between phases. This includes foundation installation for the offshore HVAC booster substations within the Hornsea Three offshore cable corridor which is expected to occur within an eight month piling phase. *Maximum design scenario – Temporal duration: jacket foundations with single piling* Up to 2,016 pin piles (1,368 for turbine foundations and 648 for other infrastructure and platform foundations) • Piling of up to 342 jacket foundations (four piles per foundation, each pin pile 4 m diameter), with up to 1,368 piles (342 x 4) in total; • Piling of up to 19 jacket foundations, up to 4 m diameter, for substations and platforms including: o Three offshore accommodation platforms (six legs with four piles per leg), with up to 72 piles (three x 24) in total; o Twelve offshore HVAC collector substations (six legs with four piles per leg), with up to 288 piles (12 x 24) in total; and o Four offshore HVDC converter substations (72 piles per foundation) with up to 288 piles (four x 72) in total. • Maximum hammer energy of up to 2,500 kJ, although typically the maximum hammer energy will be considerably less than this, with only a proportion of the piles requiring the maximum hammer energy (i.e. up to 2,500 kJ); • Maximum four hours piling duration per pile (including 30 minute soft start); • Maximum total piling duration 8,064 hours of piling (four x 2,016); • Piling could occur as single vessel scenario or two concurrent vessels (at opposite ends of the site) although maximum design temporal scenario is for single piling; • Assumed that four pin piles could be installed in each 24 hour period for single piling, or up to eight pin piles installed for concurrent piling, plus a 20% contingency; • Therefore maximum number of days (single piling scenario) on which piling could occur is 604.8 days (2,016 pin piles ((1,368 pin piles for turbines + 72 pin piles for accommodation platforms + 288 pin piles for offshore HVAC collector substations + 288 pin piles for offshore HVDC converter substations) / four a day) x 20% contingency) within the Hornsea Three array area. • Foundation installation could occur over 2.5 years in up to two phases (i.e. of ~1.25 years each phase) with a gap of up to six years between phases.	*Spatial Extent* The spatial maximum design scenario equates to the greatest area of effect from subsea noise at any one time during piling. Volume 4, annex 3.1: Subsea Noise predicted the greatest area of effect was for 5,000 kJ hammer and a 7 m diameter pile. The monopile foundation for the HVAC transmission option results in the maximum design scenario spatially. Two vessels piling concurrently at maximum spacing would result in the largest area of impact at any one time. *Temporal Extent* The temporal maximum design scenario represents the longest duration of effects from subsea noise. This scenario assumes piled foundations again but this time for jackets as this could result in a longer duration of piling per foundation. The pin pile foundation for the HVDC transmission option results in the maximum design scenario temporally. Scenario assumes longest duration of piling per pile (4 hours) and number of days piling is estimated assuming four pile jacket foundation installed per day, although realistically there is potential to install up to eight piles in one day. Single vessel piling is assumed as this would prolong the total number of days on which piling could occur over the three years piling phase (although noting that the piling phase itself has not actually increased under this scenario).

<table>
<tr><th>Potential impact</th><th>Maximum design scenario</th><th>Justification</th></tr>
<tr><td>Accidental pollution events during the construction phase resulting in potential effects on fish and shellfish receptors.</td><td>Synthetic compound (e.g. from antifouling biocides), heavy metal and hydrocarbon contamination resulting from offshore infrastructure installation and up to 11,566 vessel movements during the construction phase:
4,446 vessel movements over construction period based on gravity base foundations (self-installing concept);
Up to 3,420 vessel movements over construction period for WTG installation;
Up to 304 vessel movements over construction period for substations;
Up to 2,856 vessel movements over construction period for inter-array cables; and
Up to 540 vessel movements over construction period for export cable.
Water-based drilling muds associated with drilling to install foundations, should this be required.
A typical offshore accommodation platform is likely to contain up to 10,000 l of coolant, up to 10,000 l of hydraulic oil and up to 3,500 kg of lubricates.
Offshore fuel storage tanks:
One tank on each of the up to three offshore accommodation platforms for helicopter fuel and with a total capacity of up to 255,000 l across the entire wind farm; and
One on each of the up to three offshore accommodation platforms for crew transfer vessel fuel and each with a capacity of 210,000 l.</td><td>These parameters represent the maximum design scenario for accidental pollution events, including the maximum number of vessel movements during construction and the offshore storage of fuel and therefore the maximum volumes of potential contaminants carried during construction activities.</td></tr>
<tr><td colspan="3">Operation phase</td></tr>
<tr><td>Long term habitat loss due to presence of turbine foundations and scour/cable protection with potential effects on fish and shellfish ecology.</td><td>Long term habitat loss of up to a total of 4,256,010 m² comprising the following:
Hornsea Three array area – Foundations
Up to a total of 1,762,326 m² across the entire Hornsea Three array from GBFs (including scour protection) for up to 342 7 MW turbines, each affecting up to 5,153 m² of seabed;
Up to a total of 158,700 m² from box GBFs (including scour protection) for up to 12 offshore HVAC collector substations, each affecting up to 13,225 m² of seabed;
Up to a total of 85,884 m² from suction caisson jacket foundations (including scour protection) for up to three offshore accommodation platforms, each affecting up to 28,628 m² of seabed;
Up to 109,200 m² from pontoon GBFs (including scour protection) for up to four offshore HVDC substations, each affecting up to 27,300 m² of seabed.
Hornsea Three array area – Cable protection
Up to a total of 595,000 m² based on installation of cable protection for 10% of the up to 850 km of inter-array cables (i.e. 85 km and 7 m wide cable corridor);
Up to a total of 157,500 m² based on the installation of cable protection for 10% of the up to 225 km of substation interconnector cables (i.e. 22.5 km and 7 m wide cable corridor). This includes all cable links between HVAC or HVDC substations and offshore accommodation platforms;
Up to a total of 39,200 m² for cable/pipeline crossings, with up to 14 crossings within the array, each with long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m².
Hornsea Three offshore cable corridor - Cable protection
Up to a total of 726,600 m² based on the installation of cable protection for 10% of the up to 1,038 km of export cable. Assumes up to six cables, and up to 7 m width of cable protection per cable; and
Up to a total of 621,600 m² for cable/pipeline crossings, with up to 37 crossings, assuming up to six cables, with each crossing having a long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m².
Cable protection may comprise gravel, concrete mattresses, rock placement, bags filled with gravel, grout or other concrete, artificial fronds or seaweed or bags of grout, concrete, or another substance that cures hard over time.</td><td>The maximum design scenario presented is associated with HVDC transmission due to the larger foundation sizes associated with the offshore HVDC substations compared to the HVAC booster substations.
Maximum design scenario is associated with the installation of gravity based foundations for all turbines, box GBFs for HVAC collector substations, suction caisson jacket foundations for offshore accommodation platforms and pontoon GBFs for four offshore HVDC substations as these foundations have the largest total surface area in contact with the seabed and therefore result in the greatest long term habitat loss. The maximum design scenario also assumes scour protection is required for all foundations.
The maximum design scenario for long term habitat loss has considered the use of cable protection (i.e. rock placement) along 10% of the subtidal inter-array cables and substation interconnector power cables. The maximum design scenario assumes that 10% of the subtidal export cables will require cable protection (i.e. rock placement).</td></tr>
</table>

Potential impact	Maximum design scenario	Justification
Underwater noise as a result of operational turbines and maintenance vessel traffic resulting in potential effects on fish and shellfish receptors.	Operational turbines Underwater noise over the design lifetime of the project (i.e. 25 years) from up to 342 operational turbines. Vessel traffic Underwater noise from vessel activity throughout the Hornsea Three array area and offshore cable corridor, including: • Jack up wind turbine visits: up to 82 visits per year over project lifetime; • Jack up platform visits: up to five visits per year over project lifetime; • Crew vessel visits: up to 2,433 per year over project lifetime; • Supply vessel accommodation platform visits: up to 312 per year over project lifetime; and Total return vessel movements per year during operation = 2,832.	The maximum design scenario is based on the maximum number of turbines over the maximum lifetime of the project rather than size of turbine since the effects are expected to be localised regardless of the power output. Noise from vessel movements based on the maximum number of operation and maintenance visits by vessels during the lifetime of the project.
Introduction of turbine foundations and scour/cable protection (hard substrates and structural complexity) leading to effects on fish and shellfish receptors by creating reef habitat.	Total introduced hard substrate of up to 5,694,330 m² comprising the following: *Hornsea Three array area – Foundations* Up to a total of 1,265,313 m² from GBFs for 342 turbines, assuming a conical/frustum shape, with a base diameter of 41 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 3,700 m². Up to a total of 1,310,886 m² of scour protection for 342 GBFs for turbines, with a per foundation scour protection of 3,833 m². Up to a total of 144,000 m² from Box GBFs for up to 12 offshore HVAC collector substations, each with a length and width of 75 m in a water depth of 40 m, giving a per foundation surface area of approximately 12,000 m². Up to a total of 91,200 m² of scour protection for 12 offshore HVAC collector substations, with a per foundation scour protection of 7,600 m². Up to a total of 174,400 m² from Pontoon GBFs (Type 1) for up to four offshore HVDC substations, with three pontoons per foundation and each pontoon having a length of up to 170 m and width of up to 35 m in a water depth of 40 m, giving a per foundation surface area of approximately 43,600 m². Up to a total of 37,800 m² of scour protection for four offshore HVDC substations, with a per foundation scour protection of 9,450 m². Up to a total of 12,079 m² from GBFs for three offshore accommodation platforms, assuming a conical/frustum shape, with a base diameter of 45 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 4,026 m². Up to a total of 12,252 m² of scour protection for three offshore accommodation platforms, with a per foundation scour protection of 4,084 m². *Hornsea Three array area – Cable protection* Up to a total of 930,612 m² from the installation of cable protection for 10% of the up to 850 km of inter-array cables and up to 225 km substation interconnector cables. Assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m². Up to a total of 48,478 m² from installation of cable protection for 12 cable/pipeline crossings within the array. Each crossing will be of 400 m length each and assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m². *Hornsea Three offshore cable corridor - Cable protection* Up to a total of 898,581 m² from the installation of cable protection for 10% of the up to 1,038 km of export cables. Assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m². Up to a total of 768,729 m² from installation of cable protection for up to 37 cable/pipeline crossings along the offshore cable corridor. Each crossing will be of 400 m length each and assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m².	Maximum surface area created by turbines, substation and offshore accommodation platform foundations, scour protection and surface protection for cables where secondary cable protection is required. This assumes that 10% of inter-array and subtidal export cables require secondary protection. For GBFs, this area includes the surfaces of the foundation shaft, cone and base from the seabed to MHWS (i.e. including intertidal habitat).

Potential impact	Maximum design scenario	Justification
Electromagnetic fields (EMF) emitted by array and export cables during the operational phase causing behavioural responses in fish and shellfish receptors.	Maximum EMF resulting from: • Up to 850 km of single AC array (maximum voltage of 170 kV); • Up to 225 km of substation interconnector cables (maximum voltage of 600 kV; HVDC or HVAC transmission); and • Up to 1,038 km of HVDC or HVAC export cable (maximum voltage of 600 kV or 400 kV for HVDC and HVAC transmission, respectively). The maximum design scenario is that array cables, substation interconnector cables and export cables will typically be buried to between 1-2 m. A Cable Burial Risk Assessment (CBRA), to be undertaken post consent, will inform cable burial depth which will depend on ground conditions. Where burial to the target depth is not possible, cables may be buried using cable protection.	HVDC transmission represents the maximum design scenario for magnetic field strengths, though for induced electrical fields it is unclear whether HVAC or HVDC transmission represents the maximum design scenario.
Temporary habitat loss and disturbance from maintenance operations (e.g. jack up operations and cable reburial).	Temporary habitat loss/disturbance of up to 2,218,500 m^2 comprising: A total of up to 2,218,500 m^2 from a total of up to 87 jack-ups per year over the 25 year design life, assuming six spud cans per jack-up barge and 170 m^2 seabed area affected per spud can (i.e. 87 x 25 x six x 170 = 2,218,500 m^2). Preventive maintenance of subsea cables including routine inspections to ensure the cable is buried to an adequate depth and not exposed. The integrity of the cable and cable protection system (i.e. bending restrictors and bend stiffeners) will also be inspected. It is expected that on average the subsea cables will require up to two visits per year for the first three years before being reduced to yearly thereafter. Maintenance works to rebury/replace and carry out repair works on subtidal array, substation interconnector and export cables, should this be required.	These parameters represent the maximum design scenario for the requirement for jack-up barge operations for all turbines and substations for the lifetime of the project. No substantive maintenance works on the export cables at the offshore cable corridor landfall site is anticipated, only access will be required periodically as outlined to inspect the cable and for geophysical surveys. Though the burial depth of the cables will be designed so that these will remain buried for the full lifetime of the project and beyond, it will be necessary to bury the cables if erosion or other natural processes cause them to become exposed. The most appropriate means of reburying any exposed cables will be assessed on an ad-hoc basis but will be no more intrusive than those used during construction.
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect fish and shellfish.	Synthetic compound (e.g. from antifouling biocides), heavy metal and hydrocarbon contamination resulting from up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations (or up to four offshore HVAC booster substations on the offshore cable corridor) and up to three offshore accommodation platforms. Accidental pollution may also result from offshore refuelling for crew vessels and helicopters: i.e. up to 2,832 round trips to port by operational and maintenance vessels (including supply/crew vessels and jack-up vessels) and up to 25,234 round trips by helicopter per year over the 25 year design life. A typical 7 MW turbine is likely to contain approximately 1,300 l of grease, 20,000 l of hydraulic oil and 2,000 l of gear oil, 80,000 l of liquid nitrogen and 7,000 kg of transformer silicon/ester oil, 2,000 l of diesel and 13,000 l of coolant. A typical offshore accommodation platform is likely to contain up to 10,000 l of coolant, up to 10,000 l of hydraulic oil and up to 3,500 kg of lubricates. Offshore fuel storage tanks: • One tank on each of the up to three offshore accommodation platforms for helicopter fuel and with a total capacity of up to 255,000 l across the entire wind farm; and • One on each of the up to three offshore accommodation platforms for crew transfer vessel fuel and each with a capacity of 210,000 l. Potential leachate from zinc or aluminium anodes used to provide cathodic protection to the turbines.	These parameters represent the maximum design scenario with regards to maximum number of turbines, vessel movements, and machinery required, and therefore the maximum volumes of potential contaminants carried during operation and maintenance activities.

Potential impact	Maximum design scenario	Justification
Potentially reduced fishing pressure within the Hornsea Three array area offering some protection and possible local enhancement within the Hornsea Three array area and potentially increased fishing pressure outside the Hornsea Three array area.	Design life 25 years. Up to 342 turbines with GBFs, 12 offshore HVAC collector substations, three offshore accommodation platforms and up to four offshore HVDC substations, inter array cables (up to 850 km) and substation interconnector cables (up to 225 km) within the Hornsea Three array area. Minimum spacing between foundations of 1 km. Operational safety zones of 500 m around offshore platforms (up to six offshore HVAC collector substations, two offshore HVDC converter stations, two accommodation platforms). 500 m safety zone during major maintenance activities. No safety zones around turbines. However, assumed 50 m safe operating distance from turbines. 500 m safety zone during major maintenance activities. Typically, buried cables will be buried to between 1-2 m. A CBRA, to be undertaken post consent, will inform cable burial depth, which will depend on ground conditions. 1 km advisory safety zone around maintenance operations along the array cables, platform inter-connector cables and accommodation inter-connector cables, centred on the cable maintenance vessel.	Assessment assumes that fisheries will not be excluded from Hornsea Three but due to logistical constraints, fishing pressure may be reduced.

Potential impact	Maximum design scenario	Justification
Decommissioning phase		
Temporary habitat loss/disturbance due to decommissioning of turbine foundations and array, substation interconnector and export cables.	Total subtidal temporary habitat loss of up to 27,377,024m^2 comprising the following: *Hornsea Three array area - Foundations* Temporary habitat loss as per construction phase, but excluding seabed preparation works, i.e.: 736,440 m^2 due to jack-up barge deployments for removal of foundations for up to 361 structures (maximum design scenario assumes up to 342 7 MW turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations and up to three offshore accommodation platforms) assuming six spud cans per barge, 170 m^2 seabed area affected per spud can and two jack up operations per turbine (361 foundations x six spud cans x 170 m^2 per spud can x two jack ups). *Hornsea Three array area - Cables* 8,500,000 m^2 from removal of up to 850 km of inter-array cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m wide corridor); 2,250,000 m^2 from removal of up to 225 km of substation interconnector cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m corridor); Up to a total of 163,222 m^2 from sandwave clearance activities for inter array and substation interconnector cables (30 m wide corridor in these areas). Up to a total of 336,650 m^2 from placement of coarse dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance within the Hornsea Three array, assuming a volume of up to 168,325 m^3, placed on the seabed within the array. 215,000 m^2 from cable barge anchor placement associated with inter array and substation interconnector cable laying assuming: one anchor (footprint 100 m^2) repositioned every 500 m ((850,000 m + 225,000) x one x 100 m^2 / 500 m =215,000 m^2). *Hornsea Three offshore cable corridor - Subtidal* 14,460,000 m^2 from removal of up to 1,038 km of export cable (up to six trenches of 173 km length) by trenching, jetting, mass flow excavator or vertical injection and similar tools currently under development augmented by mobile sediment clearance and cable protection installation (up to 10 m width of seabed or 30 m for the 34 km of sandwaves along the offshore cable corridor). Up to a total of 364,112 m^2 from placement of coarse, dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance on the offshore cable corridor, assuming a volume of up to 182,056 m^3, placed on the seabed within the Hornsea Three offshore cable corridor. 351,600 m^2 from cable barge anchor placement associated with cable laying for all subtidal export cables broken down as follows: • First 20 km of Hornsea Three offshore cable corridor: Up to seven anchors (footprint of 100 m^2 each) repositioned every 500 m for up to six export cables (20,000 m x seven x 100 m^2 x six / 500 m = 168,000 m^2); and • Export cables beyond 20 km: one anchor (footprint of 100 m^2) repositioned every 500 m for up to six export cables ((173,000 m – 20,000) x one x 100 m^2 x six / 500 m = 183,600 m^2).	Maximum design scenario as per construction phase, excluding seabed preparation works, and assumes the removal of all foundations and all buried subtidal cables. Piled foundations would be removed to approximately 2 m below the seabed. The necessity to remove cables will be reviewed at the time, after consideration of the environmental impact of the removal operation and safety of the cables left in situ (see volume 1, chapter 3: Project Description). Therefore, the maximum design scenario has assumed the removal of all cables, although this is likely to be over precautionary.
Temporary increases in suspended sediment concentrations and associated sediment deposition from removal of array and substation interconnector cables, export cables and turbine foundations.	Increases of SSC and sediment deposition associated with the removal of up to 361 foundations (i.e. up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations (or up to four offshore HVAC booster substations on the offshore cable corridor) and up to three accommodation platforms) and up to 2,113 km of array (including substation interconnector cables) and export cables.	Maximum design scenario as per construction phase and assumes the removal of all foundations and all subtidal cables.
Seabed disturbances within the Hornsea Three offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology.	Seabed disturbance arising from removal of foundations and cables as described above for temporary increases in SSC (Hornsea Three offshore cable corridor only).	This scenario represents the maximum design scenario for the Hornsea Three offshore cable corridor installation and therefore the maximum amount of contaminated sediment that may be released into the water column during decommissioning activities.

Potential impact	Maximum design scenario	Justification
Decommissioning activities producing subsea noise resulting in potential effect on fish and shellfish receptors.	Underwater noise associated with decommissioning of up to 361 foundations, including (but not limited to) high powered water jetting/cutting apparatus and grinding or drilling techniques, and 2,113 km of array and export cables. Vessel noise from up to 11,566 vessel movements during the decommissioning phase: 4,446 vessel movements over construction period based on gravity base foundations (self-installing concept); Up to 3,420 vessel movements over construction period for turbine installation; Up to 304 vessel movements over construction period for substations; Up to 2,856 vessel movements over construction period for array cables; and Up to 540 vessel movements over construction period for export cable.	Vessel movements will be as per construction phase and assumes the removal of all foundations and all subtidal cables. Assumes cables will be removed using similar methods as those employed during construction, e.g. trenching, jetting, mass flow excavator. Foundations to be removed by methods including abrasive cutting, with foundations removed to approximately 2 m below the seabed.
Effects on fish and shellfish receptors due to removal of foundations and cable protection leading to loss of hard substrates and structural complexity.	Total removal of up to 1,595,791 m^2 of hard substrate comprising the following: *Hornsea Three array area - Foundations* Up to a total of 1,265,312 m^2 from GBFs for 342 turbines, assuming a conical/frustum shape, with a base diameter of 41 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 3,700 m^2. Up to a total of 144,000 m2 from Box GBFs for up to 12 offshore HVAC collector substations, each with a length and width of 75 m in a water depth of 40 m, giving a per foundation surface area of approximately 12,000 m^2. Up to a total of 174,400 m^2 from Pontoon GBFs (Type 1) for up to four offshore HVDC substations, with three pontoons per foundation and each pontoon having a length of up to 170 m and width of up to 35 m in a water depth of 40 m, giving a per foundation surface area of approximately 43,600 m^2. Up to a total of 12,079 m^2 from GBFs for three offshore accommodation platforms, assuming a conical/frustum shape, with a base diameter of 45 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 4,026 m^2.	Maximum design scenario for introduced hard substrate as per operational phase but assuming that scour protection and cable protection will be left in situ.

Potential impact	Maximum design scenario	Justification
Permanent habitat loss/alteration due to presence of scour/cable protection left *in situ* post decommissioning with potential effects on fish and shellfish ecology.	Permanent habitat loss/alteration of up to 3,592,038 m^2 comprising the following: *Hornsea Three array area - Foundations* Up to a total of 1,310,886 m^2 of scour protection for 342 GBFs for WTGs, with a per foundation scour protection of 3,833 m^2. Up to a total of 91,200 m^2 of scour protection for 12 offshore HVAC collector substations, with a per foundation scour protection of 7,600 m^2. Up to a total of 37,800 m^2 of scour protection for four offshore HVDC substations, with a per foundation scour protection of 9,450 m^2. Up to a total of 12,252 m^2 of scour protection for three offshore accommodation platforms, with a per foundation scour protection of 4,084 m^2. *Hornsea Three array area - Cables* Up to a total of 595,000 m^2 based on installation of cable protection for 10% of the up to 850 km of inter-array cables (i.e., 85 km and 7 m wide cable corridor); Up to a total of 157,500 m^2 based on the installation of cable protection for 10% of the up to 225 km of substation interconnector cables (i.e., 22.5 km and 7 m wide cable corridor). This includes all cable links between HVAC or HVDC substations and offshore accommodation platforms; Up to a total of 39,200 m^2 for cable/pipeline crossings, with up to 14 crossings within the array, each with long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m^2. *Hornsea Three offshore cable corridor - Subtidal* Up to a total of 726,600 m^2 based on the installation of cable protection for 10% of the up to 1,038 km of export cable. Assumes up to six cables, and up to 7 m width of cable protection per cable; and Up to a total of 621,600 m^2 for cable/pipeline crossings, with up to 37 crossings along the offshore cable corridor, assuming up to six cables, with each crossing with long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m^2. Cable protection may comprise gravel, concrete mattresses, rock placement, bags filled with gravel, grout or other concrete, artificial fronds or seaweed or bags of grout, concrete, or another substance that cures hard over time.	Maximum design scenario for long term habitat loss as per operational phase but assuming that foundations will be removed but scour and cable protection will be left in situ.
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect fish and shellfish ecology.	Maximum design scenario is identical to that of the construction phase.	Maximum design scenario as per construction phase.

Table 3.12: Impacts scoped out of the assessment for fish and shellfish ecology.

Potential impact	Justification
Construction phase	
Seabed disturbances within the Hornsea Three array area leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology.	Benthic sampling undertaken across the former Hornsea Zone indicated that contamination in offshore sediments is low and at levels which are unlikely to result in adverse effects on marine receptors. Therefore it is considered unlikely that there would be any pathways for an impact on fish and shellfish receptors within the Hornsea Three array area, as agreed with the through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG (see Table 3.6). This impact has not been scoped out for the Hornsea Three offshore cable corridor.
Decommissioning phase	
Seabed disturbances within the Hornsea Three array area leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology.	Benthic sampling undertaken across the former Hornsea Zone indicated that contamination in offshore sediments is low and at levels which are unlikely to result in adverse effects on marine receptors. Therefore it is considered unlikely that there would be any pathways for an impact on fish and shellfish receptors within the Hornsea Three array area, as agreed with the through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG (see Table 3.6). This impact has not been scoped out for the Hornsea Three offshore cable corridor.

3.9 Impact assessment criteria

3.9.1.1 The criteria for determining the significance of effects is a two-stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The terms used to define sensitivity and magnitude are based on those used in the Design Manual for Roads and Bridges (DMRB) methodology, which is described in further detail in volume 1, chapter 5: Environmental Impact Assessment Methodology. The fish and shellfish ecology EIA has followed this methodology set out in Chapter 5: Environmental Impact Assessment Methodology. Specific to the fish and shellfish ecology EIA, the following guidance documents have also been considered:

- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater and Coastal (CIEEM, 2016);
- Offshore Wind Farms. Guidance Note for EIA in Respect of FEPA (Food and Environment Protection Act 1985) and CPA (Coast Protection Act 1949) Requirements (Cefas *et al*., 2004);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Judd, 2012); and
- Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008).

3.9.1.2 In addition, the fish and shellfish ecology EIA has considered the legislative framework as defined by the Offshore Marine Conservation (Natural Habitats, and c.) Regulations 2007 (Offshore Habitats Regulations) (as amended), the Conservation of Habitats and Species Regulations 2010 (Habitats Regulations) (as amended), the Wildlife and Countryside Act 1981 (as amended) and the MCAA 2009 (as amended).

3.9.1.3 The EIA has also taken into consideration the requirements of the United Nations Environment Programme (UNEP) Convention on Biological Diversity (CBD), in particular those listed under Article 8 of the Convention. Article 8 of the CBD relates to *in-situ* conservation and includes reference to the need to protect areas for nature conservation. Therefore, where necessary, mitigation measures have been designed in to Hornsea Three to ensure the *in-situ* conservation of fish and shellfish ecology.

3.9.1.4 The sensitivity of fish and shellfish VERs has been defined by an assessment of the combined vulnerability of the receptor to a given impact and the likely rate of recoverability to pre-impact conditions. Vulnerability is defined as the susceptibility of a species to disturbance, damage or death, from a specific external factor. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. It is dependent on its ability to recover or recruit subject to the extent of disturbance/damage incurred. Information on these aspects of sensitivity of the fish and shellfish VERs to given impacts has been informed by the best available evidence following environmental impact or experimental manipulation in the field and evidence from analogous activities such as those associated with aggregate extraction and oil and gas industries. These assessments have been combined with the assessed status (i.e. the level of designation/importance) of the affected receptor as defined in Figure 3.3 and as presented in Table 3.10 for the fish and shellfish VERs being considered in this assessment. The overall sensitivity of a receptor to an impact then identified from a five point scale as presented in Table 3.13.

Table 3.13: Definition of terms relating to the sensitivity of the receptor.

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 high vulnerability and low recoverability.
Medium	Locally important receptors with high vulnerability and no ability for recovery. Regionally important receptors with medium to high vulnerability and low recoverability. Nationally and internationally important receptors with medium vulnerability and medium recoverability.
Low	Locally important receptors with medium to high vulnerability and low recoverability. Regionally important receptors with low vulnerability and medium to high recoverability. Nationally and internationally important receptors with low vulnerability and high recoverability.
Negligible	Receptor is not vulnerable to impacts regardless of value/importance. Locally important receptors with low vulnerability and medium to high recoverability.

3.9.1.5 The criteria for defining magnitude in this chapter are outlined in Table 3.14 below.

Table 3.14: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition used in this chapter
Major	The proposal would affect the conservation status of the site or feature, with loss of ecological functionality.
Moderate	The feature's conservation status would not be affected, but the impact is likely to be significant in terms of ecological objectives or populations.
Minor	Minor shift away from baseline but the impact is of limited temporal or physical extent.
Negligible	Very slight change from baseline condition.
No change	No change from baseline conditions.

3.9.1.6 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 particular method employed for this assessment is presented in Table 3.15. Where a range of significance of effect is presented in Table 3.15, the final assessment for each effect is based upon expert judgement.

3.9.1.7 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 3.15: Matrix used for the assessment of the significance of the effect.

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

3.9.1.8 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 3.6.3 of this chapter (with the assessment on the site itself deferred to the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a)).

3.9.1.9 With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site (e.g. SSSIs which have not been assessed within the Draft Report to Inform the Appropriate Assessment), 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 southern North Sea fish and shellfish study area, an assessment of the impacts on the overall site is made in this chapter using the EIA methodology. As detailed in volume 5, chapter 3.1, there are no nationally (e.g. SSSIs or MCZs) designated sites with listed fish or shellfish features which lie outside internationally designated sites within the southern North Sea fish and shellfish study area and therefore no assessment has been undertaken.

3.9.1.10 The Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a) is available alongside this PEIR and has been prepared in accordance with Advice Note Ten: Habitats Regulations Assessment Relevant to NSIPs (PINS, 2016).

3.10 Measures adopted as part of Hornsea Three

3.10.1.1 As part of the project design process, a number of designed-in measures have been proposed to reduce the potential for impacts on fish and shellfish ecology (see Table 3.16). These measures are considered standard industry practice for this type of development and have therefore been considered in the assessment presented in section 3.11 below. Assessment of sensitivity, magnitude and therefore significance includes implementation of these measures.

3.11 Assessment of significance

3.11.1 Construction phase

3.11.1.1 The impacts of the offshore construction of Hornsea Three have been assessed on fish and shellfish ecology. The environmental impacts arising from the construction of Hornsea Three the Project are listed in Table 3.11 above along with the maximum design scenario against which each construction phase impact has been assessed.

3.11.1.2 A description of the potential effect on fish and shellfish receptors caused by each identified impact is given below.

Table 3.16: Designed-in measures adopted as part of Hornsea Three.

Measures adopted as part of Hornsea Three	Justification
A CoCP will be developed and implemented to cover the construction phase and an appropriate PEMMP will be produced and followed to cover the operation and maintenance phase of Hornsea Three. The latter will include planning for accidental spills, contain a biosecurity plan to limit the spread of invasive and non-native species (INNS), address all potential contaminant releases and include key emergency contact details (e.g. Environment Agency (EA), Natural England and MCA). A Decommissioning Programme will be developed to cover the decommissioning phase.	Measures will be adopted to ensure that the potential for release of pollutants from construction, operation and maintenance, and decommissioning plant is minimised. In this manner, accidental release of potential contaminants from rigs and supply/service vessels will be strictly controlled, thus providing protection for marine life across all phases of the offshore wind farm development.
Array, inter-accommodation, export and inter-connector cables will typically be buried to between 1-2 m. A cable burial risk assessment (CBRA) will inform cable burial depth which will depend on ground conditions, with this CBRA to be undertaken post consent.	While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and fish and shellfish receptors, thereby potentially reducing the effect on those receptors.
During piling operations, soft starts will be used, with lower hammer energies (i.e. approximately 15% of the maximum hammer energy; see paragraph 3.11.1.44) used at the beginning of the piling sequence before increasing energies to the higher levels.	This measure will reduce the risk of injury to fish species in the immediate vicinity of piling operations.

Temporary habitat loss/disturbance from construction operations including foundation installation (e.g. jack-up operations and seabed preparation works) and cable laying operations (including anchor placement) may affect fish ecology.

Magnitude of impact

3.11.1.3 Temporary habitat loss/disturbance will occur during construction operations and is likely to include sediment compaction and disturbance during foundation installation (i.e. jack up operations and anchor placements), sediment disturbance during seabed preparation prior to gravity base installation and cable burial operations (including sandwave clearance for cable installation in the Hornsea Three array area and offshore cable corridor). All fish and shellfish receptors have the potential to be affected by this impact, through loss of spawning, nursery or feeding habitats, though demersal fish and shellfish species and demersal spawning species have the greatest potential to be affected. For the purposes of the current assessment, coarse, granular material disturbed during seabed preparation and sandwave clearance activities and disposed of within Hornsea Three during construction will result in sediment deposition in mounds of depths of between tens of centimetres to several metres. Due to the depth of sediment deposition, this may lead to mortality of some less mobile fish and shellfish species (e.g. crustaceans or sandeel) and loss of habitat beneath these areas. However, it is likely that any mounds of granular material will erode over time, reducing in size, and as the sediment type deposited to the seabed will be similar to those in surrounding areas, fish and shellfish VERs would be expected to recolonise these areas (discussed further below) and this habitat loss has therefore been considered temporary.

3.11.1.4 The total maximum area of subtidal habitat loss due to construction activities described in Table 3.11 is predicted to be approximately 31,728,118 m^2 (31,73 km^2). This equates to 0.02% of the total seabed area within the southern North Sea fish and shellfish study area and 2.59% of the area within the Hornsea Three project boundary. Activities resulting in the temporary habitat loss will occur intermittently throughout the construction period and will be highly localised to the vicinity of the construction activities (i.e. limited to the immediate footprints).

3.11.1.5 The combined total disturbance of 2.59% of the seabed habitat within the Hornsea Three project boundary is not expected to diminish regional ecosystem functions (i.e. fish habitat or biodiversity functions) as the seabed habitats present within Hornsea Three are widespread within the southern North Sea fish and shellfish study area (see chapter 2: Benthic Ecology).

3.11.1.6 The impact is predicted to be of local spatial extent (i.e. within Hornsea Three), short term duration, intermittent and reversible. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of the receptor

3.11.1.7 In general, mobile fish species are able to avoid temporary disturbance (EMU, 2004). The most vulnerable species are likely to be shellfish which are much less mobile than fish. Overwintering female berried brown crab bury themselves in sediment, often seeking out gravel banks, during which time these animals are relatively immobile and therefore particularly sensitive to habitat loss/disturbance. Egg bearing lobster are likely to be more mobile than egg bearing brown crab, though one mark recapture study in Norway showed that 84% of berried female lobster remained within 500 m of their release site (Agnalt *et al*., 2007). Evidence from other stocks around the world are less clear, with limited movement recorded for some stocks and long distance migrations documented for other stocks (e.g. Campbell and Stasko,1985; Comeau and Savoie, 2002). The Hornsea Three offshore cable corridor is likely to coincide with overwintering and spawning grounds for brown crab and potentially lobster (see volume 5, annex, 3.1: Fish and Shellfish Ecology Technical Report), though the proportion of this habitat affected through cable installation is small in the context of the available habitat in the southern North Sea fish and shellfish study area (see paragraph 3.11.1.5). Indirect effects on fish and shellfish species include loss of feeding habitat and prey items. However, since this impact is predicted to affect only a small proportion of benthic habitats in the southern North Sea fish and shellfish study area, with similar habitats (and prey species) occurring throughout the area (see chapter 2: Benthic Ecology), these effects are likely to be limited.

3.11.1.8 As discussed above, the Hornsea Three offshore cable route corridor was found to coincide with a part of the southern North Sea which is known to be important habitat for a number of shellfish species, including brown crab and lobster, which potentially have spawning and overwintering grounds in this part of the southern North Sea, including parts of the offshore cable corridor. Habitat loss in this area will represent temporary disturbance to habitats (i.e. during cable laying) within a relatively small corridor (i.e. loss/disturbance to six corridors of 10 m width within the Hornsea Three offshore cable route corridor) and as noted in paragraph 3.11.1.4, will occur intermittently during the construction phase. This relatively small corridor within which temporary habitat loss/disturbance will occur intermittently during the construction phase is not likely to create a barrier to migrating crustacean species.

3.11.1.9 Spawning and nursery habitats for *Nephrops* within the southern North Sea fish and shellfish study area have been mapped (see volume 5, annex 3.1: Fish and Shellfish Technical Report) and temporary loss/disturbance of seabed habitats as a result of construction activities within Hornsea Three are predicted to affect a small proportion of these (i.e. <0.1% of these habitats within the southern North Sea fish and shellfish study area). The most important habitats for this species within Hornsea Three are the deep water, muddy sand habitats in Markham's Hole (in the southeast of the Hornsea Three array area) and Outer Silver Pit (along the northern boundary), although these habitats extend over a wider area to the north and northwest of Hornsea Three, with only a relatively small proportion of these habitats affected within the Hornsea Three array area.

3.11.1.10 The recoverability and rate of recovery of an area after large-scale sea bed disturbance (e.g. dredging or trawling activities) is linked to the substrate type (Newell *et al*., 1998; Desprez 2000). Mud or sand habitats, similar to those found in the Hornsea Three fish and shellfish study area, have been shown to return to baseline species abundance after approximately one to two years (Newell *et al*., 1998; Desprez, 2000; chapter 2: Benthic Ecology). Harder gravely and rocky substrate takes proportionally longer to re-establish: up to ten years for boulder coastlines (Newell *et al*., 1998).

3.11.1.11 Larger crustacea (e.g. *Nephrops*, brown crab, European lobster) are classed as equilibrium species (Newell *et al*., 1998), only capable of recolonising an area once the original substrate type has returned. The sensitivity of these receptors is therefore higher than for smaller benthic organisms which move in and colonise new substrate immediately after the effect. Therefore, although recovery of benthic assemblages may occur over relatively fast timescales (e.g. within one to two years; see chapter 2: Benthic Ecology), recovery of the equilibrium species may take up to ten years in some areas of coarse sediments (Phua *et al*., 2002). Larval settlement will also increase the rate of recovery in an area (Phua *et al*., 2002), with shellfish spawning and nursery habitats in the vicinity of Hornsea Three (see volume 5, annex 3.1: Fish and Shellfish Technical Report) potentially increasing the rate of recovery into disturbed areas.

3.11.1.12 The fish species in the southern North Sea fish and shellfish study area which are likely to be most sensitive to temporary habitat loss are those species which spawn on or near the seabed sediment (e.g. herring, sandeel, short spined sea scorpion, dragonet and elasmobranchs including the spotted ray). Elasmobranchs occur within the southern North Sea fish and shellfish study area, though at low abundances. Spawning and nursery habitats for these species are also likely to occur within the inshore sections of the Hornsea Three offshore cable corridor (Walker *et al*., 1997; Ellis *et al*., 2012; McCully *et al*., 2013).

3.11.1.13 Sandeel are known to have low intensity spawning habitats within the Hornsea Three fish and shellfish study area with high intensity (i.e. more important) spawning habitat for this species located to the north of the Hornsea Three array area, outside the area affected by temporary habitat loss (see Table 3.9 and Figure 3.20 and 3.21 of volume 5, annex 3.1: Fish and Shellfish Technical Report). Temporary habitat loss is predicted to affect only a small proportion of sandeel habitats within the Hornsea Three boundary (i.e. <3% of the Hornsea Three area) and this area is smaller still in the context of the known sandeel habitats (e.g. as mapped by Jensen *et al*., 2010; see Figure 3.22 of volume 5, annex 3.1: Fish and Shellfish Technical Report) and the potential sandeel habitats (i.e. “preferred” sediment types defined by Latto *et al*., 2013; see Figure 3.23 of volume 5, annex 3.1: Fish and Shellfish Technical Report in the wider southern North Sea fish and shellfish study area. It should also be noted, however, that the maximum temporary habitat loss predicted is likely to be spread over up to 11 years throughout the potential construction period, with temporary habitat loss only affecting a small proportion of this total at any one time.

3.11.1.14 Physical disturbance to sandeel habitats may also lead to direct effects on adult and juvenile sandeel (e.g. increased mortality), where individuals are not able to colonise viable sandy habitats in the immediate vicinity, or where habitats may be at carrying capacity. Sandeel may also be particularly vulnerable during their winter hibernation period when these animals are less mobile. Recovery of sandeel populations would be expected following construction operations. Effects of offshore wind farm construction (Jensen *et al*., 2004) and operation (i.e. post construction van Deurs *et al*., 2012) on sandeel populations have been examined through short term and long term monitoring studies at the Horns Rev offshore wind farm. These monitoring studies have shown that offshore wind farm construction and operation has not led to significant negative effects on sandeel populations. Further information on recovery potential of sandeel can also be inferred from a study by Jensen *et al*. (2010), which examined mixing of adult sandeel populations at different fishing grounds within the entire North Sea. This study showed evidence of mixing of sandeel populations between different fishing grounds located up to 5 km apart and mixing within fishing grounds to distances of up to 28 km. This suggests that some recovery of adult populations would be predicted following construction operations, with adults recolonising suitable sandy substrates from adjacent unimpacted habitats (e.g. the high intensity spawning habitats to the north of the Hornsea Three array area). Recovery may also occur through larval recolonisation of suitable sandy sediments (which was not investigated in the Jensen *et al*., 2010 study) with sandeel larvae likely to be distributed throughout the southern North Sea fish and shellfish study area, particularly the high intensity spawning habitats to the north of Hornsea Three during spring months following spawning in winter/spring (see Ellis *et al*., 2012, Table 3.9 and volume 5, annex 3.1: Fish and Shellfish Technical Report).

3.11.1.15 The main autumn herring spawning habitat in the southern North Sea is located off Flamborough Head, outside the area affected by temporary habitat loss, although some areas of coarse, gravelly sediment where herring spawning has been recorded historically within Hornsea Three. The proportion of coarse gravelly sediments affected during construction of Hornsea Three are expected to be limited in the context of the available habitat within the Hornsea Three fish and shellfish study area and the wider southern North Sea fish and shellfish study area.

3.11.1.16 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. The sensitivity of these receptors is therefore considered to be **low**.

3.11.1.17 Brown crab, European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.1.18 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

<u>Significance of the effect</u>

3.11.1.19 The proportion of fish and shellfish habitats (including spawning, nursery and feeding habitats) affected by temporary habitat loss/disturbance is predicted to be small, with similar habitats occurring throughout the southern North Sea fish and shellfish study area and with recovery of these habitats expected following disturbance.

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

3.11.1.21 For migratory fish species, due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs (i.e. the Humber Estuary SAC is over 140 km from the Hornsea Three array area), the **low** sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.1.22 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Increased suspended sediment concentrations (SSC) and associated sediment deposition as a result of foundation installation, cable installation and seabed preparation resulting in potential effects on fish and shellfish receptors.

<u>Magnitude of impact</u>

3.11.1.23 Table 3.11 presents the maximum design scenario associated with increases in SSC and deposition associated with drilling operations for monopile foundation installation. The Marine Processes assessment (chapter 1: Marine Processes) concluded that SSC during this activity will be increased by tens to hundreds of thousands of mg/l at the point of sediment release (i.e. near the water surface). Further afield SSC increases of low tens of mg/l will be present in a narrow plume, tens to a few hundreds of metres wide and between 3.5 and 7 km length, aligned with the tidal stream downstream from the source. Outside of this area, SSC of less than 10 mg/l may occur due to ongoing dispersion and dilution of fine material. Fine sediment concentrations may persist in suspension for hours to days, but will become diluted to concentrations indistinguishable from the background levels within around one day. Deposition of coarse grained and sandy deposits from drilling of a single monopile foundation will result in sediment accumulation of tens of centimetres to metres and for the purposes of this impact assessment this would be considered habitat loss and is therefore considered in paragraph 3.11.1.3 *et seq*. Fine grained material from drilling operations will be dispersed widely within the surrounding region and will not settle with a measurable thickness.

3.11.1.24 Table 3.11 presents the maximum design scenario associated with increases in SSC and deposition associated with seabed preparation for installation of GBFs. As described in paragraph 3.11.1.3, deposition of coarse, granular sediments from seabed preparation activities is considered temporary habitat loss for the purposes of this assessment. Increases in SSC and subsequent deposition are therefore related to the passive phase of the plume comprised of finer sediments which are likely to stay in suspension and will therefore affect a larger area. Chapter 1: Marine Processes predicted that sand sized material could remain in suspension for up to approximately 15 minutes and therefore may be transported up to approximately 0.5 km, with increases in SSC in excess of natural ranges over a short timescale. Finer sediment fractions would remain in suspension for a longer period, affecting a larger area for a longer period. Elevations in SSC above background levels at distances of hundreds of metres to a few kilometres are predicted to be relatively low (i.e. less than ~20 mg/l) and within the range of natural variability. After 24 hours, elevations in SSC are predicted to typically be less than 5 mg/l, i.e. well within the range of natural variability.

3.11.1.25 The maximum design scenario for increases in SSC associated with inter array, substation interconnector and export cable installation are predicted to occur as a result of installation by mass flow excavator (see Table 3.11 and chapter 1: Marine Processes for full details). Disturbance of medium to coarse sand and gravels during cable installation are likely to result in a temporally and spatially limited plume affecting SSC levels (and settling out of suspension) in close proximity to the point of release. SSC will be locally elevated within the plume close to the active cable burial by up to tens or hundreds of thousands of mg/l, although the change will only be present for a very short time locally (i.e. seconds to tens of seconds) before the material resettles to the seabed. Changes in SSC and deposition will be spatially limited to within metres downstream of the cable for gravels and within tens of metres for sands, with some variability depending on the height to which the material is ejected and current speeds at the time of release. Finer material will be advected away from the release location by the prevailing tidal current. High initial concentrations (similar to sands and gravels) are to be expected but will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within hundreds to a few thousands of metres of the point of release. Only a small proportion of the material disturbed is expected to be fines, with a corresponding reduction in the expected levels of SSC.

3.11.1.26 Irrespective of sediment type, the volumes of sediment being displaced and deposited locally are relatively limited (up to 6 m^3 per metre of cable burial) which also limits the combinations of sediment deposition thickness and extent that might realistically occur. The assessment presented in chapter 1: Marine Processes suggests that the extent and so the area of deposition will normally be much smaller for sands and gravels, leading to a greater average thickness of deposition in the order of tens of centimetres to a few metres in the immediate vicinity of the cable trench. Fine material, by contrast, will be distributed much more widely, becoming so dispersed that it is unlikely to settle in measurable thickness locally.

3.11.1.27 As detailed in Table 3.11, sandwave clearance is also expected to be required at discrete locations both within the Hornsea Three array area and along the Hornsea Three offshore cable corridor. As described in paragraph 3.11.1.3, deposition of coarse, granular sediments from sandwave clearance is considered temporary habitat loss for the purposes of this assessment. Increases in SSC and subsequent deposition are therefore related to the passive phase of the plume comprised of finer sediments which are likely to stay in suspension and therefore will affect a larger area. Chapter 1: Marine Processes predicted that impacts related to increases in SSC were likely to be similar to those for seabed preparation for GBF installation (see paragraph 3.11.1.24), with elevated SSCs in close proximity to sandwave clearance activities and lower levels, reflective of natural baseline conditions, at greater distances. It was predicted that increases in depth averaged SSC of 5-10 mg/l would extend less than 13 km upstream and downstream of the source where a trailer suction hopper dredger was used for sandwave clearance. Where a mass excavator tool was used SSC of 5-10 mg/l would extend less than 17.5 km from the source (chapter 1: Marine Processes).

3.11.1.28 The impact of construction operations leading to increases in SSC and associated sediment deposition is predicted to be of local spatial extent, short term duration, intermittent and reversible. It is predicted that the impact will affect fish and shellfish receptors indirectly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.11.1.29 In terms of SSC, adult fish species are more mobile than many of the other fish and shellfish receptors, and therefore may show avoidance behaviour within areas affected by increased SSC (ABP Research, 2007; EMU, 2004), making them less susceptible to physiological effects of this impact. Juvenile fish are more likely to be affected by habitat disturbances such as increased SSC than adult fish. This is due to the decreased mobility of juvenile fish and these animals are therefore less able to avoid impacts. Juveniles are likely to occur throughout Hornsea Three, with some species using offshore areas as nursery habitats while inshore areas are more important for others (see section 3.7.2). Due to the temporary increases in SSC associated with winter storm events and the occurrence of juveniles in inshore areas (where SSCs are typically higher), it can be expected that most fish juveniles expected to occur in Hornsea Three (e.g. plaice, sprat, herring, whiting and sandeel) will be largely unaffected by the low level temporary increases in SSC, as these species are likely to be within the range of natural variability.

3.11.1.30 Migratory fish species known to occur in the area are also expected to have some tolerance to naturally high SSC, given their migration routes pass through estuarine habitats (e.g. the Humber Estuary) which have background SSC which are considerably higher than those expected in the southern North Sea. As it is predicted that construction activities associated with Hornsea Three will produce temporary and short lived increases in SSC, with levels below those experienced in estuarine environments, it would be expected that any migratory species should only be temporarily affected by such an issue. Any adverse effects on these species are likely to be short-term behavioural effects (i.e. avoidance), and are not expected to create a barrier to migration to rivers or estuaries used by these species (e.g. including the Humber Estuary) in the southern North Sea fish and shellfish study area (see section 3.7.5).

3.11.1.31 Many shellfish species, such as brown crab, have a high tolerance to SSC and are reported to be insensitive to increases in turbidity; however, they are likely to avoid areas of increased suspended sediment concentration as they rely on visual acuity during predation (Neal and Wilson, 2008). Berried crustaceans (e.g. brown crab, European lobster and *Nephrops*) are likely to be more vulnerable to increased SSC as the eggs carried by these species require regular aeration. Increased SSC along the Hornsea Three offshore cable corridor (potential habitat for egg bearing and spawning brown crab and lobster in the Hornsea Three fish and shellfish study area) will only affect a small area at any one time and will be temporary in nature, with sediments settling to the seabed quickly following disturbance (see paragraph 3.11.1.25). *Nephrops* are not considered to be sensitive to increases in SSC or subsequent sediment deposition, since this is a burrowing species with the ability to excavate any sediment deposited within their burrows (Sabatini and Hill, 2008).

3.11.1.32 The species likely to be affected by sediment deposition are those which either feed or spawn on or near the sea bed. The majority of species which have known spawning grounds in close proximity to Hornsea Three are pelagic spawners and so it is likely that these species will not be affected. Demersal spawners within the Hornsea Three fish and shellfish study area include herring and sandeel.

3.11.1.33 Sandeel eggs are likely to be tolerant to sediment deposition due to the nature of re-suspension and deposition within their natural high energy environment. High intensity spawning sites for sandeel occur within the Hornsea Three fish and shellfish study area (see section 3.7.2 and Table 3.9), however the main area of high intensity spawning is to the north of Hornsea Three where sediment deposition is expected to be minimal (see paragraphs 3.11.1.23 and 3.11.1.24 and chapter 1: Marine Processes) and so it can be concluded that effects on sandeel spawning populations are predicted to be limited. Sandeel populations are also sensitive to sediment type within their habitat, preferring coarse to medium sands and showing reduced selection or avoidance of gravel and fine sediments (Holland *et al*., 2005). Therefore, any increase in the fine sediment fraction of their habitat may cause avoidance behaviour until such time that the current removes fine sediments in suspension or on the seabed. Again it is unlikely that these effects will have any impact on sandeel receptors within the Hornsea Three fish and shellfish study area as sediment deposition levels here are expected to be low.

3.11.1.34 With respect to the effects of sediment deposition on herring spawning activity, it has been shown that herring eggs are tolerant of very high levels of SSC (Mesieh *et al*., 1981; Kiorbe *et al*., 1981). Detrimental effects may be seen if smothering occurs and the deposited sediment is not removed by the currents (Birklund and Wijsmam, 2005), however this would be expected to occur quickly with such a small amount of sediment deposition being forecast. Furthermore, as discussed in section 3.2.6 of volume 5, annex 3.1, evidence of herring spawning has not been recorded in the vicinity of Hornsea Three in recent years, despite the presence of suitable sediments, and therefore no effects are predicted on this species.

3.11.1.35 Based on the increase in sensitivity of herring eggs to the smothering effects of increased sediment deposition, herring is deemed to be of medium vulnerability, high recoverability and of regional importance in the southern North Sea fish and shellfish study area, and therefore the sensitivity of this receptor is considered to be **medium**. However, due to the distance between known spawning grounds and Hornsea Three, no effects of increased SSC and sediment deposition are predicted to occur on herring spawning habitats.

3.11.1.36 All other fish and shellfish receptors within the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of the receptor is therefore considered to be **low**.

3.11.1.37 Brown crab and lobster are deemed to be of medium vulnerability, high recoverability and regional importance in the southern North Sea fish and shellfish study area. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of the effect

3.11.1.38 Increases in SSC and associated sediment deposition will represent a temporary and short term, intermittent impact, affecting a relatively small proportion of the fish and shellfish habitats in the southern North Sea fish and shellfish study area. Most fish and shellfish receptors are predicted to have some tolerance to this impact. Overall, it is predicted that the sensitivity of fish and shellfish receptors is considered to be **low** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

3.11.1.39 Due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.1.40 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Seabed disturbances within the Hornsea Three offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology.

3.11.1.41 Subtidal sediment contamination data is currently not available for the Hornsea Three offshore cable corridor, therefore it is not possible to assess this impact in the PEIR. However, as discussed in section 1.6.4 of chapter 2: Benthic Ecology, a site-specific survey will be undertaken along the Hornsea Three offshore cable corridor, as agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG, and sediment contaminant data acquired in the pending survey will inform the assessment for this impact in the final EIA report.

Underwater noise as a result of foundation installation (i.e. piling) and other construction activities (e.g. cable installation) resulting in potential effects on fish and shellfish receptors.

3.11.1.42 As detailed in Table 3.11, construction activities, in particular the pile-driving of foundations for offshore structures, will result in high levels of underwater noise that will be audible to fish and shellfish over ranges of hundreds of metres to tens of kilometres around Hornsea Three, depending on the relative sensitivity of the individual species. At the highest noise levels, sub-lethal and lethal effects may occur, resulting in injury and in extreme cases cause the death of exposed species. The assessment below focusses on underwater noise from pile driving for the installation of foundations for offshore structures (i.e. turbines, substations and accommodation platforms). While other activities (e.g. cable laying or burial, dredging operations, vessel movements) will result in underwater noise, these have the potential to affect a relatively small area in the immediate vicinity of the activities and are therefore inconsequential in the context of the underwater noise from piling operations.

Magnitude of impact

3.11.1.43 Piling operations will take place intermittently within Hornsea Three during the construction phase; with piling operations potentially occurring over 2.5 years in up to two phases (i.e. of ~1.25 years each phase) with a gap of up to six years between phases (see Table 3.11). As outlined in Table 3.11, two maximum design scenarios are considered with respect to underwater noise during the construction phase: a spatial maximum design scenario and a temporal maximum design scenario. To inform this impact assessment subsea noise modelling has been undertaken, with consideration of the key parameters associated with these two scenarios (e.g. hammer energies), with full details of the modelling undertaken presented in volume 4, annex 3.1.

3.11.1.44 The spatial maximum design scenario considers the greatest area of effect from subsea noise at any one time during piling, and subsea noise modelling indicated that the greatest potential area of effect was for a 7 m diameter monopole being driven with 5,000 kJ hammer energy. It should be noted that this maximum hammer energy is considered highly conservative. Although the absolute maximum hammer energy to be identified within the design envelope is 5,000 kJ, hammer energies will be significantly lower for the overwhelming majority of the time and the driving energy will be raised to 5,000kJ only when absolutely necessary. To minimise fatigue loading on the piles, hammer energies are continuous, set at the minimum required, which also reduces likelihood of breakdown of the equipment. Hammer energies will therefore typically start at low levels (15% soft start of 750kJ) and gradually increase to the maximum required installation energy during the piling of the final metres, which is typically significantly less than the maximum consented hammer energy. Preliminary analysis undertaken by Hornsea Three indicate that the expected the average hammer energy across the entire construction programme to be less than 2,000 kJ and the expected average maximum energy at each position (i.e. for the final few metres) to be less than 2,500 kJ.

3.11.1.45 The temporal maximum design scenario represents the longest duration of effects from subsea noise and assumes a scenario whereby piled jacket foundations are used for all offshore structures. The temporal scenario includes maximum hammer energy of 2,500 kJ for pin pile installation, which is also considered conservative with many of the assumptions discussed in paragraph 3.11.1.45 also expected to be relevant to this maximum hammer energy.

3.11.1.46 With respect to the duration of piling activities, the maximum design scenarios detailed in Table 3.11 also make conservative assumptions. The maximum duration of piling is assumed to be four hours per pile, with the temporal maximum design scenario assuming a maximum total duration of piling of 8,064 hours, based on this maximum per pile duration. This duration would be considerably less in the event of fewer foundations, different foundation types (e.g. monopiles), or shorter piling durations. Analysis of recent piling records at DONG Energy wind farms indicates that piling of monopoles is typically an average of two hours or less, with timings slightly longer at the beginning of construction and reducing as experience is gained from the site, e.g. site-specific ground conditions. Piling at substations typically takes longer averaging three hours or less.

3.11.1.47 As detailed in paragraph 3.11.1.43, in order to quantify the spatial extent of any potential noise impacts on fish populations, predictive subsea modelling was undertaken, with modelling undertaken using the two maximum design hammer energies (i.e. 5,000 kJ for monopoles and 2,500 kJ for pin piles) at five representative locations: three at points around the boundary of the Hornsea Three array area and two within the offshore HVAC booster substation search area (i.e. in the nearshore section of the Hornsea Three offshore cable corridor). The following sensitivity assessment provides a summary of the key results of this modelling in the context of the impact assessment on fish receptors, with full details of the underwater noise modelling presented in volume 4, annex 3.1: Subsea Noise Technical Report. No specific guidance for effects (e.g. injury or behavioural effects) on shellfish species are currently available and therefore a qualitative assessment was undertaken on these species, with no underwater noise modelling completed specifically for shellfish

3.11.1.48 The impact of construction related underwater noise is predicted to be of local to regional spatial extent, short to medium term duration (i.e. up to a three year piling phase), intermittent and reversible (for non-injurious effects). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.11.1.49 Underwater noise can potentially have a negative impact on fish species ranging from physical injury/mortality to behavioural effects. In general, biological damage as a result of sound is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration, such as an explosion. However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. For example, a continuous source operating at a given sound pressure level has a higher total energy and is therefore more damaging (Southall *et al*., 2007) than an intermittent source reaching the same sound pressure level (SPL)).

3.11.1.50 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 have highlighted some of the shortcomings of impact assessments, including the use of broad criteria for injury and behavioural effects based on limited studies. One of the key data gaps with respect to impacts on fish and shellfish populations relates to the effects of the particle motion element of underwater noise, which is considered to be more important for many fish species, and particularly invertebrates (i.e. including shellfish), than sound pressure which has been the main consideration in noise impact assessments to date.

3.11.1.51 Recent peer reviewed guidelines have been published by the Acoustical Society of America (ASA) and provide directions and recommendations for setting criteria (including injury and behavioural criteria) for fish. For the purposes of this assessment, these Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*., 2014) were considered to be most relevant for impacts of underwater noise on fish species. The Popper *et al.* (2014) guidelines broadly group fish into the following categories based on their anatomy and the available information on hearing of other fish species with comparable anatomies:

- Group 1: Fishes lacking swim bladders that are sensitive only to sound particle motion and show sensitivity to a narrow band of frequencies (includes flatfishes and elasmobranchs);
- Group 2: Fishes with a swim bladder where the organ does not appear to play a role in hearing. These fish are sensitive only to particle motion and show sensitivity to a narrow band of frequencies (includes salmonids and some tuna);
- Group 3: Fishes with swim bladders that are close, but not intimately connected to the ear. These fishes are sensitive to both particle motion and sound pressure and show a more extended frequency range than groups 1 and 2, extending to about 500 Hz (includes gadoids and eels); and
- Group 4: Fishes that have special structures mechanically linking the swim bladder to the ear. These fishes are sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3 (includes clupeids such as herring, sprat and shads).

3.11.1.52 There have been a few studies on the ability of aquatic invertebrates (including shellfish) to respond to noise (e.g. Wale *et al*., 2013; Roberts *et al*., 2016), although these are insufficient to make firm conclusions about sensitivity. It is highly likely that aquatic invertebrates can detect particle motion, including seabed vibration and what evidence there is indicates those species are primarily sensitive to particle motion at frequencies well below 1 kHz (Hawkings and Popper, 2016).

Injury criteria

3.11.1.53 There is a lack of accepted injury criteria for fish species and recent reviews (e.g. Popper and Hastings, 2009; Popper *et al*., 2014; Hawkins *et al*., 2014b) on the effects of anthropogenic sound on fishes concluded that there are substantial gaps in the knowledge that need to be filled before meaningful noise exposure criteria can be developed. The recent ASA guidelines (Popper *et al*., 2014) have provided recommendations for setting injury criteria for fish from a range of noise sources, with Table 3.17 summarising the fish injury criteria recommended for pile driving. For the purposes of the current assessment, the underwater noise technical report has modelled the criteria given for Group 4 Fish, i.e. those where the swim bladder is involved in hearing, as the most precautionary threshold. The modelling results for SEL_{cum} (i.e. cumulative sound exposure level) assume a fleeing animal, with the receptor fleeing from the source at a constant rate of 1.5 ms^{-1} based on data from Hirata (1999).

Table 3.17: Criteria for onset of injury in fish due to piling operations (Popper *et al*., 2014). All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist.

Type of fish	Mortality and potential mortal injury		Recoverable Injury		TTS[b] (SEL_{cum} Weighted dB re 1 µPa².s)
	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 µPa².s)	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 µPa².s)	
Group 1 Fish: no swim bladder (particle motion detection)	>213	>219	>213	>216	>>186
Group 2 Fish: swim bladder is not involved in hearing (particle motion detection)	>207	210	>207	>203	>186
Group 3 and 4 Fish: swim bladder involved in hearing (pressure and particle motion detection)	>207	207	>207	203	186
Eggs and larvae	>207	>210	N: Moderate risk[a] I: Low risk F: Low risk		N: Moderate risk[a] I: Low risk F: Low risk

a: Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near field (N; i.e. 10s of metres), intermediate (I; i.e. 100s of metres), and far field (F; i.e. 1000s of metres); Popper *et al*. (2014).

b: Temporary Threshold Shift.

3.11.1.54 The full results of the modelling of injury ranges for fish species are presented in volume 4, annex 3.1: Subsea Noise Technical Report. These show that for the 5,000 kJ hammer energy (i.e. monopile foundations) within the Hornsea Three array area, recoverable injury effects may be expected within a mean range of approximately 1 km, based on SPL_{peak}, and a mean range of up to 4 km, based on SEL_{cum}, assuming a fleeing animal. For the 2,500 kJ hammer energy (pin piles) within the Hornsea Three array area, recoverable injury effects may be expected within a more restricted area, with a mean range of up to 400 m, based on SPL_{peak}, and a mean range of approximately 1.5 km, based on SEL_{cum}, assuming a fleeing animal. Recoverable injury ranges associated with the offshore HVAC booster stations on the Hornsea Three offshore cable corridor are expected to be smaller than those predicted for the Hornsea Three array area, i.e. 100s of metres.

3.11.1.55 These injury ranges are for recoverable 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). Potential for mortality or mortal injury may 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 (i.e. starting at lower hammer energies and building up to the maximum hammer energy; see paragraph 3.11.1.46). This means that fish in close proximity to piling operations will move away from the impact range, before noise levels reach a level likely to cause irreversible injury.

3.11.1.56 Although there is currently limited understanding of the effects of piling noise on fish eggs and larvae, a study by the Institute for Marine Resources and Ecosystem Studies (IMARES) (Bolle *et al*., 2011; 2012) which exposed common sole larvae to piling noise, observed no statistically significant effect on their survival rates for a piling sequence which resulted in a SEL dose of 206 dB re 1 µPa²•s. For fish larvae, the risk of mortality due to prolonged noise exposure would be significantly reduced by any drift of larvae due to water currents (up to 0.7 m/s in the Hornsea Three array area; see chapter 1: Marine Processes) and would substantially reduce the risk of mortality to an insignificant level based on recent work by Bolle *et al*. (2011; 2012). Effects on fish larvae may therefore occur within ranges smaller than those summarised in paragraph 3.11.1.54 above, noting that the ranges these are based on are the most precautionary criteria for fish injury. It is however, not possible to establish if mortality might occur or indeed at what range from the pile, as the work by Bolle *et al*. (2011; 2012) was unable to induce a statistically significant change in survival rates of fish larvae, following a prolonged exposure with a substantial cumulative SEL dose.

Behavioural impacts

3.11.1.57 As indicated in the fish groupings presented in paragraph 3.11.1.51 (and paragraph 3.11.1.52 for shellfish), different fish and shellfish species will 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 (also known as C-turn responses), 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 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 recent ASA guidelines (Popper *et al*., 2014) provide qualitative behavioural criteria for fish from a range of noise sources. These categorise the risks of effects in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. tens of metres), “intermediate” (i.e. hundreds of metres) or “far” (i.e. thousands of metres). These behavioural criteria for piling operations are summarised in Table 3.18 for the four fish groupings considered in paragraph 3.11.1.51.

Table 3.18: Criteria for onset of behavioural effects in fish from piling operations (Popper *et al*., 2014).

Type of fish	Masking	Behaviour
Group 1 Fish: no swim bladder (particle motion detection)	N: Moderate risk I: Low risk F: Low risk	N: High risk I: Moderate risk F: Low risk
Group 2 Fish: swim bladder is not involved in hearing (particle motion detection)	N: Moderate risk I: Low risk F: Low risk	N: High risk I: Moderate risk F: Low risk
Group 3 and 4 Fish: swim bladder involved in hearing (pressure and particle motion detection	N: High risk I: High risk F: Moderate risk	N: High risk I: High risk F: Moderate risk
Eggs and larvae	N: Moderate risk I: Low risk F: Low risk	N: Moderate risk I: Low risk F: Low risk

a: Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near field (N; i.e. 10s of metres), intermediate (I; i.e. 100s of metres), and far field (F; i.e. 1000s of metres); Popper *et al*. (2014).

3.11.1.58 Group 1 Fish (e.g. flatfish and elasmobranchs), Group 2 Fish (e.g. salmonids) and shellfish are less sensitive to sound pressure, with these species detecting sound in the environment through particle motion (paragraph 3.11.1.51). Fish sensitivity to the acoustic particle velocity component of the sound field has been noted by a number of researchers (Hawkins, 2006; Nedwell *et al*., 2007; Popper and Hastings, 2009; Sigray and Andersson, 2011) and the potential for marine piling to generate the type of sound fields that may contain substantial acoustic particle velocity components has been noted in the literature (Hawkins, 2009). Sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al*., 2010; Hawkins *et al*., 2014a).

3.11.1.59 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). Aquatic decapod crustaceans are equipped with a number of receptor types potentially capable of responding to the particle motion component of underwater noise (e.g. the vibration of the water molecules which results in the pressure wave) and ground borne vibration (Popper *et al*., 2001). 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. Sandeel may be particularly affected by vibration through the seabed during winter hibernation when sandeel remain buried in sandy sediments.

3.11.1.60 When considering particle motion, it should be noted that little or no data exists on the effect on demersal fish or shellfish species or on the levels generated during marine impact piling (Hawkins and Popper, 2016). However as indicated by the risk criteria outlined for Group 1 and Group 2 species in Table 3.18, particle motion generated from piling would be expected to decay more rapidly than the acoustic pressure component in the water (see volume 4, annex 3.1: Subsea Noise Technical Report), with a low risk of behavioural effects in the far field (i.e. kilometres from the source). Behavioural effects on these fish and shellfish populations in the Hornsea Three fish and shellfish study area are likely to be spatially limited to within kilometres of piling operations. Although spawning and nursery habitats are present within Hornsea Three fish and shellfish study area (e.g. for plaice, lemon sole, sole, sandeel and *Nephrops*), these extend over a wide area across the southern North Sea fish and shellfish study area. 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. Effects of underwater noise on brown crab and lobster habitats in the inshore sections of the Hornsea Three offshore cable corridor are expected to be more limited than the Hornsea Three array area, due to the relatively small amount of piling required at the offshore HVAC booster substation on the Hornsea Three offshore cable corridor (Table 3.11).

3.11.1.61 Group 3 (including gadoids such as cod and whiting) and Group 4 fish (including herring and sprat) are more sensitive to the sound pressure component of underwater noise (see paragraph 3.11.1.51) and, as indicated in Table 3.18, the risk of behavioural effects in the intermediate and far fields are therefore greater for these species. A number of studies have examined the behavioural effects of the sound pressure component of impulsive noise (including piling operations and seismic airgun surveys) on fish species, including gadoids. Mueller-Blenkle *et al*. (2010) measured behavioural responses of cod (and sole) to sounds representative of those produced during marine piling, with considerable variation across subjects (i.e. depending on the age, sex, condition etc. of the fish, as well as the possible effects of confinement in cages on the overall stress levels in the fish). This study concluded that it was not possible to find an obvious relationship between the level of exposure and the extent of the behavioural response, although an observable behavioural response was reported at 140 to 161 dB re 1 µPa SPL_{peak} for cod and 144 to 156 dB re 1 µPa SPL_{peak} for sole. However, these thresholds should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this.

3.11.1.62 A study by Pearson *et al*. (1992) on the effects of geophysical survey noise on caged rockfish *Sebastes* spp. observed a startle or C-turn response at peak pressure levels beginning around 200 dB re 1 µPa, although this was less common with the larger fish. Studies by Curtin University in Australia for the oil and gas industry by McCauley *et al*. (2000) exposed various fish species in large cages to seismic airgun noise and assessed behaviour, physiological and pathological changes. The study made the following observations:

- A general fish behaviour response to move to the bottom of the cage during periods of high level exposure (greater than root mean square (RMS) levels of around 156-161 dB re 1 µPa; approximately equivalent to SPL_{peak} levels of around 168 to 173 dB re 1 µPa);
- A greater startle response by small fish to the above levels;
- A return to normal behavioural patterns some 14 to 30 minutes after airgun operations ceased;
- No significant physiological stress increases attributed to air gun exposure; and
- Some preliminary evidence of damage to the hair cells when exposed to the highest levels, although it was determined that such damage would only likely occur at short range from the source.

3.11.1.63 The authors did point out that any potential seismic effects on fish may not necessarily translate to population scale effect or disruption to fisheries and McCauley *et al*. (2000) show that caged fish experiments can lead to variable results. While these studies are informative to some degree, these, and other similar studies, do not provide an evidence base that is sufficiently robust to propose quantitative criteria for behavioural effects (Hawkins and Popper, 2016; Popper *et al*., 2014) and as such the qualitative criteria outlined in Table 3.18 are proposed.

3.11.1.64 It should also be noted that fish and shellfish behavioural responses to underwater noise are highly dependent on a number of factors such as the type of fish/shellfish, its sex, age and condition, as well as other stressors to which the fish is or has been exposed. For example, it would be expected that smaller fish might show behavioural responses at slightly lower levels. In addition to this, the response of the fish will depend on the reasons and drivers for the fish being in the area. Foraging or spawning, for example, may increase the desire for the fish to remain in the area despite the elevated noise level (see Peña *et al*., 2013).

3.11.1.65 Behavioural effects on cod, whiting, sprat and herring would therefore be expected to occur over the range of tens of kilometres, although as detailed above, this may not necessarily result in a strong avoidance reaction. Spawning and nursery habitats for these species coincide with Hornsea Three and extend across the wider southern North Sea fish and shellfish study area and effects on these habitats would be expected to occur. The proportion of these habitats that are likely to be affected by underwater noise from piling operations within Hornsea Three would be expected to be small in the context of the widespread nature of these habitats in the southern North Sea fish and shellfish study area. Key spawning habitats for herring are located approximately 80 km to the west of the Hornsea Three array area and therefore adult spawning herring at these spawning habitats would not be expected to be affected by construction related underwater noise at Hornsea Three.

3.11.1.66 Effects on migratory species may also occur as a result of construction related underwater noise from Hornsea Three. Shad would be expected to have similar sensitivities as herring and sprat (all are members of the clupeid family; Group 4, see paragraph 3.11.1.51), with potential behavioural responses to the far field (i.e. kilometres to tens of kilometres). European eel would be expected to have some sensitivity to both particle motion and sound pressure components of piling noise (Group 3 Fish, see paragraph 3.11.1.51) and therefore may show some behavioural responses in the far field, although as discussed above, these may not necessarily include strong avoidance responses. Salmonids (including salmon and trout) are included in Group 2 Fish (see paragraph 3.11.1.51) and would therefore be sensitive to the particle motion component of piling noise, with a low risk of behavioural effects in the far field. Sea lamprey would similarly be expected to be more sensitive to the particle motion component of piling noise (Group 2 Fish, see paragraph 3.11.1.51), again with a low risk of behavioural effects in the far field. Due to the considerable distance between Hornsea Three and the coast of the UK, effects on migration, including barrier effects, effects on coastal migrations or movement to/from coastal habitats during key migration periods, would not be expected.

3.11.1.67 Herring, sprat, cod, whiting, allis and twaite shad and European eel are considered to be of medium vulnerability, high recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be medium.

3.11.1.68 All other fish and shellfish VERs within the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be low.

Significance of the effect

3.11.1.69 Construction related underwater noise will represent a temporary, short to medium term duration (i.e. up to a three year piling phase) and intermittent impact, affecting a relatively small proportion of the habitats in the southern North Sea fish and shellfish study area. Overall, it is predicted that the sensitivity of fish and shellfish receptors is considered to be low to medium and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

3.11.1.70 Due to the large distance between Hornsea Three and coastal areas, the low to medium sensitivity of receptors and the absence of barrier effects on fish migration, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 1.7.5), are predicted to be of minor significance, which is not significant in EIA terms.

3.11.1.71 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Accidental pollution events during the construction phase resulting in potential effects on fish and shellfish receptors.

3.11.1.72 Accidental spillage of chemicals and substances (e.g. grout) from vessels used in the construction phase and offshore fuel storage tanks may impact on fish and shellfish, with extreme spills potentially resulting in behavioural effects such as avoidance of affected areas and impacts on spawning within the area affected by such a spill. Chemical spills may also have sub-lethal to lethal effects dependent on the spatial and temporal extent of the exposure and the level of toxicity.

Magnitude of impact

3.11.1.73 Table 3.11 provides a summary of the potential sources of pollution during the construction phase, including vessel movements, use of drilling muds and storage of chemicals including lubricants, coolant, hydraulic oil and fuel on offshore platforms. The magnitude of the impact is dependent on the nature of the pollution incident but the SEA carried out by DECC (2011; section 5.13.2.1) recognised that, "renewable energy developments have a generally limited potential for accidental loss of containment of hydrocarbons and chemicals, due to the relatively small inventories contained on the installations (principally hydraulic, gearbox and other lubricating oils, depending on the type of installation)". Any spill or leak within the offshore regions of Hornsea Three would be immediately diluted and rapidly dispersed.

3.11.1.74 Throughout construction there will be the requirement to store fuel offshore for the purposes of refuelling crew transfer vessels (CTVs) and/or helicopters with fuel storage assumed to be placed on offshore accommodation platforms (see Table 3.11). An impact upon fish and shellfish receptors would only be realised if an incident occurs where the fuel is accidentally released.

3.11.1.75 The historical frequency of pollution events in the southern North Sea fish and shellfish study area is low considering the density of existing marine traffic in the area. For example, as reported in volume 5, annex 7.1: Navigation Risk Assessment, within a 10 nm buffer from the Hornsea Three array area, only five unique incidents were reported during a ten year period from 2005 to 2014, with only one of those reporting an escape of harmful substances. Given the designed-in mitigation (Table 3.16) which is proposed during the construction phase of Hornsea Three (i.e. a CoCP), it is considered that the likelihood of accidental release is extremely low.

3.11.1.76 The impact is predicted to be of local to regional spatial extent, short term duration, intermittent and reversible. It is predicted that the impact has the potential to affect fish and shellfish receptors both directly and indirectly, although due to control measures to be implemented throughout the construction phase, the likelihood of such as impact is extremely low. The magnitude is therefore, considered to be negligible.

Sensitivity of the receptor

3.11.1.77 The sensitivity of the receptors will vary depending on a range of factors including species and life stage. Due to their increased mobility, adult fish are less likely to be affected by marine pollution than fish eggs and larvae which are likely to be particularly sensitive, with potentially toxic effects of pollutants on fish eggs and larvae (Westerhagen, 1988). Effects of marine pollution (e.g. heavy metals and hydrocarbon pollution) on fish eggs and larvae are likely to include abnormal development, delayed hatching and reduced hatching success (Bunn *et al*., 2000). Any such events therefore will have varying levels of effect dependent on the species present and pollutants involved. However, as fuel and oil spills are likely to be dispersed on the surface, effects on fish and shellfish receptors are likely to be limited.

3.11.1.78 The scientific literature suggests that the majority of issues arising from severe pollution events (although as noted above, these are unlikely to occur for Hornsea Three) occur after the initial pollutant is cleared (Piatt and Anderson, 1996; Amara *et al*., 2004; Claireaux *et al*., 2004). The primary mortalities which occur whilst the spill is present on the water surface may be unavoidable, however after clearing has commenced, it has been shown that major ecological effects are present months after the event (Amara *et al*., 2004; Claireaux *et al*., 2004). Juvenile sole have been shown to exhibit greatly reduced growth rates from three months after exposure to petroleum oil with no recovery seen after six months from the time of exposure (Amara *et al*., 2004). This suggests that whilst surface spills may not affect fish and shellfish species through direct contact with the pollutant, indirect effects from pollution events may impact fish and shellfish species due to delayed response to reduced feeding capabilities and habitat quality resulting from the initial spill.

3.11.1.79 Incidental bioaccumulation may also occur as a result of accidental pollution events such as oil or petroleum spills with implications for fish and shellfish receptors. Bechmann *et al*., (2010) showed that exposure of shrimp embryos to polycyclic aromatic hydrocarbons (PAHs) caused high mortality rates in the larvae when kept in clean water after hatching had occurred. The species *Pandalus borealis* used in this study is a good biomarker for bioaccumulation as it utilises the entire water column through diurnal migration, therefore experiencing both high surface concentrations and low benthic concentrations of PAH (Bechmann *et al*., 2010).

3.11.1.80 Accidental release of pollutants and consequent bioaccumulation has been shown to affect many flatfish (Eggens *et al*., 1995; Ingrasdøttir *et al*., 2012) and crustacean species (Palmork and Solbakken, 1979; Berge and Brevik, 1996). Due to the high level of commercial fisheries operating in the southern North Sea fish and shellfish study area, any release of pollutants such as heavy metals (e.g. mercury, cadmium, copper etc.) or petroleum-based compounds (e.g. PAH) have the potential to accumulate within commercial fish stocks through trophic dynamics (Baeyens *et al*., 2003).

3.11.1.81 The fish and shellfish receptors within the southern North Sea fish and shellfish study area are deemed to be of low to medium vulnerability, high recoverability and local to international importance in the southern North Sea fish and shellfish study area. The sensitivity of the receptor is therefore, is considered to be **low** to **medium**.

<u>Significance of the effect</u>

3.11.1.82 Overall, it is predicted that the sensitivity of fish and shellfish receptors is **low** to **medium** and the magnitude is deemed to be **negligible**, with a low likelihood of a pollution event occurring due to the implementation of the CoCP (see Table 3.16). The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.11.1.83 Due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low to medium sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.1.84 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Future monitoring

3.11.1.85 No fish and shellfish monitoring to test the predictions made within the impact assessment for the construction phase is considered necessary at this stage.

3.11.2 Operational and maintenance phase

3.11.2.1 The impacts of the offshore operation and maintenance of Hornsea Three have been assessed on fish and shellfish ecology. The environmental impacts arising from the operation and maintenance of Hornsea Three are listed in Table 3.11 along with the maximum design scenario against which each operation and maintenance phase impact has been assessed.

3.11.2.2 A description of the potential effect on fish and shellfish receptors caused by each identified impact is given below.

Long term habitat loss due to presence of turbine foundations and scour/cable protection with potential effects on fish and shellfish ecology.

3.11.2.3 The presence of turbine and substation foundations and associated scour protection and cable protection for offshore cables (including cable crossings) has the potential to impact on fish and shellfish by the removal of essential habitats for survival (e.g. spawning, nursery and feeding habitats). As detailed in paragraph 3.11.1.7 *et seq*., shellfish species (e.g. brown crab, lobster and *Nephrops*) and demersal spawning fish species (e.g. sandeel and herring) with spawning grounds coinciding with the Hornsea Three fish and shellfish study area are likely to be most vulnerable to long term habitat loss as these species have specific spawning habitat requirements.

<u>Magnitude of impact</u>

3.11.2.4 The long term habitat loss due to the presence of foundations, scour protection and cable protection is estimated to be up to 4.26 km^2 (Table 3.11) which represents 0.35% of the area within the Hornsea Three project boundary and 0.002% of the area of the southern North Sea fish and shellfish study area. Comparable habitats are present and widespread within the southern North Sea fish and shellfish study area (see chapter 2: Benthic Ecology). No long term habitat loss due to maintenance activity is expected.

3.11.2.5 The impact is predicted to be of a local spatial extent (i.e. within Hornsea Three), 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 directly. The magnitude is therefore considered to be **minor**.

Sensitivity of the receptor

3.11.2.6 Fish and shellfish species that are reliant upon the presence of suitable sediment/habitat for their survival are considered to be more vulnerable to change depending on the availability of habitat within the wider geographical region. The Hornsea Three fish and shellfish study area coincides with fish spawning and nursery habitats including plaice, lemon sole, common sole, dab, herring, sprat, whiting, cod, sandeel and elasmobranchs (i.e. thornback and spotted ray; Coull *et al*., 1998, Ellis *et al*., 2012; see section 3.7.2). The fish species most vulnerable to habitat loss include herring and sandeel which are demersal spawning species (i.e. eggs are laid on the seabed), as these have specific habitat requirements for spawning (i.e. gravelly sediments for herring and sandy sediments for sandeel). The main herring spawning ground in the southern North Sea fish and shellfish study area is located to the far west of Hornsea Three, off Flamborough Head and therefore will not be affected by long term habitat loss. As well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history and loss of this specific type of habitat could represent an impact on this species. However, as detailed in paragraph 3.11.1.14, monitoring at other offshore wind farm sites has indicated that the presence of operational wind farm structures has not led to significant negative effects on sandeel populations in the long term.

3.11.2.7 The Hornsea Three fish and shellfish study area also coincides with low intensity sandeel spawning habitat and long term habitat loss will result in direct impacts on this habitat, though as detailed above (paragraph 3.11.1.14), the proportion of habitat affected within the Hornsea Three project boundary is small and this area is smaller still in the context of the known sandeel habitats (e.g. as mapped by Jensen *et al*., 2010; see Figure 3.22 of volume 5, annex 3.1: Fish and Shellfish Technical Report) and the potential sandeel habitats (i.e. "preferred" sediment types defined by Latto *et al*., 2013; see Figure 3.23 of volume 5, annex 3.1: Fish and Shellfish Technical Report) in the wider southern North Sea fish and shellfish study area.

3.11.2.8 Hornsea Three coincides with known *Nephrops* spawning habitat in the southern North Sea fish and shellfish study area and long term habitat loss is predicted to affect a small proportion of this habitat, particularly where structures are placed in deep water areas within Markham's Hole (in the east of the Hornsea Three array area) and the Outer Silver Pit (along the northern boundary of Hornsea Three). As well as affecting a relatively small proportion of *Nephrops* habitat within the Hornsea Three array area, extensive areas of *Nephrops* habitat to the north and northwest of the Hornsea Three array area (i.e. the majority of the Outer Silver Pit) will be unaffected by long term habitat loss. Brown crab and lobster spawning and nursery habitats have the potential to occur along the Hornsea Three offshore cable corridor, particularly the inshore sections, and therefore have the potential to be affected by long term habitat loss due to placement of cable protection. The proportion of brown crab and lobster spawning and overwintering habitats affected is, however, likely to be small in the context of the available habitats in this part of the southern North Sea fish and shellfish study area.

3.11.2.9 Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and of local to international importance within the southern North Sea fish and shellfish study area (recoverability is not applicable for this impact due to the impact occurring over the lifetime of the project). Given the widespread nature of spawning and nursery habitat in the wider southern North Sea fish and shellfish study area, the sensitivity of these receptors is therefore considered to be **low**.

3.11.2.10 Brown crab and European lobster are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.2.11 Sandeel and herring are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. Due to the specific habitat requirement of these species, the sensitivity of these receptors is considered to be **medium** (although no effects of long term habitat loss are predicted for herring).

Significance of the effect

3.11.2.12 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 in the southern North Sea fish and shellfish study area are likely to be affected. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

3.11.2.13 For migratory fish species, due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs, the **low** sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.2.14 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Underwater noise as a result of operational turbines and maintenance vessel traffic resulting in potential effects on fish and shellfish receptors

3.11.2.15 Underwater noise levels during the operational phase are predicted to be considerably lower than those of the construction phase, being limited to noise from operational turbines and maintenance vessel traffic.

Magnitude of impact

3.11.2.16 As detailed in Table 3.11, during the operational phase, underwater noise is predicted to occur as a result of the operation of up to 342 turbines within the Hornsea Three array area. Underwater noise from an operational turbine mainly originates from the mechanically generated vibration from the turbines which is transmitted into the sea through the structure of the support pile and foundations (volume 4, annex 3.1: Subsea Noise Technical Report; see also 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 thus 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 receptor's hearing ability and the ambient sound levels.

3.11.2.17 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 show that behavioural responses of fish are only likely at close ranges from the turbine (i.e. a few metres; Wahlberg and Westerberg, 2005). 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.

3.11.2.18 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 (2004). Volume 4, annex 3.1: Subsea Noise Technical Report presents operational noise levels measured from a number of operational offshore wind farm projects and predicted source levels for the range of possible turbine sizes at Hornsea Three. These showed generally low levels of operational noise, with the largest 15 MW turbine predicted to have a SPL of 158.5 dB re 1 µPa @ 1 m (RMS), below the level stated by Sand *et al*. (2001). Any potential avoidance reactions (should they occur) would, however, be limited to a short distance from the operational turbine with the potential for acclimatisation occurring over the lifetime of the project.

3.11.2.19 As detailed in Table 3.11, noise would also result from surface vessels servicing the offshore wind farm, with up to 2,832 return vessel movements per year during operation. However, noise levels reported by Malme *et al*. (1989) and Richardson *et al*. (1995) for large surface vessels indicate that physiological damage to fish and shellfish is unlikely, although the levels could be sufficient to cause local disturbance of sensitive marine fauna (e.g. clupeids such as herring and sprat) in the immediate vicinity of the vessel, depending on ambient noise levels. Considering the operational turbine noise of the offshore wind farm and any associated service vessels, the ambient noise levels within the Hornsea Three project boundary would be expected to be lower than those present in the vicinity of nearby shipping lanes.

3.11.2.20 The impact is predicted to be of a highly localised spatial extent (i.e. in the immediate vicinity of operational turbines and service vessels), 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 therefore, considered to be **negligible**.

Sensitivity of the receptor

3.11.2.21 Given the low noise levels associated with turbines, any risk of significant behavioural disturbance for fish and shellfish would be limited to the area immediately surrounding the turbine, which represents a very small proportion of the total area of Hornsea Three. A major contributor to the ambient noise is sea-state, which would be expected to increase as the turbine rotational speed increases with wind speed. Increased ambient noise may exceed the turbine noise, as has been observed by Tougaard *et al*. (2009) at three offshore wind farms; Middelgrunden and Vindeby in Denmark and Bockstigen-Valar in Sweden. Investigations at all three offshore wind farms resulted in no response by fish and shellfish receptors. Sensitivities of fish and shellfish receptors to underwater noise are discussed fully in paragraph 3.11.1.49 *et seq*.

3.11.2.22 Herring, sprat, cod, whiting, allis and twaite shad and European eel are considered to be of medium vulnerability, high recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.2.23 All other fish and shellfish VERs within the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be **low**.

Significance of the effect

3.11.2.24 Subsea noise resulting from turbine operation and vessel movement will represent a long term and continuous impact throughout the lifetime of the project. However, any risk of significant behavioural disturbance for fish and shellfish would be highly limited to the area around the turbine/vessel. Overall, it is predicted that the sensitivity of fish and shellfish receptors is **low** to **medium** and the magnitude is predicted to be **negligible**. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.11.2.25 Due to the highly localised scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low to medium sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.11.2.26 Conclusions on the effect on the site integrity of European sites within the southern North Sea fish and shellfish study area are beyond the scope of this PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Introduction of turbine foundations and scour/cable protection (hard substrates and structural complexity) leading to effects on fish and shellfish receptors by creating reef habitat.

3.11.2.27 Foundation and scour protection components of offshore wind farms can be viewed as artificial reefs, as these add hard substrate to areas typically characterised by soft, sedimentary environments. Man-made structures placed on the seabed attract many marine organisms including benthic species normally associated with hard substrates (see chapter 2: Benthic Ecology) and therefore, may have indirect effects on fish and shellfish populations through their potential to act as artificial reefs and to bring about changes to food resources (Inger *et al*., 2009). Additionally, man-made structures may also have direct effects on fish through their potential to act as fish aggregation devices; significant increases in abundances of fish species such as sprat have been observed following installation of these structures (Petersen and Malm, 2006).

Magnitude of impact

3.11.2.28 As detailed in Table 3.11, up to 5,694,330 m² of new hard substrate habitat will be created in Hornsea Three as a result of the installation of GBFs, associated scour protection and cable protection for array, substation interconnector and export cables, including cable and pipeline crossings.

3.11.2.29 The impact is predicted to be of local spatial extent (i.e. within Hornsea Three), long term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact has the potential to affect fish and shellfish receptors both directly and indirectly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.11.2.30 Hard substrate habitat created by the introduction of turbine foundations and scour/cable protection are likely to be primarily colonised within hours or days after construction by demersal and semi-pelagic fish species (Andersson, 2011). Continued colonisation has been seen for a number of years after the initial construction, until a stratified recolonised population is formed (Krone *et al*., 2013). Fish aggregate from the surrounding areas, attracted by feeding opportunities or the prospect of encountering other individuals which may increase the carrying capacity of the area (Andersson and Öhman, 2010; Bohnsack, 1989).

3.11.2.31 The dominant natural substrate character of the construction area (e.g. soft sediment or hard rocky seabed) will determine the number of new species found on the introduced vertical hard surface and associated scour protection. When placed on an area of seabed which is already characterised by rocky substrates, few species will be added to the area, but the increase in total hard substrate could sustain higher abundance (Andersson and Öhman, 2010). Conversely, when placed on a soft seabed, most of the colonising fish will be normally associated with rocky (or other hard bottom) habitats, thus the overall diversity of the area may increase (Andersson *et al*., 2009). A new baseline species assemblage will be formed via recolonisation and the original soft-bottom population will be displaced (Desprez, 2000). This was observed in studies by Leonhard *et al*. (Danish Energy Agency, 2012) at the Horns Rev offshore wind farm, and Bergström *et al*. (2013) at the Lillgrund offshore wind farm, where an increase in fish species associated with reefs, such as goldsinny wrasse *Ctenolabrus rupestris*, lumpsucker *Cycloplerus lumpus* and eelpout *Zoarces viviparous*, and a decrease in the original sandy-bottom fish population, were reported.

3.11.2.32 The longest monitoring programme conducted to date at the Lillgrund offshore wind farm in the Öresund Strait in southern Sweden, showed no overall increase in fish numbers, although redistribution towards the foundations within the offshore wind farm area was noticed for some species (i.e. cod, eel and eelpout; Andersson, 2011). More species were recorded after construction than before, which is consistent with the hypothesis that localised increases in biodiversity may occur following the introduction of hard substrates in a soft sediment environment. Overall, results from earlier studies reported in the scientific literature did not provide robust data (e.g. some were visual observations with no quantitative data) that could be generalised to the effects of artificial structures on fish abundance in offshore wind farm areas (Wilhelmsson *et al*., 2010). More recent papers are, however, beginning to assess population changes and observations of recolonisation in a more quantitative manner (Krone *et al*., 2013).

3.11.2.33 There is uncertainty as to whether artificial reefs facilitate recruitment in the local population, or whether the effects are simply a result of concentrating biomass from surrounding areas (Inger *et al*., 2009). Linley *et al*. (2007) concluded that finfish species were likely to have a neutral to positive likelihood of benefitting, which is supported by evidence demonstrating that abundance of fish can be greater within the vicinity of wind turbine foundations than in the surrounding areas, although species richness and diversity show little difference (Wilhelmsson *et al*., 2006a; Inger *et al*., 2009). A number of studies on the effects of vertical structures and offshore wind farm structures on fish and benthic assemblages have been undertaken in the Baltic Sea (Wilhelmsson *et al*., 2006a; 2006b). These studies have shown evidence of increased abundances of small demersal fish species (including gobies *Gobidae*, and goldsinny wrasse) in the vicinity of structures, most likely due to the increase in abundance of epifaunal communities which increase the structural complexity of the habitat (e.g. mussels and barnacles *Cirripedia* spp.). It was speculated that in true marine environments (e.g. the North Sea), offshore wind farms may enhance local species richness and diversity, with small demersal species such as gobies providing prey items for larger, commercially important species including cod (which have been recorded aggregating around vertical steel constructions in the North Sea; Wilhelmsson *et al*., 2006a). Monitoring of fish populations in the vicinity of an offshore wind farm off the coast of the Netherlands indicated that the offshore wind farm acted as a refuge for at least part of the cod population (Lindeboom *et al*., 2011; Winter *et al*., 2010).

3.11.2.34 In contrast, post construction fisheries surveys conducted in line with the FEPA licence requirements for the Barrow and North Hoyle offshore wind farms, found no evidence of fish abundance across these sites being affected, either positively or negatively, by the presence of the offshore wind farms (Cefas, 2009; BOWind, 2008) therefore suggesting that any effects, if seen, are likely to be highly localised.

3.11.2.35 It is likely that the greatest potential for positive effects exists for crustacean species, such as crab and lobster, due to expansion of their natural habitats (Linley *et al*., 2007) and the creation of additional refuge areas. Where foundations and scour protection are placed within areas of sandy and coarse sediments, this will represent novel habitat and new potential sources of food in these areas and could potentially extend the habitat range of some shellfish species. Post-construction monitoring surveys at the Horns Rev offshore wind farm noted that the hard substrates were used as a hatchery or nursery grounds for several species, and was particularly successful for brown crab. They concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult, 2006). As both crab and lobster are commercially exploited within the Hornsea Three fish and shellfish study area, particularly along nearshore sections of the Hornsea Three offshore cable corridor, there is potential for benefits to the fisheries, depending on the materials used in construction of the offshore wind farm.

3.11.2.36 Other shellfish species, such as the blue mussel *Mytilus edulis*, have the potential for great expansion of their normal habitat due to increased hard substrate in areas of sandy habitat. Krone *et al*., (2013) coined the term 'mytilusation' to describe this mass biofouling process recorded at a platform in the German Bight, North Sea. It was found that over a three year period, almost the entire vertical surface of area of the platform piles had been colonised by three key species blue mussel, the amphipod *Jassa* spp. and anthozoans (mainly *Metridium senile*). These three species were observed to occur in depth-dependant bands, attracting pelagic fish species such as horse mackerel *Trachurus trachurus* and demersal pouting *Trisopterus luscus* in great numbers. Layers of shell detritus were visible at the base of the foundations due to the mussel populations above and both velvet swimming crab and brown crabs were recorded here. These species were not typical of baseline species assemblage, providing further evidence of localised changes in fish and shellfish assemblages in the vicinity of foundation structures.

3.11.2.37 The colonisation of new habitats may potentially lead to the introduction of non-indigenous and invasive species (see chapter 2: Benthic Ecology for detailed discussion). With respect to fish and shellfish populations, this may have indirect adverse effects on shellfish populations as a result of competition. However, no non- indigenous species were identified as present in the area during surveys across the former Hornsea Zone and some of the more common non- indigenous species that are now found in the waters of the UK such as the Chinese mitten crab *Eriocheir sinensis* prefer more estuarine conditions and more sheltered, lower energy environments. There is little evidence of adverse effects resulting from colonisation of other offshore wind farms by non- indigenous species; the post construction monitoring report for the Barrow offshore wind farm demonstrated no evidence of invasive or alien species on or around the monopiles (EMU, 2008a), and a similar study of the Kentish Flats monopiles only identified slipper limpet *Crepidula fornicata* (EMU, 2008b). Potential negative effects of the introduction of non-indigenous species are discussed in detail in chapter 2: Benthic Ecology.

3.11.2.38 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.

3.11.2.39 Fish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and local to international value in the southern North Sea fish and shellfish study area (recoverability is not relevant to this impact). The sensitivity of the receptors is therefore considered to be low.

Significance of the effect

3.11.2.40 There is some uncertainty associated with the likely effects of introduction of hard substrates into the marine environment on fish and shellfish 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, it is predicted that the sensitivity of fish and shellfish receptors is low to medium and the magnitude is predicted to be minor. The effect will, therefore, be of minor beneficial significance, which is not significant in EIA terms.

3.11.2.41 Due to the localised scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.11.2.42 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Electromagnetic fields (EMF) emitted by array and export cables during the operational phase causing behavioural responses in fish and shellfish receptors

3.11.2.43 EMF will result from the installation of array, substation interconnector and export cables, with the potential for both AC and DC cables to be installed, depending on the design of the offshore transmission infrastructure (see Table 3.11). The transport of electricity through subsea power cables has the potential to emit a localised EMF which could potentially affect the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species (including elasmobranchs) and migratory fish species (CMACS, 2003).

Magnitude of impact

3.11.2.44 EMF comprise both the electric (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in tesla (T). Background measurements of the magnetic field are approximately 50 μT in the North Sea, and the naturally occurring electric field in the North Sea is approximately 25 μV m^{-1} (Tasker *et al*., 2010). It is common practice to block the direct electrical field (E) using conductive sheathing, meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resultant induced electrical field (iE). A key misconception in the understanding of the effects of EMF has been the assertion that cable burial will mitigate iE and B field effects and that there will be no externally detectable electric fields generated by industry standard subsea power cables. The conclusion of the COWRIE EMF study (Gill *et al*., 2005) and subsequent clarification in the Phase 2 COWRIE EMF report (Gill *et al*., 2009) highlights the fact that it is impractical to assume that cables can be buried at depths that will reduce the magnitude of the B field, and hence the sediment-sea water interface iE field, is below that at which these fields could be detected by certain marine organisms on or close to the seabed.

3.11.2.45 A variety of design and installation factors affect EMF levels in the vicinity of the cable. These include current flow, distance between cables, cable orientation relative to the earth's magnetic field (DC only), cable insulation, number of conductors, configuration of cable and burial depth. Clear differences between AC and DC systems are apparent: the flow of electricity in an AC cable changes direction (as per the frequency of the AC transmission) and creates a constantly varying electric field in the surrounding marine environment (Huang, 2005). Conversely, DC cables transmit energy in one direction creating a static electric and magnetic field. Average magnetic fields of DC cables are also higher than those of equivalent AC cables (Table 3.19).

3.11.2.46 Induced electric fields emitted from AC and DC cables are not directly comparable, though modelling studies have shown average iE fields from submarine DC cables of 194 μV m^{-1} at 0 m horizontal distance from the cable (assuming cable burial to 1 m below seabed and a 5 knot current), with field strength decreasing with horizontal and vertical distance from the cable. As fish and other mobile marine organisms also cause movement of electrical charges even in still water, the movement of a fish at five knots would also experience a similar electrical field. The modelling of induced electrical fields for AC cables requires consideration of the size of an organism and its distance from the cable. Modelling of induced electrical fields in a small shark of 150 cm length, swimming 0.6 m above and parallel to a 60 Hz AC cable buried to 1 m produced a maximum iE field strength of 765 μV m-1 (Normandeau *et al*., 2011). Other orientations will result in lower values of induced electric fields. Ultimately, the effects would depend on site and project specific factors related to both the magnitude of EMFs and the ecology of local populations including spatial, temporal patterns of habitat use.

3.11.2.47 The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source. Modelling studies have indicated that the range of the field is in the order of 10 m each side of the cable (assuming 1 m burial) (see Table 3.23; Normandeau *et al*., 2011).

Table 3.19: **Average magnetic fields (μT) generated for AC and DC export cables at horizontal distances from the cable** (assuming cable burial to a depth of 1 m; source; modified from Normandeau *et al*., 2011).

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

3.11.2.48 The impact is predicted to be of local spatial extent (i.e. restricted to within Hornsea Three, long term duration (i.e. the lifetime of the project), continuous and irreversible (during the lifetime of the project). It is predicted that the impact has the potential to affect both fish and shellfish receptors both directly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.11.2.49 Molluscs, crustaceans and fish (particularly elasmobranchs) are able to detect applied or modified magnetic fields. Species for which there is evidence of a response to E and B fields include elasmobranchs (sharks, skates and rays), river lamprey, sea lamprey, cod (E field only), European eel, plaice and Atlantic salmon (Gill *et al*., 2005). Data on the use that marine species make of these capabilities is limited, although it can be inferred that the life functions supported by an electric sense may include detection of prey, predators or conspecifics to assist with feeding, predator avoidance, and social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*., 2005; Normandeau *et al*., 2011). Therefore, the EMF emitted by subsea cables may interfere with these functions in areas where the cable EMF levels are detectable by the organism, causing expenditure of energy moving to areas which may not be suitable for finding either prey species or members of the same species, or expenditure of energy to moving away from areas where predators are mistakenly located.

3.11.2.50 Crustacea, including lobster and crab, have been shown to demonstrate a response to B fields, with the Caribbean spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (Boles and Lohmann, 2003). However, it is uncertain if other crustaceans including commercially important brown crab and European lobster are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*., 2011; Ueno *et al*., 1986). Indirect evidence from post construction monitoring programmes undertaken in operational offshore wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence of submarine power cables and associated magnetic fields. However, it should be noted that there have been no shellfish specific EMF monitoring programmes.

3.11.2.51 Elasmobranchs (i.e. sharks, skates and rays) are known to be the most electro-receptive of all fish. These species possess specialised electro-receptors which enable them to detect very weak voltage gradients (down to 0.5 μV m^{-1}) in the environment naturally emitted from their prey (Gill *et al*., 2005). Both attraction and repulsion reactions to E-fields have been observed in elasmobranch species. Spurdog, one of the elasmobranch species known to occur within the southern North Sea fish and shellfish study area, though at low abundances, avoided electrical fields at 10 μV cm^{-1} (Gill and Taylor, 2001). Gill and Taylor (2001) found limited laboratory based evidence that the lesser spotted dogfish avoids DC E-fields at emission intensities similar to those predicted from offshore wind farm AC cables (i.e. 10 μV cm^{-1}), but was attracted to DC emissions at levels similar to those emanating from their prey (i.e. 0.1 μVcm^{-1} at 10 cm from the source). A COWRIE-sponsored mesocosm study demonstrated that the lesser spotted dogfish and thornback ray were able to respond to EMF of the type and intensity associated with subsea cables; the responses of some ray individuals suggested a greater searching effort when the cables were switched on. However, the responses were not predictable and did not always occur (Gill *et al*., 2009). The offshore areas of the Hornsea Three fish and shellfish study area (i.e. where most of the electrical cabling will be installed) was not found to be of particular importance for elasmobranch species, with only very low abundances of these species recorded in these areas (e.g. in the vicinity of the Hornsea Three array area) during surveys across the former Hornsea Zone. Inshore areas were more important, particularly for thornback and spotted ray where records of spawning were recorded (McCully *et al*., 2013; see Table 3.9).

3.11.2.52 Another concern with EMF is the potential for interference with the navigation of sensitive migratory species. Lampreys possess specialised ampullary electroreceptors that are sensitive to weak, low frequency electric fields (Bodznick and Northcutt, 1981; Bodznick and Preston, 1983), but information regarding what use they make of the electric sense is limited. Chung-Davidson *et al*. (2008) found that weak electric fields may play a role in the reproduction of sea lamprey and it was suggested that electrical stimuli mediate different behaviours in feeding-stage and spawning-stage individuals. This study (Chung-Davidson *et al*, 2008) showed that migration behaviour of sea lamprey was affected (i.e. adults did not move) when stimulated with electrical fields of intensities of between 2.5 and 100 mV/m, with normal behaviour observed at electrical field intensities higher and lower than this range. These levels were considerably higher than modelled induced electrical fields expected from DC or AC subsea cables (i.e. 0.194 and 0.765 mV/m, respectively; see paragraph 3.11.2.45).

3.11.2.53 Atlantic salmon and European eel have both been found to possess magnetic material of a size suitable for magnetoreception, and these species can use the earth's magnetic field for orientation and direction finding during migration (Gill and Bartlett, 2010). Mark and recapture experiments undertaken at the operational offshore wind farm of Nysted showed that eel did cross the export cable (Hvidt *et al*., 2003) but studies on European eel in the Baltic Sea have highlighted some limited effects of subsea cables. The swimming speed during migration was shown to change in the short term (tens of minutes) with exposure to AC electric subsea cables, even though the overall direction remained unaffected (Westerberg and Langenfelt, 2008). The authors concluded that any delaying effect (i.e. on average 40 minutes) would not be likely to influence fitness in a 7,000 km migration. Research in Sweden on the effects of a HVDC cable on the migration patterns of a range of fish species, including salmonids, failed to find any effect (Westerberg *et al*., 2007; Wilhelmsson *et al*., 2010).

3.11.2.54 Woodruff *et al*. (2012) undertook a study on the effects of EMF on representative fish and shellfish species. Species were chosen for the laboratory tests based on their ecology, commercial value and potential to encounter EMF in their natural habitat and included: juvenile coho salmon *Oncorhynchus kisutch*, Atlantic halibut *Hippoglossus hippoglossus*, California halibut *Paralicthys californicus*, rainbow trout *Oncorhynchus mykiss*, and Dungeness crab *Metacarcinus magister* (Woodruff *et al*., 2012). Throughout the laboratory tests, these species were subjected to a range of EMF intensities which may be encountered under field conditions in order to observe any effects on development, physiology or behaviour. Woodruff *et al*. (2012) summarised that few statistically significant effects were observed over all laboratory tests from preliminary results and that replication of these tests was needed to confirm the negligible effects of EMF on these species.

3.11.2.55 The review by Gill and Bartlett (2010) highlights the mixed results from the few studies that have been reported and that there is no clear evidence as to what, if any, the overall effect of EMFs on migration and movement behaviour of these species is likely to be. It concludes that EMFs from subsea cables and cabling orientation may interact with migratory eel (and perhaps salmonids) if their migration route takes them over the cables, particularly in shallow waters (less than 20 m) where there is a greater probability of encounter with the high voltage cables coming ashore. Current understanding suggests that where a migration route is parallel to the EMF source there is likely to be no influence on the direction of migration (Öhman *et al*., 2007), whereas there may be a limited effect (i.e. reduced swimming speed in immediate vicinity of cables) on eel migratory routes for cables that are either at right or oblique angles to the migration route (Westerberg and Langenfelt, 2008). Effects on fish migration may therefore be expected in the inshore section of the Hornsea Three offshore cable corridor, should this coastal route be used by migratory species, although as discussed above any such effects are likely to be short lived and affecting only a small area of habitat within metres of the buried cable.

3.11.2.56 Elasmobranch species are deemed to be of medium vulnerability and local importance in the southern North Sea fish and shellfish study area and therefore are considered to have low sensitivity.

3.11.2.57 Migratory fish species are deemed to be of medium vulnerability and regional to international importance in the southern North Sea fish and shellfish study area and therefore are considered to have low to medium sensitivity, although effects will be largely limited to coastal areas close to the Hornsea Three offshore cable corridor landfall.

3.11.2.58 All other fish and shellfish receptors are deemed to be of low vulnerability and are of local to regional importance in the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore, considered to be low.

Significance of the effect

3.11.2.59 EMF from Hornsea Three electrical cables will represent a long term and continuous impact throughout the lifetime of the project. However, effects will be highly localised, affecting a relatively small proportion of the fish and shellfish habitats in the southern North Sea fish and shellfish study area, i.e. within metres of the cables. Overall, it is predicted that the sensitivity of fish and shellfish is low to medium and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

3.11.2.60 For migratory fish species, due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 1.7.5), are predicted to be of minor significance, which is not significant in EIA terms.

3.11.2.61 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Temporary habitat loss and disturbance from maintenance operations (e.g. jack up operations and cable reburial)

3.11.2.62 Temporary habitat loss/disturbance is likely to occur during the operational phase of Hornsea Three as a result of spud-can leg impacts from maintenance operations including jack-up operations and cable reburial works (where necessary). The impacts associated with these operations are likely to be similar in nature to those associated with the construction phase (see paragraphs 3.11.1.3 *et seq*.).

Magnitude of impact

3.11.2.63 The operation and maintenance phase is assumed to involve up to 87 jack-up operations per year over the 25 year design life of Hornsea Three, which will lead to a total area of temporary habitat disturbance of up to 2,218,500 m^2 (Table 3.11) over the entire design lifetime of the project. Impacts will be limited to the immediate area around the turbine foundations, where spud-can legs will come into contact with the seabed. Similarly, subtidal cable reburial/repair works (if and when necessary) will affect habitats in the immediate vicinity of cable reburial operations. As outlined in volume 1, chapter 3: Project Description, it is expected that, on average, the subsea cables will require up to two visits per year for the first three years, reducing to yearly thereafter for preventative maintenance including routine inspections to ensure the cable is buried to an adequate depth. Additional visits may be required by specialised vessels should remedial measures be required, although it is not possible to accurately quantify the area potentially affected.

3.11.2.64 The impact is predicted to be of local spatial extent (i.e. within Hornsea Three), short term duration, intermittent and reversible. It is predicted that the impact has the potential to affect fish and shellfish receptors both directly. The magnitude is therefore, considered to be **negligible**.

Sensitivity of the receptor

3.11.2.65 Sensitivity of receptors to temporary habitat loss/disturbance is discussed in detail in paragraph 3.11.1.7 *et seq*. The receptors affected by this impact during the operational phase would be largely restricted to those within the Hornsea Three project boundary, i.e. within the Hornsea Three array area, in the immediate vicinity of offshore HVAC booster substations on the Hornsea Three offshore cable corridor and, if cable reburial is required, at discrete sections of the Hornsea Three offshore cable corridor. The species most likely to be affected are demersal fish species and shellfish species whose life strategies are strongly connected to the use of the sea bed for shelter (i.e. through burrowing) or for reproduction (e.g. herring and sandeel spawn eggs onto the seabed).

3.11.2.66 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. The sensitivity of these receptors is therefore considered to be **low**.

3.11.2.67 Brown crab, European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.2.68 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

Significance of the effect

3.11.2.69 Temporary habitat loss as a result of maintenance operations during the lifetime of Hornsea Three is predicted to affect a very small proportion of fish and shellfish habitats within the Hornsea Three fish and shellfish study area, with limited effects on fish and shellfish VERs. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be **low** to **medium** and the magnitude is deemed to be **negligible**. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.11.2.70 For migratory fish species, due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs, the **low** sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.2.71 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect fish and shellfish

3.11.2.72 Accidental spillage of chemicals and substances from vessels used in maintenance activities, from offshore fuel storage tanks and from the turbines and offshore substations themselves may impact on fish and shellfish, resulting in behavioural effects such as displacement from affected areas and prevention of spawning. Chemical spills may also have sub-lethal to lethal effects dependent on the life stage of the organism, exposure level and the level of toxicity.

Magnitude of impact

3.11.2.73 The magnitude of the impact is entirely dependent on the nature of the pollution incident but it is recognised that the potential for accidental loss is generally limited due to the small inventories contained on the installations (DECC, 2011). Any spill or leak within Hornsea Three would be subject to immediate dilution and rapid dispersal.

3.11.2.74 A typical turbine (nominal output 7 MW) within Hornsea Three will also contain components which will require lubricants and hydraulic oils in order to operate (see Table 3.11). However, the nacelle, tower and hub of the turbines will be designed to retain any leaks should any occur. With respect to leachate from anodes, dissolved zinc from anodes is toxic to marine life at low concentrations; the Environmental Quality Standard (EQS) is 40 µg/l (annual mean value), but no such EQS currently exists for aluminium. The concentrations of zinc and aluminium released into the marine environment from sacrificial anodes are likely to be minimal and well below the EQS for zinc.

3.11.2.75 A potential for accidental spills will also occur as a result of the 2,382 round trips to port by maintenance and operational vessels and up to 25,234 round trips by helicopter over the 25 year design life of the project (Table 3.11). However, as the majority of these vessels will be crew/supply vessels and helicopters, these will be typically small and will therefore be carrying only limited amounts of potential contaminants. Although larger operational and maintenance vessels may contain larger quantities of potential pollutants (e.g. jack up vessels) such as diesel oil, movements of these vessels will be far fewer in comparison to smaller vessels. Throughout the operational phase there will be the requirement to store fuel offshore for the purposes of refuelling crew transfer vessels and/or helicopters, with this storage expected to be placed on offshore accommodation platforms (see Table 3.11).

3.11.2.76 An impact upon fish and shellfish receptors would only be realised if an incident occurs where the fuel is accidentally released. Historically, the number of accidental pollution incidents in the southern North Sea fish and shellfish study area is low, particularly considering the large amount of industrial and commercial marine users. Given the designed-in mitigation (Table 3.16) which is proposed for the operation and maintenance phase (i.e. a PEMMP), it is considered that the likelihood of accidental release is extremely low.

3.11.2.77 The impact is predicted to be of local to regional spatial extent, short term duration, intermittent and reversible. It is predicted that the impact will affect the receptor directly and indirectly, though due to the implementation of appropriate control measures during the operational phase, the risk of a spill occurring is extremely low. The magnitude is therefore, considered to be **negligible**.

Sensitivity of the receptor

3.11.2.78 The sensitivity of the receptors will vary depending on a range of factors including species and life stage (see paragraph 3.11.1.77 *et seq*.), with adult fish less likely to be affected by marine pollution, due to their increased mobility, compared to fish eggs, larvae, juveniles and shellfish species. Any such pollution events will therefore have varying levels of effect dependent on the species present and pollutants involved. However, as fuel and oil spills are likely to be dispersed on the surface, effects on fish and shellfish receptors are likely to be limited.

3.11.2.79 The fish and shellfish receptors within the southern North Sea fish and shellfish study area are considered to be of low to medium vulnerability, high recoverability and local to international importance in the southern North Sea fish and shellfish study area. The sensitivity of the receptor is therefore, considered to be **low** to **medium**.

Significance of the effect

3.11.2.80 Overall, it is predicted that the sensitivity of fish and shellfish receptors is **low** to **medium** and the magnitude is deemed to be **negligible**, with a low likelihood of a pollution event occurring due to the implementation of the control measures during the operational phase (see Table 3.16). The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

3.11.2.81 Due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low to medium sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.2.82 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Potentially reduced fishing pressure within the Hornsea Three array area offering some protection and possible local enhancement within the Hornsea Three array area and potentially increased fishing pressure outside the Hornsea Three array area.

3.11.2.83 During the Hornsea Three operational phase, the intensity of fishing activities (including trawling and potting) may be reduced within the Hornsea Three array area and on the offshore cable corridor in the vicinity of offshore HVAC booster substations. This has the potential to enhance fish and shellfish populations by providing refuge from fishing activities for certain species targeted by commercial fisheries in the southern North Sea fish and shellfish study area.

Magnitude of impact

3.11.2.84 Fishing activity may be reduced within Hornsea Three as a result of 500 m operational safety zones around offshore substations and as a result of the physical presence of the infrastructure within the Hornsea Three array area. The maximum design scenario for reduced fishing pressure in the Hornsea Three array area assumes no fishing restrictions or safety zones enforced around the turbines or the Hornsea Three offshore cable corridor during the design life of Hornsea Three (see Table 3.11). It is assumed, however, that for logistical and safety reasons, trawling activity may potentially be reduced within Hornsea Three. However, the extent to which this additional reduction will take place, outside the enforced 500 m operational safety zones around offshore substations, is not possible to quantify.

3.11.2.85 Other scenarios will result in greater exclusions of fishing activity within the Hornsea Three array area, up to a scenario of exclusion of all fishing activity within the Hornsea Three array area (i.e. the maximum design scenario assessed in chapter 6: Commercial Fisheries). These scenarios would result in a less adverse scenario (i.e. greater benefit) to fish and shellfish than the minimal exclusion scenario assessed here.

3.11.2.86 The impact is predicted to be of a local spatial extent (within the Hornsea Three array area), 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 directly. The magnitude is therefore considered to be minor.

3.11.2.87 A reduction in fishing pressure within the Hornsea Three array area may increase fishing pressure in areas adjacent to Hornsea Three. However it is expected that any increase in fishing activity in areas adjacent to the Hornsea Three array area would have a localised effect on fish populations in the southern North Sea fish and shellfish study area, with any population level effects minimised by fisheries management measures (e.g. quotas, days at sea etc.).

3.11.2.88 The impact is predicted to be of a local spatial extent (i.e. adjacent Hornsea Three array area), 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 directly. The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

3.11.2.89 A range of species are targeted by commercial fisheries in the region including many of the fish and shellfish VERs identified in the Hornsea Three fish and shellfish study area (e.g. plaice, sole, cod, whiting, herring, *Nephrops*, brown crab and lobster; Table 3.10). These species are likely to observe the greatest benefit from a reduction in fishing effort within the Hornsea Three array area, although non-target fish caught as by-catch are also likely to benefit due to a reduction in fishing mortality.

3.11.2.90 The habitat protected from trawling may also become a refuge for young and spawning fish, thus providing benefits to the fish populations beyond the immediate exclusion area (Byrne Ó Cléirigh *et al*., 2000). However, many of the commercially important species in the area are highly mobile and therefore may not significantly benefit from a reduction in fishing pressure. Fishing pressure may be displaced from Hornsea Three to neighbouring areas, which these commercially important species also inhabit (Rodmell and Johnson, 2003). Sandeel may benefit from a reduction in fishing activities within the Hornsea Three array area due to the site fidelity and specific habitat requirements of this species which are present within some parts of the Hornsea Three array area (Holland *et al*., 2005). However, beneficial effects on sandeel populations within offshore wind farm sites (due to fisheries exclusion) has not been detected in long term monitoring studies (van Deurs *et al*., 2012).

3.11.2.91 Trawling can damage the seabed and its marine life (Hart *et al*., 2004). Therefore, the potential reduction in trawl fishing within Hornsea Three may benefit shellfish communities that were historically disturbed by trawling activity (Byrne Ó Cléirigh *et al*., 2000).

3.11.2.92 Fish and shellfish receptors 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. The sensitivity of these receptors is therefore considered to be low.

3.11.2.93 Receptors likely to be affected by an increase in fishing pressure outside the Hornsea Three array area include those demersal fish species targeted by commercial fisheries occurring within Hornsea Three, (e.g. plaice, sole and *Nephrops*). 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 in the southern North Sea fish and shellfish study area.

3.11.2.94 Fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be insensitive to this impact and of local to international importance in the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore, considered to be negligible.

Significance of the effect

3.11.2.95 There is considerable uncertainty associated with the potential benefits to fish and shellfish populations as a result of the potential reduction of fishing activities within the Hornsea Three array area due to the mobility of most of the receptors identified. Potential benefits are most likely to be realised by species with limited mobility and specific habitat requirement (e.g. sandeel, *Nephrops* and other crustaceans). Overall, it is predicted that the sensitivity of fish and shellfish receptors to potential reduction in fishing pressure is considered to be **low** and the magnitude is deemed to be **minor**. The effect will therefore be of **minor** beneficial significance, which is not significant in EIA terms.

3.11.2.96 Limited displacement of fishing activity within the Hornsea Three array area may lead to increases in fishing activity outside the Hornsea Three array area. The extent to which commercial fisheries will be displaced will have a limited effect on fish and shellfish populations in the southern North Sea fish and shellfish study area, with fish and shellfish receptors not likely to be sensitive to this change in fishing activity. Overall, it is predicted that the sensitivity of fish and shellfish receptors to displacement of fishing activity from the Hornsea Three array area is considered to be **negligible** and the magnitude is deemed to be **negligible**. The effect will therefore be of **negligible** adverse significance, which is not significant in EIA terms.

3.11.2.97 Due to the localised scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.2.98 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Future monitoring

3.11.2.99 No fish and shellfish monitoring to test the predictions made within the impact assessment for the operation and maintenance phase is considered necessary at this stage.

3.11.3 Decommissioning phase

3.11.3.1 The impacts of the offshore decommissioning of Hornsea Three have been assessed on fish and shellfish ecology. The environmental effects arising from the decommissioning of Hornsea Three are listed in Table 3.11 along with the maximum design scenario against which each decommissioning phase impact has been assessed.

3.11.3.2 A description of the potential effect on fish and shellfish receptors caused by each identified impact is given below.

Temporary habitat loss/disturbance due to decommissioning of turbine foundations and array, substation interconnector and export cables.

3.11.3.3 The nature and extent of temporary habitat loss/disturbance during decommissioning (i.e. from cable removal operations and working areas etc.) is likely to be similar to that described for installation of these during the construction phase in paragraphs 3.11.1.1 *et seq*. (i.e. cable installation, anchor placements and jack-up operations). However, this approach is precautionary, as there is no statutory requirement for decommissioned cables to be removed. Therefore, cables may be left buried in place or alternatively partially removed by pulling the cables back out of the ducts (see volume 1 chapter 3: Project Description). Such details will be included within the Decommissioning Programme which will be developed to minimise environmental disturbance and will be updated throughout the lifetime of Hornsea Three to account for changing best practice.

Magnitude of impact

3.11.3.4 As detailed in Table 3.11, the magnitude of temporary habitat loss/disturbance is predicted to be lower than that described for the construction phase (paragraphs 3.11.1.1 *et seq*), as seabed preparation works and/or drilling will not be required. The total maximum area of temporary loss/disturbance due to the decommissioning activities described above is predicted to be 27,377,024 m^2. This equates to 0.01% of the total seabed area within the southern North Sea fish and shellfish study area and 2.24% of the area of Hornsea Three. The impacts on subtidal habitats will occur intermittently throughout the decommissioning phase.

3.11.3.5 As with the construction phase, the impact is predicted to be of local spatial extent (i.e. within Hornsea Three), short term duration, intermittent and reversible. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of the receptor

3.11.3.6 Sensitivity of fish and shellfish VERs to temporary habitat loss/disturbance is fully discussed in paragraph 3.11.1.7 *et seq*., with those species with the greatest sensitivity to this impact being the species with limited mobility and those with specific habitat requirements. 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. The sensitivity of these receptors is therefore considered to be **low**.

3.11.3.7 Brown crab, European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.3.8 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

Significance of the effect

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

3.11.3.10 For migratory fish species, due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs, the **low** sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.3.11 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Temporary increases in suspended sediment concentrations (SSC) and associated sediment deposition from removal of array and substation interconnector cables, export cables and turbine foundations.

3.11.3.12 Based on the information available at the time of writing, the effects of temporary increases in SSC and associated sediment deposition associated with removal of turbine foundations and electrical cables during the decommissioning phase on fish and shellfish VERs are expected to be the same or similar to the effects from construction. The significance of effect is therefore **minor** adverse, which is not significant in EIA terms (see paragraph 3.11.1.23 *et seq*.).

3.11.3.13 Due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.3.14 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology.

3.11.3.15 Subtidal sediment contamination data is currently not available for the Hornsea Three offshore cable corridor, therefore it is not possible to assess this impact in the PEIR. However, as discussed in section 1.6.4 of chapter 2: Benthic Ecology, a site-specific survey will be undertaken along the Hornsea Three offshore cable corridor, as agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG, and sediment contaminant data acquired in the pending survey will inform the assessment for this impact in the final EIA report.

Decommissioning activities producing subsea noise resulting in potential effect on fish and shellfish receptors.

Magnitude of impact

3.11.3.16 Decommissioning of offshore infrastructure for Hornsea Three may result in temporarily elevated underwater noise levels which may have behavioural effects on fish 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. As detailed in volume 4, annex 3.1: Noise Technical Report, these may include high powered water jetting/cutting apparatus and grinding of drilling techniques. Abrasive cutting, often anticipated for wind turbine removal, would not be expected to be significantly higher than general surface vessel noise. 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.

3.11.3.17 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 extremely localised spatial extent, the expected magnitude is considered to be **negligible**.

Sensitivity of the receptor

3.11.3.18 Given the low noise levels associated with offshore wind farm decommissioning, any risk of significant behavioural disturbance (i.e. avoidance) for fish and shellfish would be limited to the area immediately surrounding the decommissioning activities. These noise levels are highly unlikely to result in injury or mortality of fish and shellfish species. Sensitivities of fish and shellfish receptors to underwater noise are discussed fully in paragraph 3.11.1.49 *et seq*.

3.11.3.19 The fish and shellfish receptors within the southern North Sea fish and shellfish study area are considered to be of low to medium vulnerability, high recoverability and local to international importance in the southern North Sea fish and shellfish study area. The sensitivity of the receptor is therefore, considered to be low to medium.

Significance of the effect

3.11.3.20 Overall, it is predicted that the sensitivity of fish and shellfish receptors is considered to be low to medium and the magnitude is deemed to be negligible. The effect will, therefore, be of negligible significance, which is not significant in EIA terms.

3.11.3.21 Due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low to medium sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.11.3.22 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Effects on fish and shellfish receptors due to removal of foundations and cable protection leading to loss of hard substrates and structural complexity.

Magnitude of impact

3.11.3.23 As detailed in Table 3.11, the removal of foundations during the decommissioning phase of Hornsea Three (assuming all scour and cable protection is left *in situ*) is predicted result in the loss of 1,595,791 m² of hard substrate. This has the potential to negatively affect fish populations that may have colonised the Hornsea Three array area during the operational phase (see paragraphs 3.11.2.27 *et seq*.). In those areas where hard substrate will be removed, the baseline species assemblage may revert back to being dominated by soft-bottom species as opposed to the opportunistic reef inhabitants which may have colonised this area during the design life with the increased amount of hard substrate available.

3.11.3.24 The impact is predicted to be of local (i.e. within Hornsea Three), long term duration, intermittent and irreversible. It is predicted that the impact will affect the receptor directly and indirectly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.11.3.25 Information on sensitivity of fish and shellfish VERs to either the increase or decrease of hard substrate are outlined in paragraphs 3.11.2.30 *et seq*. The loss of reef habitats due to removal of GBFs is likely to impact these same species however the previous species assemblage may benefit from the seabed returning to the baseline state present before construction of the offshore wind farm. In this case, the impacts of reef removal may balance the losses experienced throughout the construction of the offshore wind farm and the habitat may return to previous conditions.

3.11.3.26 As discussed in paragraph 3.11.2.38, 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.

3.11.3.27 Fish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and local to international value in the southern North Sea fish and shellfish study area (recoverability is not relevant to this impact). The sensitivity of the receptors is therefore considered to be low.

Significance of the effect

3.11.3.28 Overall, it is predicted that the sensitivity of fish and shellfish receptors is low to medium and the magnitude is predicted to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

3.11.3.29 Due to the localised scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.11.3.30 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Permanent habitat loss/alteration due to presence of scour/cable protection left *in situ* post decommissioning with potential effects on fish and shellfish ecology.

3.11.3.31 As detailed in Table 3.11, it is assumed that during the decommissioning phase, all offshore infrastructure will be removed from the seabed during decommissioning (i.e. all foundations and subsea cables), with the exception of scour protection and cable protection which will be left *in situ*. This approach is considered highly precautionary and the precise programme to be followed will use the best available advice and guidance at the time and as per the decommissioning programme to be agreed with MMO as per conditions to the Deemed Marine Licence. Hornsea Three will continue to discuss the need for, and feasibility of, removal of cable and scour protection in certain sensitive areas as the project progresses.

Magnitude of impact

3.11.3.32 Removal of foundations and cables will result in the reversal of a proportion of the long term habitat loss predicted during the operational phase (see paragraphs 3.11.2.3 *et seq*.), although due to cable and scour protection being left *in situ* there will be some habitat loss which will continue post decommissioning, which is considered permanent habitat loss for the purposes of this assessment. This permanent habitat loss is predicted to affect up to 3,592,038 m^2 of seabed habitats within the Hornsea Three project boundary which equates to 0.002% of the southern North Sea fish and shellfish study area and 0.29% of the seabed within the Hornsea Three project boundary.

3.11.3.33 The impact is predicted to be of local spatial extent (i.e. within Hornsea Three), permanent, continuous and irreversible. It is predicted that the impact will affect the receptors directly and indirectly. The magnitude is therefore, considered to be **minor**.

Sensitivity of the receptor

3.11.3.34 Sensitivity of fish and shellfish receptors to habitat loss are discussed in paragraph 3.11.2.6 *et seq*. with those species with the greatest sensitivity to this impact being the species with limited mobility and those with specific habitat requirements (e.g. sandeel and *Nephrops*). Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and of local to international importance within the southern North Sea fish and shellfish study area (recoverability is not applicable for this impact). Given the widespread nature of spawning and nursery habitat in the wider southern North Sea fish and shellfish study area, the sensitivity of these receptors is therefore considered to be **low**.

3.11.3.35 Brown crab and European lobster are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.11.3.36 Sandeel and herring are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. Due to the specific habitat requirement of these species, the sensitivity of these receptors is therefore considered to be **medium** (although no effects of this impact are predicted for herring).

Significance of the effect

3.11.3.37 Permanent habitat loss following decommissioning will represent a permanent and continuous impact. However, only a relatively small proportion of the fish and shellfish habitat in the southern North Sea fish and shellfish study area is likely to be affected. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

3.11.3.38 For migratory fish species, due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs, the **low** sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.3.39 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect fish and shellfish ecology.

3.11.3.40 Based on the information available at the time of writing, the effects of accidental pollution evens during the decommissioning phase on fish and shellfish VERs are expected to be the same or similar to the effects from construction. The significance of effect is therefore **negligible**, which is not significant in EIA terms.

3.11.3.41 Due to the small scale of the impact, the large distance between Hornsea Three and SACs/SCIs and the low to medium sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **negligible** significance, which is not significant in EIA terms.

3.11.3.42 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Future monitoring

3.11.3.43 No fish and shellfish monitoring to test the predictions made within the impact assessment for the decommissioning phase is considered necessary at this stage.

3.12 Cumulative Effect Assessment methodology

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

3.12.1.1 The Cumulative Effect Assessment (CEA) takes into account the impact associated with Hornsea Three together with other projects and plans. The projects and plans selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise undertaken as part of the 'CEA long list' of projects (see volume 4, annex 5.2: Cumulative Effects Screening Matrix and annex 5.3: Location of Schemes). Each project on the CEA long list has been considered on a case by case basis for scoping in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

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

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

3.12.1.3 The specific projects scoped into this CEA and the Tiers into which they have been allocated, are outlined in Table 3.20. The projects included as operational in this assessment have been commissioned since the baseline studies for this project were undertaken and as such were excluded from the baseline assessment.

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

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

Table 3.20: List of other projects and plans considered within the CEA.

Tier	Phase	Project/Plan	Distance from Hornsea Three array area	Distance from Hornsea Three offshore cable route corridor	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
1	*Offshore wind farms*							
	Under construction	Dudgeon	87 km	11 km	Up to 168 turbines consented, 67 constructed	2015 to 2017	No	Yes
		Race Bank	114 km	28 km	Up to 206 turbines consented, 91 constructed.	2015 to 2017	No	Yes
		Hornsea Project One	7 km	7 km	Up to 240 turbines consented	2017 to 2018	No	Yes
	Approved	Dogger Bank Creyke Beck A	76 km	91 km	Up to 300 turbines consented	2021 to 2024	Yes	Yes
		Dogger Bank Creyke Beck B	99 km	115 km				
		Hornsea Project Two	7 km	18 km	Up to 300 turbines consented	2017 to 2019	No	Yes
		Triton Knoll	100 km	44 km	Up to 288 turbines consented	2017 to 2021	Yes	Yes
		Dogger Bank Teesside B	95 km	108 km	Up to 200 turbines consented	2023 to 2026	Yes	Yes
	Aggregate extraction and disposal sites							
	Operational (with on-going effects)	Humber 3 - 484	43 km	0 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 481/1-2	126 km	41 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 481/1-2	127 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 481/1-2	126 km	41 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 481/1-2	127 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Outer Dowsing - 515/1-2	102 km	41 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Outer Dowsing - 515/1-2	88 km	38 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Humber 4 - 490	19 km	13 km	Operational	N/A	Yes (operational activity overlapping with Hornsea Three construction)	Yes

Tier	Phase	Project/Plan	Distance from Hornsea Three array area	Distance from Hornsea Three offshore cable route corridor	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
		Humber 7 - 491	4 km	0 km	Operational	N/A	Yes (operational activity overlapping with Hornsea Three construction)	Yes
		Inner Dowsing - 481	125 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 481	125 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Humber	77 km	32 km	Operational	N/A	Yes (operational activity overlapping with Hornsea Three construction)	Yes
		West of Inner Dowsing Bank	131 km	48 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
	Application	Humber 4 and 7 - 506	13 km	8 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Humber 5 - 483	14 km	2 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
		Inner Dowsing - 439	131 km	48 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction)	No
	Cables and pipelines							
	Pre-commission	PL2237 - SATURN TO MIMAS	33 km	22 km	3 inch Pre-commission CHEMICAL pipeline operated by CONOCOPHILLIPS	2017 to 2018	No	Yes
		PLU3122 - JULIET TO PICKERILL A UMBILICAL	89 km	50 km	138 mm Pre-commission MIXED HYDROCARBONS pipeline operated by ENGIE	2017 to 2018	No	Yes
		PL3088 - CYGNUS TO ETS GAS PIPELINE	48 km	64 km	24 inch Pre-commission GAS pipeline operated by ENGIE	2017 to 2018	No	Yes
		PL2894 - KATY TO KELVIN GAS EXPORT PIPELINE	39 km	53 km	10 inch Pre-commission GAS pipeline operated by CONOCOPHILLIPS	2019 to 2021	Yes	Yes
		PL2895 - KELVIN TO KATY METHANOL PIPELINE	39 km	53 km	2 inch Pre-commission METHANOL pipeline operated by CONOCOPHILLIPS	2019 to 2021	Yes	Yes
		PL3121 - JULIET TO PICKERILL A GAS PIPELINE	50 km	89 km	12 inch Pre-commission MIXED HYDROCARBONS pipeline operated by ENGIE	2019 to 2021	Yes	Yes

Tier	Phase	Project/Plan	Distance from Hornsea Three array area	Distance from Hornsea Three offshore cable route corridor	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
	Under-construction	PL0219_PR K4-Z to K5-A	20 km	35 km	6-inch Under construction Gas pipeline operated by Total E&P Nederland B.V.	2017 to 2018	No	Yes
		PL0219_UM K4-Z to K5-A	20 km	35 km	5-inch Under construction Control pipeline operated by Total E&P Nederland B.V.	2017 to 2018	No	Yes
	Proposed	PL0221_HS D18-A to D15-FA-1	19 km	45 km	2-inch Proposed Methanol pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes
		PL0221_PR D18-A to D15-FA-1	19 km	45 km	8-inch Proposed Gas pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes
2	*Offshore wind farms*							
	Proposed	Norfolk Vanguard	73 km	51 km	Up to 1,800 MW and between 120-257 turbines	2020 to 2022	Yes	Yes
	Cables and pipelines							
	Proposed	Viking Interconnector	13 km	18 km	High voltage (up to 500 kV) Direct Current (DC) electricity interconnector	2019 to 2022	Yes	Yes

3.12.2 Maximum design scenario

3.12.2.1 The maximum design scenarios identified in Table 3.21 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. The cumulative impact presented and assessed in this section have been selected from the details provided in the Hornsea Three project description (volume 1, chapter 3: Project Description), as well as the information available on other projects and plans, in order to inform a 'maximum design scenario'. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope (e.g. different turbine layout), to that assessed here be taken forward in the final design scheme.

3.12.2.2 The following impact assessments set out in Table 3.11 have not been considered within the CEA due to the highly localised nature of some of the impacts (i.e. within the Hornsea Three boundary only) and/or where the potential significance of impact has been assessed as negligible for Hornsea Three alone. These impacts are:

- Underwater noise as a result of operational turbines and maintenance vessel traffic resulting in potential effects on fish and shellfish receptors (significance assessed as negligible);
- Temporary habitat loss and disturbance from maintenance operations (i.e. jack up operations) resulting in potential effects on fish and shellfish receptors (significance assessed as negligible); and
- Accidental pollution events during the operation and maintenance phase resulting in potential effects on fish and shellfish receptors (significance assessed as negligible).

3.12.2.3 Accidental pollution events during the construction phase resulting in potential effects on fish and shellfish receptors has also been screened out of the CEA due to the assumption that management measures, similar to those being employed for Hornsea Three, will also be in place for the other projects considered within the CEA. These management measures will reduce the risk of these incidents occurring and minimise the magnitude of the impact, should these occur (e.g. CoCP and PEMMP, see Table 3.16).

Table 3.21: Maximum design scenario considered for the assessment of potential cumulative impacts on fish and shellfish ecology.

Potential impact	Maximum design scenario	Justification
Construction phase		
Cumulative temporary habitat loss/disturbance of fish and shellfish habitats as a result of offshore wind farm construction, aggregate extraction and dredge disposal activities and cable and pipeline installation.	Maximum design scenario as described for construction phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of Hornsea Three: *Tier 1* • All licensed aggregate extraction and disposal areas (i.e. Humber 3 - 484, Inner Dowsing - 481/1-2, Inner Dowsing - 481/1-2, Inner Dowsing - 481/1-2, Inner Dowsing - 481/1-2, Outer Dowsing - 515/1-2, Outer Dowsing - 515/1-2, Humber 4 - 490, Humber 7 - 491, Inner Dowsing - 481, Inner Dowsing - 481, Humber and West of Inner Dowsing Bank; assuming an average of 10% of the total licensed area is dredged at any one time); • All application aggregate extraction areas (i.e. Humber 4 and 7 - 506, Humber 5 – 483, Inner Dowsing - 439); • Cables and pipelines (i.e. PL2237 – Saturn to Mimas, PLU3122 and PL3121 – Juliet to Pickerill A gas pipeline and umbilical, PL3088 – Cygnus to ETS gas pipeline, PL2894 – Katy to Kelvin gas export pipeline, PL2895 – Kelvin to Katy methanol pipeline, PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical, PL0221_HS D18-A to D15-FA-1 and PL0221_PR D18-A to D15-FA-1); • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank and Hornsea Project One); and • Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). *Tier 2* • Cables and pipelines (i.e. Viking Interconnector). Tier 3 • No Tier 3 projects.	Maximum additive temporary habitat loss is calculated within a representative 50 km buffer of Hornsea Three as fish and shellfish habitats (e.g. sediment types and water depths) within this buffer are representative of those within the Hornsea Three fish and shellfish study area. Areas of temporary habitat loss for other offshore wind farms have been taken from the respective Environmental Statement chapters, where available. An average of 10% of the total licensed aggregate extraction areas is assumed to be dredged at any one time. This is based on Annual Reports produced by the Crown Estate for the Humber region which report that for at least the last five years, dredging each year has taken place within 5 to 10% of the total licensed area (Crown Estate, 2012). Therefore, as a precautionary approach, 10% has been assumed for this assessment.
Cumulative temporary increases in suspended sediment concentrations (SSC) and sediment deposition as a result of offshore wind farm construction and aggregate extraction activities.	Maximum design scenario as described for construction phase of Hornsea Three (for both foundation and cable installation) assessed cumulatively with the following Tier 1 licensed/consented/ aggregate extraction areas: • Humber 3 (484); • Humber 4 and 7 (506); and • Humber 5 (483).	Maximum potential for interactive effects from increases in suspended sediment concentrations and consequent deposition (chapter 1: Marine Processes).
Cumulative effect of underwater noise from piling operations at other offshore wind farm sites	Maximum design scenario as described for construction phase assessed cumulatively with the full development of the following marine projects within a representative 100 km buffer of the Hornsea Three array area: *Tier 1* • Consented offshore wind farm projects (i.e. Dogger Bank Creyke Beck A and B, Dogger Bank Teesside B, Triton Knoll and Hornsea Project Two). *Tier 2* • Proposed offshore wind farm project (i.e. Norfolk Vanguard). Tier 3 • No Tier 3 projects.	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 Three array area. This larger buffer was used for this impact assessment as effects of underwater noise are expected to occur over a wider area than other impacts, i.e. construction related noise impacts on fish behaviour would be expected over the range of 10s of km, while other impacts (e.g. habitat loss, increase in SSC), would only occur within the Hornsea Three boundary or within a few km of it. Fish and shellfish habitats (e.g. sediment types and water depths) within this 100 km buffer are representative of those within the Hornsea Three fish and shellfish study area and wider southern North Sea fish and shellfish study area.

Potential impact	Maximum design scenario	Justification
Operation phase		
Cumulative long term loss of fish and shellfish habitats from offshore wind farm infrastructure and cables and pipelines.	Maximum *design* scenario as described for operation and maintenance phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of Hornsea Three: Tier 1 • Cables and pipelines (i.e. PL2237 – Saturn to Mimas, PLU3122 and PL3121 – Juliet to Pickerill A gas pipeline and umbilical, PL3088 – Cygnus to ETS gas pipeline, PL2894 – Katy to Kelvin gas export pipeline, PL2895 – Kelvin to Katy methanol pipeline, PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical, PL0221_HS D18-A to D15-FA-1 and PL0221_PR D18-A to D15-FA-1); • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank and Hornsea Project One); and • Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). *Tier 2* • Cables and pipelines (i.e. Viking Interconnector). Tier 3 • No Tier 3 projects.	Maximum additive long term habitat loss is calculated within a representative 50 km buffer of Hornsea Three as fish and shellfish habitats (e.g. sediment types and water depths) within this buffer are representative of those within the Hornsea Three fish and shellfish study area. Areas of temporary habitat loss for other offshore wind farms have been taken from the respective Environmental Statements, where available.
Cumulative introduction of hard substrates from offshore wind farm infrastructure leading to effects on fish and shellfish receptors by creating reef habitat.	Maximum *design* scenario as described for operation and maintenance phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of Hornsea Three: Tier 1 • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank and Hornsea Project One); and • Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). Tier 2 and Tier 3: • No Tier 2 or Tier 3 projects.	Maximum cumulative habitat creation is calculated within a representative 50 km buffer of Hornsea Three as fish and shellfish habitats (e.g. sediment types and water depths) within this buffer are representative of those within the Hornsea Three fish and shellfish study area.
Cumulative effects of EMF emitted by subsea cables from offshore wind farms and interconnectors leading to effects on fish and shellfish ecology.	Maximum *design* scenario as described for operational phase assessed cumulatively with the following proposed or existing marine projects within a 50 km buffer of Hornsea Three. Tier 1: • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank and Hornsea Project One); and • Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). *Tier 2* • Cables and pipelines (i.e. Viking Interconnector). Tier 3 • No Tier 3 projects.	Maximum cumulative effects of EMF from subsea electrical cabling lengths is considered within a representative 50 km buffer of Hornsea Three as fish and shellfish habitats (e.g. sediment types and water depths) within this buffer are representative of those within the Hornsea Three fish and shellfish study area.
Cumulative displacement of fishing pressure as a result of offshore wind farm operation leading to effects on fish and shellfish ecology.	Maximum *design* scenario as described for operation and maintenance phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of Hornsea Three: Tier 1: • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank and Hornsea Project One); and • Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). Tier 2 and Tier 3: • No Tier 2 or Tier 3 projects.	Maximum potential cumulative displacement of fisheries is considered within a representative 50 km buffer of Hornsea Three as fish and shellfish habitats (e.g. sediment types and water depths) within this buffer are representative of those within the Hornsea Three fish and shellfish study area.

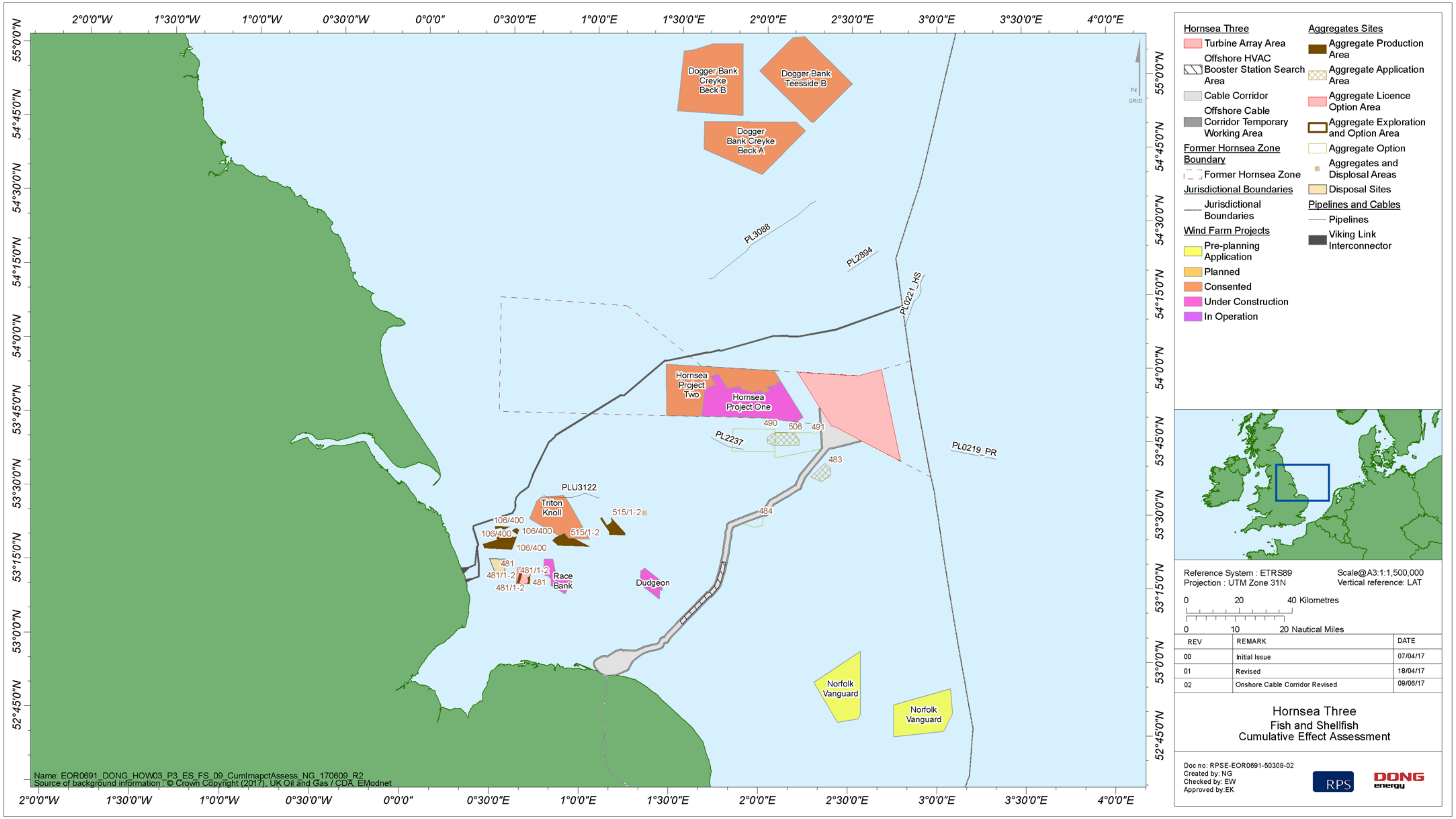

Figure 3.4: Offshore project/plans/activities screened into the Hornsea Three Cumulative Effects Assessment (CEA) for fish and shellfish ecology.

3.13 Cumulative Effect Assessment

3.13.1.1 A description of the significance of cumulative effects upon fish and shellfish ecology receptors arising from each identified impact is given below.

3.13.2 Construction phase

Cumulative temporary habitat loss/disturbance of fish and shellfish habitats as a result of offshore wind farm construction, aggregate extraction and dredge disposal activities and cable and pipeline installation.

3.13.2.1 There is the potential for cumulative temporary habitat loss as a result of construction activities associated with Hornsea Three and other offshore wind farm projects (i.e. from cable burial, anchor placements and seabed preparation for the installation of GBFs), aggregate extraction and dredge disposal activities and cable and pipeline installation (see Table 3.21 and Figure 3.4). For the purposes of this PEIR, this additive impact has been assessed within a representative 50 km buffer of Hornsea Three using the tiered approach outlined above in section 3.12.1). The 50 km buffer area was used as within this buffer, fish and shellfish habitats (e.g. sediment types and water depths) are representative of those within the Hornsea Three fish and shellfish study area and therefore the impacts and receptors affected by projects within this buffer are likely to be similar to those for Hornsea Three. No Tier 2 or Tier 3 projects have been identified.

3.13.2.2 As discussed in paragraph 3.12.1.4, 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.

3.13.2.3 This CEA has been based on information available in Environmental Statements where available. It is noted however, that the project parameters quoted in Environmental Statements, particularly offshore wind farms, are often refined during the determination period of the application or post consent. Specifically, it is noted that the Applicant for Hornsea Project One has gained consent for an overall maximum number of turbines within Hornsea Project One of 240, as opposed to 332 assumed within this CEA. Similarly, Hornsea Project Two has gained consent for an overall maximum number of turbines within Hornsea Project Two of 300, as opposed to 360 assumed within this CEA. The assessment for Hornsea Three has been undertaken on the basis of a design envelope for Hornsea Project One of up to 332 turbines as presented in the submission documentation in July 2013 and for Hornsea Project Two of up to 360 turbines as presented in the submission documentation in January 2015. However, as the Secretary of State has awarded Development Consent for a maximum of 240 turbines for Hornsea Project One and 300 turbines for Hornsea Project Two, the level of impact on fish and shellfish ecology would likely be reduced from those presented here.

Tier 1

Magnitude of impact

3.13.2.4 Predicted cumulative temporary habitat loss/disturbance from each of the Tier 1 plans/projects/activities is presented in Table 3.22 together with a breakdown of the sources of this data from the relevant Environmental Statements and any assumptions made where necessary information was not presented in these Environmental Statements. Table 3.22 shows that for all projects/plans/activities in the Tier 1 assessment, the cumulative temporary habitat loss/disturbance is estimated at 171.24 km^2. This will represent approximately 0.09% of the southern North Sea fish and shellfish study area, affecting fish and shellfish habitats of a similar nature to those recorded within the Hornsea Three fish and shellfish study area. Cumulative temporary habitat loss impacts will be localised to within the project boundaries shown in Figure 3.4.

3.13.2.5 The assumption that an average of 10% of the total licensed areas will be dredged within a given year is based on annual reports produced by The Crown Estate for the Humber region which state that recent dredging has taken place within 5 to 10% of the total licensed area each year. In 2012 9.9% of the total licensed area was dredged (Crown Estate, 2012). The estimate of temporary habitat loss resulting from aggregate extraction activities is also likely to be an over-estimation as only a proportion of the active licence areas are dredged at any one time allowing for recovery between dredging events.

3.13.2.6 The cumulative impact of temporary habitat loss is predicted to be of regional spatial extent, medium term duration, intermittent and reversible but with a relatively small proportion of the total loss occurring at any one time. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be minor.

Table 3.22: Cumulative temporary habitat loss for Hornsea Three and other plans/projects/activities in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Total predicted temporary habitat loss (km^2)	Source
Tier 1		
Offshore wind farms		
Hornsea Three	31.73	See Table 3.11
Dudgeon	1.23	Values taken from Environmental Statement (Dudgeon Offshore Wind Limited, 2009, 2009): 1.2 km^2 from cable installation and 0.0315 km^2 from jack-up barges.
Race Bank	1.02	Values taken from Environmental Statement (Centrica Energy, 2009): 0.01236 km^2 from jack-up barges, 0.8641 km^2 from export cable installation and 139 km of array cables (1 m width disturbance).
Triton Knoll	2.45	Values taken from Environmental Statement (TKOWFL, 2012): 0.53 km^2 from array and inter-substation cable installation, 0.60 km^2 from jack-up barges and 1.319 km^2 from seabed preparation.
Hornsea Project One	28.52	Values taken from Environmental Statement (SMart Wind, 2013): 0.143 km^2 from jack-up barges, 5.3 km^2 from array and inter-connector cable burial, 6 km^2 from export cable burial, 16.8 km^2 from seabed preparation and 0.279 km^2 from anchor placements.
Hornsea Project Two	45.53	Values taken from Environmental Statement (SMart Wind, 2015): 0.466 km^2 from jack up barges, 8.47 km^2 from array and inter-connector cable burial, 17.498 km^2 from export cable burial, 18.162 km^2 from seabed preparation and 0.930 km^2 from anchor placements.
Total Offshore Wind Farms	110.48	
Cables and Pipelines		
PL2237 - Saturn to Mimas	0.28	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 13.4 km pipeline length.
PLU3122 and PL3121 Juliet to Pickerill A Gas Pipeline and Umbilical	0.46	Values taken from Environmental Statement (GDF Suez, 2012).
PL3088 - Cygnus to ETS Gas Pipeline	1.33	Values taken from Environmental Statement (GDF Suez, 2011).
PL2894 - Katy to Kelvin Gas Export Pipeline	0.29	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 14 km pipeline length.
PL2895 - Kelvin to Katy Methanol Pipeline	0.29	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 14 km pipeline length.
PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical	0.36	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 17.2 km pipeline length.
PL0221_HS D18-A to D15-FA-1	0.45	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 21.5 km pipeline length.
PL0221_PR D18-A to D15-FA-1	0.45	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 21.5 km pipeline length.
Total Cables and Pipelines	3.92	
Aggregate extraction and dredge disposal areas		
Licensed areas	46.27	10% of total licenced areas of 462.7 km^2.
Application areas	10.57	10% of total application areas of 105.7 km^2.
Total aggregate extraction	56.84	
Total Tier 1	171.24	
Tier 2		
Cables and Pipelines		
Viking Interconnector.	1.86	Assumptions made for the cumulative assessment: trench width of 10 m for up to two cable circuits along the 93 km interconnector length in UK waters within a 50 km buffer of Hornsea Three.
Total Tier 2	173.10	

Sensitivity of the receptor

3.13.2.7 Full discussion of the sensitivity of fish and shellfish VERs to temporary habitat loss is presented in section 3.11.1.7 *et seq.* which concludes that most species have a relatively low vulnerability to temporary habitat loss and disturbance. Those species which have specific habitat requirements, including sandeel and other demersal spawning species and shellfish species, are considered to have greater sensitivity. In the context of sandeel spawning habitats within the southern North Sea fish and shellfish study area, the total sandeel habitat as mapped by Jensen *et al*. (2010) covers approximately 33,566 km^2. Cumulative temporary habitat loss from Tier 1 projects is predicted to result in a loss of 0.15% of sandeel spawning habitat (as mapped by Ellis *et al*., 2012; see Figure 3.20 and 3.21 of volume 5, annex 3.1: Fish and Shellfish Technical Report), with the vast majority of this (including all temporary habitat loss from Hornsea Three) occurring outside high intensity sandeel spawning habitats to the north. The predicted cumulative temporary habitat loss is also small in the context of the seabed sediment suitable for colonisation by sandeel (i.e. “preferred” sediment types as defined by Latto *et al*., 2013; see Figure 3.23 of volume 5, annex 3.1: Fish and Shellfish Technical Report) which extend over much of the southern North Sea fish and shellfish study area.

3.13.2.8 Cumulative effects of habitat loss are likely to affect brown crab and lobster populations in the area inshore of the Hornsea Three array area (i.e. along the offshore cable corridor), where potential overwintering, spawning and nursery habitats are likely to occur. Cumulative habitat losses within the Hornsea Three array area and the Hornsea Projects One and Two arrays are unlikely to affect brown crab and lobster overwintering, spawning or nursery habitats as the baseline characterisation indicated that these habitats primarily occur closer to the coast in inshore waters. These habitats are therefore more likely to be affected by Round 2 offshore wind farm projects and aggregate extraction activities, in addition to the aforementioned Round 3 export cabling, which are located in more inshore areas. As detailed in paragraph 3.13.2.4, the temporary habitat loss from these more inshore projects and activities is likely to be limited in extent at any one time and the proportion of available habitat affected is expected to be small. Cumulative effects of temporary habitat loss on *Nephrops* are likely to be limited, with the majority of effects expected within the Hornsea Three array area. This species is more likely to occur in deeper, muddy sand habitats such as Markham's Hole and Outer Silver Pit to the north of Hornsea Three. Most of the projects considered within this CEA (particularly offshore wind farms and aggregate extraction sites) largely occur within shallower areas, with sediments characterised by sand and gravel which are unsuitable for this species.

3.13.2.9 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. The sensitivity of these receptors is therefore considered to be low.

3.13.2.10 Brown crab, European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be medium.

3.13.2.11 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be medium.

Significance of the effect

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

3.13.2.13 For migratory fish species, due to the relatively small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of minor significance, which is not significant in EIA terms.

3.13.2.14 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Tier 2

Magnitude of impact

3.13.2.15 The Tier 2 assessment includes all Tier 1 projects and the proposed Viking Interconnector. There is currently no detailed information on the impact of temporary habitat loss during cable installation for this project and therefore the same assumptions have been made as for Hornsea Three (see Table 3.22). If further detailed information becomes available prior to the compilation of the Hornsea Three Environmental Statement, this will be included in the CEA.

3.13.2.16 The cumulative impact of temporary habitat loss is predicted to be of regional spatial extent, medium term duration, intermittent and reversible but with a relatively small proportion of the total loss occurring at any one time. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.13.2.17 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. The sensitivity of these receptors is therefore considered to be **low**.

3.13.2.18 Brown crab, European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.13.2.19 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

Significance of the effect

3.13.2.20 Overall, it is predicted that the sensitivity of fish and shellfish is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect of Tier 2 projects will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

3.13.2.21 For migratory fish species, due to the relatively small scale of the impact, the **low** sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of **minor** significance, which is not significant in EIA terms.

3.13.2.22 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Cumulative temporary increases in suspended sediment concentrations (SSC) and sediment deposition as a result of offshore wind farm construction and aggregate extraction activities.

Tier 1

3.13.2.23 There is potential for cumulative impacts from increased SSC and associated sediment deposition to occur during the construction of Hornsea Three and aggregate extraction activities within one tidal excursion (see Table 3.21 and chapter 1: Marine Processes). No Tier 2 or Tier 3 projects have been identified.

Magnitude of impact

3.13.2.24 The licensed aggregate extraction areas Humber 3 (484) and application areas Humber 4 and 7 (506) and Humber 5 (483) are located 43, 13 and 14 km from the Hornsea Three array area, respectively, and 0, 8 and 2 km from the Hornsea Three offshore cable corridor, respectively (see Figure 3.4).

3.13.2.25 The target material at these marine aggregate areas is sands and gravels. The aggregate deposits in this region are generally understood to contain <5% fines (silt and clay) and therefore the concentrations of this fraction in the overflow from the dredging vessels are anticipated to be relatively low. Aggregate extraction operations may release sediment into the water column through overspill and/or screening. The spatial extent of this plume will largely be determined by the sediments being extracted and the local hydrodynamic regime, with heavier gravel-sized particles settling rapidly at the discharge point, whilst sand-sized particles typically settling within about 250 m to 500 m and within 5 km where tidal currents are strong (chapter 1: Marine Processes).

3.13.2.26 Plume dispersion modelling results for Humber 3 and Humber 5 showed that the maximum extent of a turbid plume resulting from dredging activity would be 15.5 km and 17.0 km, respectively (ABPmer, 2013b). Maximum increases in near-seabed concentrations could exceed 600 mg/l in close proximity to the dredger within the application areas for a period of one hour, before reducing to approximately 50 to 150 mg/l for the remainder of the dredging period. It is expected that a return to near background concentrations would take approximately four days during spring tides or slightly longer during neap tides. The maximum sedimentation thickness resulting from the dredge plumes is expected to be approximately 1 mm in very close proximity to the dredge location, though the settled material will be transitory with the changing flood/ebb and spring/neap variations in the tidal currents (ABPmer, 2013b). Deposition of dispersed sediment resulting from cable laying activities in Hornsea Three at aggregate extraction areas is considered to be low, as levels of deposition resulting from cable laying is predicted to be approximately 0.06 m within 100 m from the Hornsea Three offshore cable corridor (chapter 1: Marine Processes).

3.13.2.27 The turbid plume arising from the proposed dredging activities at Humber 4 and 7 (506; see Figure 3.4) is predicted to extend between 2.5 to 4 km to the north northwest and between 2 to 3 km to the south southwest of the area (ABPmer, 2010). Depth averaged increases in SSC of between 50 and 70 mg/l above background levels would be likely to occur within the dredging area and in the streamline of the dredger at Area 506 (ABPmer, 2010). Outside of the dredging area, SSC of 50 mg/l above background levels would be likely to occur. The plume was predicted to extend no further than 4 km north northwest or 3 km south southwest and at this point, the predicted increase in SSC was less than 10 mg/l.

3.13.2.28 The plumes arising from both the aggregate extraction-related dredging activity and the Hornsea Three extraction activity are generally predicted to coalesce together, creating a larger plume with concentrations similar to the alone activities, as opposed to an additive plume with a higher concentration (chapter 1: Marine Processes). It is considered that activities would mostly likely cause an additive plume of higher concentrations only if cable installation for Hornsea Three took place at the same time and in the vicinity of the western margin of Humber 5 and eastern margin of Humber 7 aggregate extraction areas, though this is predicted to cause a maximum additive plume of a few 10's mg/l over the construction of Hornsea Three alone, as described in paragraphs 3.11.1.23 *et seq*. (see also chapter 1: Marine Processes). These higher concentration plumes would also be short lived, persisting for no longer than a few hours.

3.13.2.29 The cumulative impact of increases in SSC and associated sediment deposition is predicted to be of local to regional spatial extent, short term duration, intermittent and reversible. It is predicted that the impact will affect the receptor directly and indirectly. The magnitude is therefore considered to be minor.

Sensitivity of the receptor

3.13.2.30 The sensitivity of fish and shellfish VERs to increases in SSC and associated sediment deposition is fully discussed in paragraphs 3.11.1.29 *et seq*. Fish and most shellfish receptors within the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of the receptor is therefore considered to be low.

3.13.2.31 Brown crab and lobster are deemed to be of medium vulnerability, high recoverability and regional importance in the southern North Sea fish and shellfish study area. The sensitivity of the receptor is therefore, considered to be low.

Significance of the effect

3.13.2.32 Overall, it is predicted that the sensitivity of fish and shellfish receptors to cumulative increases in SSC and associated sediment deposition, is considered to be low and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

3.13.2.33 Due to the small scale of the impact, the large distance between projects considered in the CEA (i.e. primarily located in offshore areas) and SACs/SCIs and the low sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.13.2.34 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Cumulative effect of underwater noise from piling operations at other offshore wind farm sites.

Tier 1

Magnitude of impact

3.13.2.35 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 in the southern North Sea fish and shellfish study area. 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 a few hundred 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.

3.13.2.36 The Tier 1 assessment includes other projects in the southern North Sea within a representative 100 km buffer around the Hornsea Three array (see Table 3.21) including the Round 2 offshore wind farm projects Triton Knoll and the Round 3 offshore wind farm projects Hornsea Project Two, Dogger Bank Creyke Beck A and B and Teesside B.

3.13.2.37 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 Three. For Hornsea Three the temporal maximum design scenario for piling duration is for jacket foundations with up to four hours per pile (see Table 3.11). 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 (see paragraph 3.12.1.4). Construction timescales, as outlined in Table 3.20, are indicative and subject to change.

3.13.2.38 For the purposes of this assessment the full length of the construction periods for all cumulative projects (i.e. 2019 to 2032 or 14 years; see Table 3.20) have been considered for potential cumulative effects due to a lack of data or information regarding piling timescales for these projects. Based on the worst case scenario for piling duration at Hornsea Three and the worst case scenarios for piling duration for the other offshore wind farms (see Table 3.23), piling activities will occur over a maximum of 1174 days over 14 years, equating to approximately 23% of the 14 year 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 specified for other projects in Table 3.23 are also likely to include the combination of onshore and offshore construction periods and as such projects are likely screened into the Tier 1 assessment that may, in reality, not overlap temporally with the construction period of Hornsea Three.

3.13.2.39 The Triton Knoll assessment predicted (for hammer energies of up to 2,700 kJ and piling durations of up to four hours) that behavioural effects would be expected to maximum distances of 42 km for herring, and 20 km for flatfish species (i.e. lemon sole and sole). No spawning or nursery habitats in the region were predicted to be affected by the elevated noise levels associated with this project (TKOWFL, 2012).

3.13.2.40 The Dogger Bank Creyke Beck assessment (Forewind, 2013) assessed the effects of piling using hammer energies of up to 2,300 kJ for up to 18 hours per jacket foundation. The Creyke Beck assessment predicted behavioural effects to ranges of 9.5 to 20 km for pelagic species and 7.5 to 20 km for demersal species (assuming a 2,300 kJ hammer energy). The assessment predicted minor adverse effects on fish spawning and nursery habitats in the southern North Sea fish and shellfish study area (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), while noise impacts were also not predicted to significantly overlap with areas characterised by high sandeel abundances. No barrier effects were predicted for migratory fish species and therefore a minor adverse effect was also predicted for these species.

Table 3.23: Cumulative piling durations for Hornsea Three and offshore wind farms within a representative 100 km buffer of Hornsea Three.

Project	Worst case piling duration (hours)	Source
Tier 1 offshore wind farms		
Hornsea Three	8,064	See Table 3.11.
Triton Knoll	1,152	Maximum piling duration of four hours per foundation, with up to 288 foundations (RWE, 2012).
Hornsea Project Two	11,522	Piling of a maximum of 1,648 piles for jacket foundations, with up to six hours per pile (Smart Wind, 2015)
Dogger Bank Creyke Beck A&B	5,400	Maximum piling duration of 18 hours per foundation, with a maximum of 300 foundations (Forewind, 2013).
Dogger Bank Teesside A&B	2,028	Total piling duration taken from Environmental Statement (Forewind, 2014) based on maximum of 200 turbines.
Total Tier 1	*28,166*	
Tier 2 offshore wind farms		
Norfolk Vanguard	No data	Scoping report provides no details on duration of piling activities during construction (Vattenfall Wind Power Ltd., 2016).

3.13.2.41 The Dogger Bank Teesside A and B assessment (Forewind, 2014) assessed a worst case scenario 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 400 turbines across both sites (i.e. 200 turbines in each Teesside A and Teesside B), although due to Dogger Bank Teesside A being outside the representative 100 km buffer from Hornsea Three, the duration presented for this project in Table 3.23 is for the 200 turbines within Teesside B only (i.e. excluding the 200 turbines within Teesside A). The Dogger Bank Teesside assessment 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 in the southern North Sea fish and shellfish study area (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. No barrier effects were predicted for migratory fish species and therefore a minor adverse effect was also predicted for these species.

3.13.2.42 The Hornsea Project Two impact assessment (SMart Wind, 2015) assessed two worst case scenarios for effects of underwater noise: a spatial maximum design scenario including up to 225 monopile foundations for 8MW turbines with a maximum hammer energy of 3,000 kJ, and a temporal maximum design scenario including piling of up to 120 jacket foundations for 15 MW turbines, with a maximum hammer energy of 1,700 kJ (both scenarios assumed substations and accommodation platforms would be on jacket foundations installed with a maximum hammer energy of 2,300 kJ). The maximum duration for pile driving at Hornsea Project Two is summarised in Table 3.23. The Hornsea Project Two impact assessment predicted behavioural effects (consistent with Hornsea Project One, using the noise levels quoted by McCauley *et al*. (2000); see paragraph 3.11.1.62) to ranges of 13 to 34 km for pelagic fish and 10 to 26 km for demersal fish (assuming the 3,000 kJ hammer energy). The assessment predicted minor adverse effects on fish spawning and nursery habitats in the southern North Sea fish and shellfish study area, with relatively small proportions of these habitats (e.g. sandeel, plaice and whiting) affected during piling operations. No significant effects were predicted on herring spawning, due to the distance between the Hornsea Project Two array area and the main spawning habitat for this population off Flamborough Head. No barrier effects were predicted for migratory fish species and therefore a minor adverse effect was also predicted for these species.

3.13.2.43 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 ten years, see paragraph 3.13.2.38), intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.13.2.44 Sensitivities of fish and shellfish receptors to underwater noise are fully detailed in paragraph 3.11.1.49 *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 (paragraph 3.6.117). Effects on shellfish species are also predicted to be limited as these species are considered to be less sensitive to noise than fish species or would only be affected at ranges much less than those predicted for fish (paragraph 3.6.22).

3.13.2.45 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 of time and the extent that behavioural reactions will cause a negative effect in individuals (Mueller-Blenke *et al*., 2010).

3.13.2.46 As discussed in paragraph 3.11.1.57 *et seq*., 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 fish and shellfish study area (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 (as discussed in paragraph 3.11.1.57), 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.

3.13.2.47 Effects on migratory species are likely to be limited to behavioural effects within the ranges discussed for the Tier 1 offshore wind farm projects above. Shad, being more sensitive to the acoustic pressure component of piling noise, would be expected to be affected according to the ranges presented for herring, while European eel, lamprey species, sea trout, Atlantic salmon and European smelt are likely to be affected to relatively smaller ranges. Due to the distance between the piling operations at these locations and the coast, there is no potential for piling noise to represent a barrier to migratory species for the projects shown in Figure 3.4. The other Round 2 and Round 3 projects included in the cumulative assessment predicted no significant effects on migratory fish species.

3.13.2.48 Herring, sprat, cod, whiting, allis and twaite shad and European eel are considered to be of medium vulnerability, high recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be medium.

3.13.2.49 All other fish and shellfish VERs within the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be low.

Significance of the effect

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

3.13.2.51 Due to the distance between piling operations and the coast, the low to medium sensitivity of receptors and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of minor significance, which is not significant in EIA terms.

3.13.2.52 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Tier 2

Magnitude of impact

3.13.2.53 The Tier 2 assessment includes all Tier 1 projects and the proposed Norfolk Vanguard offshore wind farm. There is currently no information on the impact of underwater noise on fish and shellfish receptors, although the Scoping Report (Vattenfall Wind Power Ltd., 2016) for this project has identified this as an impact to be assessed in the EIA. If further information becomes available prior to the compilation of the Hornsea Three Environmental Statement, this will be included in the CEA.

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

Sensitivity of the receptor

3.13.2.55 The fish and shellfish assemblages of Norfolk Vanguard are expected to be broadly similar to those of Hornsea Three, with species such as plaice, sole, cod, sandeel, sprat, herring and elasmobranchs occurring in the zone of influence of the project (Vattenfall Wind Power Ltd., 2016). As detailed above, however, information on the impacts of the proposed offshore wind farm on these receptors is not currently available.

3.13.2.56 As discussed in paragraph 3.13.2.48, herring, sprat, cod, whiting, allis and twaite shad and European eel are considered to be of medium vulnerability, high recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be medium.

3.13.2.57 All other fish and shellfish VERs within the southern North Sea fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be low.

Significance of the effect

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

3.13.2.59 Due to the distance between piling operations and the coast, the low to medium sensitivity of receptors and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of minor significance, which is not significant in EIA terms.

3.13.2.60 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

3.13.3 Operation and maintenance phase

Cumulative long term loss of fish and shellfish habitats from offshore wind farm infrastructure and cables and pipelines.

3.13.3.1 Cumulative long term habitat loss is predicted to occur as a result of the presence of Hornsea Three infrastructure, offshore wind farms which are consented or under construction and cables and pipelines within a representative 50 km buffer of Hornsea Three (see Table 3.21 and Figure 3.4). 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. No Tier 2 or Tier 3 projects have been identified.

Tier 1

Magnitude of impact

3.13.3.2 The predicted cumulative long term habitat loss from all Tier 1 projects is presented in Table 3.24. The cumulative long term habitat loss within a 50 km buffer of Hornsea Three is estimated to be 15.36 km^2 which equates to 0.06% of the total area of subtidal habitat within a representative 50 km buffer of Hornsea Three, or less than 0.001% of the southern North Sea fish and shellfish study area. Comparable habitats are widely distributed in the southern North Sea fish and shellfish ecology study area (see volume 5, annex 3.1: Fish and Shellfish Technical Report) so this loss is not predicted to diminish regional ecosystem functions.

3.13.3.3 The cumulative impact of long term habitat loss is predicted to be of a regional spatial extent, long term duration, continuous and irreversible (during the lifetime of the projects considered). It is predicted that the impact will affect the fish and shellfish receptors directly. The magnitude is therefore considered to be minor.

Table 3.24: Cumulative long term habitat loss for Hornsea Three and other plans/projects in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Total predicted long term habitat loss (km^2)	Source
Tier 1		
Offshore wind farms		
Hornsea Three	4.26	See Table 3.11.
Dudgeon	0.42	Values taken from Environmental Statement (Dudgeon Offshore Wind Limited, 2009, 2009)
Race Bank	0.10	Values taken from Environmental Statement (Centrica Energy, 2009)
Triton Knoll	0.88	Values taken from Environmental Statement (TKOWFL, 2012)
Hornsea Project One	4.23	Values taken from Environmental Statement (SMart Wind, 2013).
Hornsea Project Two	5.45	Values taken from Environmental Statement (SMart Wind, 2015).
Total Offshore Wind Farms	15.34	
Cables and Pipelines		
PLU3122 and PL3121 Juliet to Pickerill A Gas Pipeline and Umbilical	0.01	Values taken from Environmental Statement (GDF Suez, 2012).
PL3088 - Cygnus to ETS Gas Pipeline	0.01	Values taken from Environmental Statement (GDF Suez, 2011).
Total Cables and Pipelines	0.02	
Total Tier 1	15.36	

<u>Sensitivity of the receptor</u>

3.13.3.4 Sensitivities of fish and shellfish VERs in the southern North Sea fish and shellfish study area to long term habitat loss are discussed in detail in paragraphs 3.11.2.6 *et seq*. which identifies fish and shellfish receptors which are dependent upon specific sediment or habitat types as being most vulnerable to habitat loss. These include sandeel, *Nephrops*, brown crab and lobster. As discussed in paragraph 3.13.3.3, cumulative long term habitat loss from Tier 1 projects (i.e. within the representative 50 km buffer from Hornsea Three) is predicted to affect only a small proportion (i.e. 0.07%) of the available habitat within the representative 50 km buffer of Hornsea Three. This number is particularly limited in the context of the known sandeel habitats (e.g. as mapped by Jensen *et al*., 2010; see Figure 3.22 of volume 5, annex 3.1: Fish and Shellfish Technical Report) and the potential sandeel habitats (i.e. "preferred" sediment types defined by Latto *et al*., 2013; see Figure 3.23 of volume 5, annex 3.1: Fish and Shellfish Technical Report) in the wider southern North Sea fish and shellfish study area. As with temporary habitat loss, the majority of this habitat loss will occur in low intensity sandeel spawning habitats (as mapped by Ellis *et al*., 2012, see Figure 3.20 and 3.21 of volume 5, annex 3.1: Fish and Shellfish Technical Report).

3.13.3.5 As discussed in paragraph 3.13.2.8, cumulative effects of long term habitat loss on *Nephrops* are likely to be limited, with the majority of effects expected within the Hornsea Three array area. This species is more likely to occur in deeper, muddy sand habitats such as Markham's Hole and Outer Silver Pit to the north of Hornsea Three. Most of the projects considered within this CEA (particularly offshore wind farms) largely occur within shallower areas, with sediments characterised by sand and gravel which are unsuitable for this species. Quantification of habitat loss on brown crab and lobster overwintering, spawning and nursery grounds is difficult, due to the lack of accurate mapping of these habitats in the southern North Sea fish and shellfish study area. These habitats are more likely to be affected by habitat loss associated with the more inshore Round 2 offshore wind farm projects, with the majority of habitat loss associated with Round 3 offshore wind farm projects occurring further offshore. In addition, there is potential for positive effects on brown crab and lobster as a result of the introduction of hard substrates into the marine environment (i.e. reef effects; see paragraph 3.13.3.25).

3.13.3.6 Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and of local to international importance within the southern North Sea fish and shellfish study area (recoverability is not applicable for this impact which will occur over the lifetime of the Tier 1 projects). Given the widespread nature of spawning and nursery habitat in the wider southern North Sea fish and shellfish study area, the sensitivity of these receptors is therefore considered to be **low**.

3.13.3.7 Brown crab and European lobster are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be **medium**.

3.13.3.8 Sandeel and herring are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. Due to the specific habitat requirement of these species, the sensitivity of these receptors is therefore considered to be medium (although no effects of long term habitat loss from Hornsea Three are predicted on herring).

Significance of the effect

3.13.3.9 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 fish and shellfish habitats in the southern North Sea fish and shellfish study area are likely to be affected. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be low to medium and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

3.13.3.10 For migratory fish species, due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.13.3.11 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Tier 2

Magnitude of impact

3.13.3.12 The Tier 2 assessment includes all Tier 1 projects and the proposed Viking Interconnector. There is currently no detailed information on the long term habitat loss from placement of cable protection for this project and due to this requirement being specific to the project and ground conditions across the interconnector route, it this has not been possible to provide a reasonable estimate for this. If further detailed information becomes available prior to the compilation of the Hornsea Three Environmental Statement, this will be included in the CEA.

3.13.3.13 The cumulative impact of long term habitat loss from Tier 2 projects is predicted to be of a regional spatial extent, long term duration, continuous and irreversible (during the lifetime of the projects considered). It is predicted that the impact will affect the fish and shellfish receptors directly. The magnitude is therefore considered to be minor.

Sensitivity of the receptor

3.13.3.14 Most fish and shellfish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and of local to international importance within the southern North Sea fish and shellfish study area (recoverability is not applicable for this impact which will occur over the lifetime of the Tier 1 projects). Given the widespread nature of spawning and nursery habitat in the wider southern North Sea fish and shellfish study area, the sensitivity of these receptors is therefore considered to be low.

3.13.3.15 Brown crab and European lobster are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore considered to be medium.

3.13.3.16 Sandeel and herring are deemed to be of high vulnerability and of regional importance within the southern North Sea fish and shellfish study area. Due to the specific habitat requirement of these species, the sensitivity of these receptors is therefore considered to be medium (although no effects of long term habitat loss from Hornsea Three are predicted on herring).

Significance of the effect

3.13.3.17 Cumulative long term habitat loss will represent a long term and continuous impact throughout the lifetime of the Tier 2 projects. However, only a relatively small proportion of the fish and shellfish habitats in the southern North Sea fish and shellfish study area are likely to be affected. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be low to medium and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

3.13.3.18 For migratory fish species, due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.13.3.19 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Cumulative introduction of hard substrates from offshore wind farm infrastructure leading to effects on fish and shellfish receptors by creating reef habitat.

3.13.3.20 As discussed in paragraphs 3.11.2.27 *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 Three infrastructure, offshore wind farms which are consented or under construction and cables and pipelines within a representative 50 km buffer of Hornsea Three (see Table 3.21 and Figure 3.4). Effects may result from the physical presence of foundations, scour protection and cable/pipeline protection. No Tier 2 or Tier 3 projects have been identified.

Tier 1

Magnitude of impact

3.13.3.21 It is difficult to accurately quantify the total area of hard substrate that will be introduced within a 50 km buffer of Hornsea Three, particularly since this is not quantified in assessments for some of the other offshore wind farms included within the Tier 1 assessment (see Table 3.20). The extent of habitat creation will depend on the exact foundation size, and scour protection and cable protection requirements which will vary for each site. However, from a review of the relevant Environmental Statements and information acquired from developers' websites, it is estimated that approximately 1,696 turbines may be constructed from all projects included within Tier 1 (Table 3.25). This assessment is considered to be precautionary as the maximum design scenario 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, in reality, be greater than the number of turbines actually constructed.

Table 3.25: Cumulative habitat creation for Hornsea Three and offshore wind farms in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Worst case number of turbines	Total predicted habitat creation (m^2)	Source
Tier 1			
Offshore wind farms			
Hornsea Three	342	5,046,797	See Table 3.11.
Dudgeon	168	1,265,544	168 turbines (consented) x 7,533 m^2 (i.e. predicted habitat creation per turbine as per Hornsea Three assumptions as value not specified in Environmental Statement).
Race Bank	206	1,551,798	206 turbines (consented) x 7,533 m^2 (i.e. predicted habitat creation per turbine as per Hornsea Three assumptions as value not specified in Environmental Statement).
Triton Knoll	288	2,169,504	288 turbines (consented) x 7,533 m^2 (i.e. predicted habitat creation per turbine as per Hornsea Three assumptions as value not specified in Environmental Statement).
Hornsea Project One	332	4,860,136	Values taken from Environmental Statement (SMart Wind, 2013)
Hornsea Project Two	360	6,239,991	Values taken from Environmental Statement (SMart Wind, 2015)
Total Offshore Wind Farms	1,696	21,133,770	
Cables and pipelines			
PLU3122 and PL3121 Juliet to Pickerill A Gas Pipeline and Umbilical	N/A	114,000	Values taken from Environmental Statement (GDF Suez, 2012).
PL3088 - Cygnus to ETS Gas Pipeline	N/A	10,000	Values taken from Environmental Statement (GDF Suez, 2011).
Total cables and pipelines	N/A	124,000	
Total habitat creation		21,905,303	

3.13.3.22 For the purposes of this assessment, it has been assumed that for all other projects where habitat creation numbers are not specified in the relevant Environmental Statement, that the area of introduced hard substrate per turbine is the same as for the Hornsea Three foundations (i.e. 7,533 m^2 including scour protection; see Table 3.25). The total for cumulative introduction of hard substrate within a 50 km buffer of Hornsea Three also includes cables and pipelines, where this information was readily available (e.g. from Environmental Statements; see Table 3.25). Where this information was not available, no estimate was made for these cable and pipeline projects. The total cumulative habitat creation is estimated to be approximately 21,905,303 m^2 for all Tier 1 projects within a 50 km buffer of Hornsea Three. This is considered to be a highly precautionary maximum design scenario as in many cases smaller turbines than those assumed for the Hornsea Three assessment will be installed for the other offshore wind farms, and also fewer turbines may actually be constructed than the number consented. Therefore, although an estimation of substrate introduced as a result of the installation of cable protection for the other offshore wind farms within the Tier 1 assessment has not been included (except for Hornsea Projects One and Hornsea Project Two) due to the difficulty in quantifying these areas, given the precaution included in the assessment these areas are likely to be well within the total cumulative estimate of 21,905,303 m^2. The maximum cumulative introduction of hard substrate equates to less than 0.1% fish and shellfish habitat within the representative 50 km buffer around Hornsea Three.

3.13.3.23 The impact will extend over the regional area but will be highly localised within each of the offshore wind farm arrays and cable/pipeline 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.

Sensitivity of the receptor

3.13.3.24 The sensitivity of subtidal receptors will be as described in paragraphs 3.11.2.30 *et seq*. Naturally-occurring hard substrate in this part of the southern North Sea fish and shellfish study area is rare and therefore the introduction of a maximum of approximately 21.91 km^2 of artificial hard substrate represents a shift in the baseline condition of the pre-construction area. Whether this effect is viewed as positive or negative is debatable and the subject of much research. For example, an increase in the abundance of a commercially important shellfish species (e.g. lobster) resulting from new habitat and shelter may be beneficial to commercial fisheries, although from an ecological perspective this may be perceived as a slight negative impact. Negative effects may also occur if non-indigenous species become established (further discussed in chapter 2: Benthic Ecology). There are therefore some uncertainties about which, if any, species may benefit and conversely which species may be adversely affected, e.g. by introduction of non-native species or by increases in species which are normally associated with substrates which are different from the baseline environment (e.g. reef species). Monitoring at existing offshore wind farms have not demonstrated any clearly negative or positive effects and therefore it is assumed that any effects on fish and shellfish populations as a result of the introduction of hard substrates would be limited in extent (see paragraphs 3.11.2.30 *et seq*.).

3.13.3.25 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.

3.13.3.26 Fish receptors in the southern North Sea fish and shellfish study area are deemed to be of low vulnerability and local to international value in the southern North Sea fish and shellfish study area (recoverability is not relevant to this impact). The sensitivity of the receptors is therefore considered to be low.

Significance of the effect

3.13.3.27 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, it is predicted that the sensitivity of fish and shellfish receptors is low to medium and the magnitude is predicted to be minor. The effect will, therefore, be of minor beneficial significance, which is not significant in EIA terms.

3.13.3.28 For migratory fish species, due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.13.3.29 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Cumulative effects of EMF emitted by subsea cables from offshore wind farms and interconnectors leading to effects on fish and shellfish ecology.

3.13.3.30 The cumulative assessment considers the effects of EMF emitted by subsea cables from Hornsea Three and other offshore wind farms (either consented or under construction) and other subsea electrical cables within a representative 50 km buffer from Hornsea Three, using the tiered approach outlined in section 3.12.1 (see Table 3.21). These have the potential to have effects on fish and shellfish receptors in the southern North Sea fish and shellfish study area.

Tier 1

Magnitude of impact

3.13.3.31 EMF, comprising magnetic (B) and induced electrical (iE) fields, have the potential to affect fish and shellfish receptors in the southern North Sea fish and shellfish study area. A variety of design and installation factors have the potential to affect EMF levels in the vicinity of electrical cables, including current flow, distance between cables, cable orientation relative to the earth's magnetic field (DC only), cable insulation, number of conductors, configuration of cable and burial depth as well as whether the subsea cabling systems are AC or DC. It has not been possible to determine the exact specifications of electrical cables for each of the offshore wind farm projects predicted to have a cumulative effect on fish and shellfish receptors, though predictions have been made for the cumulative length of electrical cables associated with the projects outlined in Table 3.26. The maximum length of array and export cables predicted for the Tier 1 assessment within a 50 km buffer of Hornsea Three is 5,343 km (Table 3.26).

3.13.3.32 The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source (i.e. in the order of 10 m each side of the cable, assuming burial to depths of 1 m; see Table 3.19; Normandeau *et al*., 2011). As such, any effects of EMF on fish and shellfish receptors are predicted to be extremely limited in extent, only affecting a relatively small proportion of the fish and shellfish habitat available in the southern North Sea.

3.13.3.33 The impact is predicted to be of highly localised spatial extent within each of the project boundaries, long term duration (i.e. the lifetime of the offshore wind farm projects), continuous and irreversible (during the lifetime of the offshore wind farm projects). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore considered to be **minor**.

Table 3.26: Cumulative EMF for Hornsea Three and offshore wind farms in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Worst cast array, substation interconnector and export cable length (km)	Source
Tier 1		
Offshore wind farms		
Hornsea Three	2,113	See Table 3.11.
Dudgeon	240	Values taken from Environmental Statement (Dudgeon Offshore Wind Limited, 2009ng, 2009).
Race Bank	200	Values taken from Environmental Statement (Centrica Energy, 2009).
Triton Knoll	475	Values taken from Environmental Statement (TKOWFL, 2012).
Hornsea Project One	1,130	Values taken from Environmental Statement (SMart Wind, 2013).
Hornsea Project Two	1,885	Values taken from Environmental Statement (SMart Wind, 2015).
Total Tier 1	5,343	
Tier 2		
Cables and pipelines		
Viking Interconnector	186	Total length of interconnector route (assuming two cables (VikingLink, 2016) in UK waters within 50 km buffer of Hornsea Three.
Total Tier 2	5,529	

Sensitivity of the receptor

3.13.3.34 The effects of EMF on fish and shellfish VERs are discussed in detail in paragraphs 3.11.2.49 *et seq*., with particular focus on the sensitivity of elasmobranchs, crustaceans and migratory fish species. Any EMF from electrical cabling is likely to dissipate rapidly with distance from the cable, resulting in a localised effect in the order of metres, if any effects occur at all.

3.13.3.35 Elasmobranch species are deemed to be of medium vulnerability and local importance in the southern North Sea fish and shellfish study area and therefore are considered to have **low** sensitivity. Migratory fish species are deemed to be of medium vulnerability and regional to international importance in the southern North Sea fish and shellfish study area and therefore are considered to have **low** to **medium** sensitivity, although effects will be largely limited to coastal areas close to the Hornsea Three offshore cable corridor landfall.

3.13.3.36 All other fish and shellfish receptors are deemed to be of low vulnerability and are of local to regional importance in the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore, considered to be **low**.

Significance of the effect

3.13.3.37 Cumulative effects of EMF as a result of electrical cables from Tier 1 projects will represent a long term and continuous impact throughout the lifetime of the projects. However, effects will be highly localised, affecting a relatively small proportion of the fish and shellfish habitats in the southern North Sea fish and shellfish study area, i.e. within metres of the cables. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

3.13.3.38 For migratory fish species, due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 1.7.5), are predicted to be of **minor** significance, which is not significant in EIA terms.

3.13.3.39 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Tier 2

Magnitude of impact

3.13.3.40 The Tier 2 assessment includes all Tier 1 projects and the proposed Viking Interconnector. The length of electrical cabling associated with the Viking Interconnector estimated in Table 3.26 was estimated on the length of the route passing within the 50 km buffer of Hornsea Three. There is currently no detailed information on how cables are to be installed for this project, although these are likely to be similar to Hornsea Three (e.g. ploughing, jetting or trenching; VikingLink, 2016) and therefore it can be assumed that the cable will be buried to a suitable depth to reduce effects of EMF on fish and shellfish receptors. If further detailed information becomes available prior to the compilation of the Hornsea Three Environmental Statement, this will be included in the CEA.

3.13.3.41 The impact is predicted to be of highly localised spatial extent within each of the project boundaries, long term duration (i.e. the lifetime of the Tier 2 offshore wind farm and interconnector projects), continuous and irreversible (during the lifetime of the projects). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore considered to be **minor**.

Sensitivity of the receptor

3.13.3.42 Elasmobranch species are deemed to be of medium vulnerability and local importance in the southern North Sea fish and shellfish study area and therefore are considered to have **low** sensitivity. Migratory fish species are deemed to be of medium vulnerability and regional to international importance in the southern North Sea fish and shellfish study area and therefore are considered to have **low** to **medium** sensitivity, although effects will be largely limited to coastal areas close to the Hornsea Three offshore cable corridor landfall.

3.13.3.43 All other fish and shellfish receptors are deemed to be of low vulnerability and are of local to regional importance in the southern North Sea fish and shellfish study area. The sensitivity of these receptors is therefore, considered to be **low**.

Significance of the effect

3.13.3.44 Cumulative effects of EMF as a result of electrical cables from Tier 2 projects will represent a long term and continuous impact throughout the lifetime of the projects. However, effects will be highly localised, affecting a relatively small proportion of the fish and shellfish habitats in the southern North Sea fish and shellfish study area, i.e. within metres of the cables. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

3.13.3.45 For migratory fish species, due to the small scale of the impact, the low sensitivity and the absence of barrier effects, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 1.7.5), are predicted to be of **minor** significance, which is not significant in EIA terms.

3.13.3.46 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

Cumulative displacement of fishing pressure as a result of offshore wind farm operation leading to effects on fish and shellfish ecology.

3.13.3.47 There is potential for cumulative adverse and beneficial impacts on fish and shellfish receptors to arise from the displacement of commercial fisheries during the operational phase of Hornsea Three together with the operation of other offshore wind farms (see chapter 6: Commercial Fisheries). For the purposes of this PEIR, this additive impact has been assessed within a representative 50 km buffer of Hornsea Three using the tiered approach outlined in section 3.12.1 (see Table 3.21).

Tier 1

Magnitude of impact

3.13.3.48 As discussed in paragraphs 3.11.2.84 *et seq*., fishing activity may be reduced within the Hornsea Three array, with a maximum design scenario for fish and shellfish assumed to include restrictions on fishing activity within 500 m operational safety zones around offshore substations and as a result of logistical and safety reasons arising from the physical presence of the offshore infrastructure. For the purposes of the CIA, similar assumptions regarding safety zones and safety/logistical issues have been made with respect to the other offshore wind farms within the Tier 1 assessment (see Table 3.21). Although as discussed in chapter 6: Commercial Fisheries, a co-existence of offshore wind farms and commercial fisheries activities is, on the whole assumed, the extent of exclusion of commercial fisheries from the offshore wind farm sites is likely to be relatively limited, though it is difficult to quantify the cumulative area accurately.

3.13.3.49 The potential positive impact of reduced commercial fishing activity on fish and shellfish receptors within offshore wind farms is predicted to be of a local spatial extent (i.e. restricted to a proportion of the area within each wind farm array), long term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly and/or indirectly. The magnitude is therefore, considered to be minor.

3.13.3.50 Conversely, the displacement of fishing pressure may result in negative effects on fish and shellfish receptors outside the offshore wind farm arrays. The magnitude of such an impact is difficult to quantify, however it is likely that the potential effect will be dispersed over a large area within the southern North Sea fish and shellfish study area, thus meaning that the specific increase in intensity of fishing in any one location is likely to be minimal. The impact is predicted to be of a regional spatial extent, long term duration, continuous and irreversible (during the lifetime of the projects). It is predicted that the impact will affect fish and shellfish receptors directly and/or indirectly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

3.13.3.51 The sensitivity of fish and shellfish VERs to this impact is discussed in full in paragraphs 3.11.2.89 *et seq*. Fish species with the greatest potential for positive effects include those targeted by commercial fisheries in the area (e.g. plaice, sole, cod, whiting and *Nephrops*), though non target species also have the potential to be affected. Shellfish receptors may also benefit from a reduction in trawling as some activities such as beam trawling can damage the seabed and its marine life (Byrne Ó Cléirigh *et al*., 2000; Hart *et al*., 2004).

3.13.3.52 Fish and shellfish receptors 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. The sensitivity of these receptors is therefore considered to be low.

Significance of the effect

3.13.3.53 There is considerable uncertainty associated with the potential benefits to fish and shellfish populations as a result of the potential reduction of fishing activities within the Tier 1 offshore wind farm projects due to the mobility of most of the receptors identified. Potential benefits are most likely to be realised by species with limited mobility and specific habitat requirement (e.g. sandeel, *Nephrops* and other crustaceans). Overall, it is predicted that the sensitivity of fish and shellfish receptors to potential reduction in fishing pressure is considered to be low and the magnitude is deemed to be minor. The effect will therefore be of minor beneficial significance, which is not significant in EIA terms.

3.13.3.54 Due to the localised scale of the impact and the low sensitivity of receptors, effects on migratory fish species (i.e. river lamprey, sea lamprey, allis shad, twaite shad and Atlantic salmon) designated as features of SACs/SCIs within the southern North Sea fish and shellfish study area (see section 3.7.5), are predicted to be of negligible significance, which is not significant in EIA terms.

3.13.3.55 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 PEIR. A full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a).

3.14 Transboundary effects

3.14.1.1 A screening of transboundary impacts has been carried out and is presented in volume 4, annex 5.4: Transboundary Impacts Screening Note. This screening exercise identified that there was potential for significant transboundary effects for fish and shellfish ecology from Hornsea Three upon the interests of other European Economic Area (EEA) States. These included direct impacts due to underwater noise from piling operations and indirect impacts caused by loss of fish and shellfish habitat or disturbance to habitat due to increased suspended sediments and deposition from the placement/removal of foundations and cables in or on the seabed. These activities have the potential to directly affect Annex II migratory fish species that are listed as features of European Sites in other EEA states, or species that are of commercial importance for fishing fleets of other EEA states.

3.14.1.2 Most of the impacts associated with construction, operation and decommissioning of Hornsea Three, including habitat loss or disturbance, will be limited in extent, with most of the impact occurring within the boundaries of Hornsea Three or in the immediate vicinity of the Hornsea Three array area and offshore cable corridor. Effects of increases in SSC are predicted to be limited in extent to a number of kilometres of Hornsea Three and are therefore not predicted to extend into the waters of other EEA states. Due to the wide ranging nature of migratory fish species in the southern North Sea fish and shellfish study area, effects on these species designated as features of SACs/SCIs in the UK and other EEA states, are assessed for each impact assessment. No significant effects (in EIA terms) were predicted on these species; conclusions on the effect on the site integrity of these SACs/SCIs is presented within the Draft Report to Inform Appropriate Assessment (DONG Energy, 2017a). Effects on all other fish and shellfish receptors (including those targeted by commercial fishing fleets from other EEA states) from all impacts, including habitat loss and disturbance and increases in SSC, were predicted to be not significant in EIA terms.

3.14.1.3 The only impact with the potential to directly affect fish and shellfish receptors of other EEA states was underwater noise during the construction phase. This assessment is presented in paragraph 3.11.1.43 *et seq*. Underwater noise levels expected to elicit behavioural responses in certain fish and shellfish, are predicted to extend to several 10s of kilometres beyond Hornsea Three and therefore have the potential to affect fish and shellfish habitats of other EEA states 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 was considered to be low to medium and the magnitude predicted to be minor. The effect was therefore considered to be minor adverse significance, which is not significant in EIA terms.

3.15 Inter-related effects

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

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

3.15.1.2 A description of the likely inter-related effects arising from Hornsea Three on fish and shellfish ecology is provided in chapter 12: Inter-Related Effects (Offshore).

3.16 Conclusion and summary

3.16.1.1 Characterisation of the baseline environment through both survey data from the former Hornsea Zone and a desk-based literature review found the species assemblage of the Hornsea Three fish and shellfish study area to be typical for this region of the southern North Sea fish and shellfish study area. The key characterising fish species consisted of a mix of both pelagic and demersal species; flounder, plaice, dab, common sole, lemon sole, cod, whiting, sprat, herring and sandeel. Many of these species are fished commercially within the southern North Sea fish and shellfish study area, as are shellfish species such as brown crab, European lobster and *Nephrops*. Many of the characterising fish and shellfish species have important nursery and spawning grounds within and in close proximity to the Hornsea Three fish and shellfish study area. A number of migratory fish species have the potential to occur in the southern North Sea fish and shellfish study area, including seven species listed as features of SACs/SCIs in the UK (i.e. the Humber Estuary SAC) and other EEA states.

3.16.1.2 The impacts on fish and shellfish receptors from all stages of the project were assessed, including impacts from habitat loss, underwater noise, increased SSC and deposition, sediment contaminants and pollution events, and EMF. Throughout the construction, operation and decommissioning phases, all impacts were found to have either negligible, minor adverse or minor beneficial effects on fish or shellfish receptors within the Hornsea Three fish and shellfish study area (i.e. not significant in EIA terms). Underwater noise from construction activities such as pile driving was not predicted to overlap with key fish spawning habitats within the southern North Sea fish and shellfish study area. No barrier effects were predicted on migratory fish species listed as features of SACs/SCIs in the southern North Sea fish and shellfish study area, including the Humber Estuary SAC.

3.16.1.3 The assessment of cumulative impacts from Hornsea Three 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 southern North Sea fish and shellfish study area, with effects predicted to be spatially and temporally limited at any one time, meaning that other habitats within the southern North Sea fish and shellfish study area would remain undisturbed. The cumulative effects of underwater noise and EMF 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.

3.17 Next steps

3.17.1.1 As discussed in section 3.6.4, as part of the Hornsea Three offshore cable corridor benthic ecology survey, additional beam trawl sampling will be undertaken across the Hornsea Three offshore cable corridor. The fish and shellfish data collected during this survey will be incorporated into the data analyses presented in volume 5, annex 3.1: Fish and Shellfish Technical Report.

3.17.1.2 The benthic ecology survey of the Hornsea Three offshore cable corridor will also provide further data on the sediment properties, including sediment chemistry, of the Hornsea Three offshore cable corridor. These data will be used to inform the assessment of the potential for release of sediment contaminants as a result of seabed disturbances (see paragraphs 3.11.1.41 and 3.11.3.15), to be presented in the Environmental Statement.

3.17.1.3 Knowledge of the anticipated maximum design scenario for piling, in terms of the maximum hammer energy, and piling sequence and duration, will improve following a review of construction experience at other offshore wind farms. Pending the outcome of the geoscience campaigns scheduled for 2017, the piling assessment will be revisited, including the subsea noise modelling, to ensure that it is consistent with the maximum design scenario presented in the Environmental Statement.

Table 3.27: Summary of potential environment effects, mitigation and monitoring.

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Construction Phase							
Temporary habitat loss/disturbance from construction operations including foundation installation (e.g. jack-up operations and seabed preparation works) and cable laying operations (including anchor placement) may affect fish ecology	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Increased SSC and associated sediment deposition as a result of foundation installation, cable installation and seabed preparation resulting in potential effects on fish and shellfish receptors	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology	N/A	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement
Underwater noise as a result of foundation installation (i.e. piling) and other construction activities (e.g. cable installation) resulting in potential effects on fish and shellfish receptors	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Accidental pollution events during the construction phase resulting in potential effects on fish and shellfish receptors	COCP	Negligible	Low to medium	Negligible (not significant in EIA terms)	None	N/A	None
Operation Phase							
Long term habitat loss due to presence of turbine foundations and scour/cable protection with potential effects on fish and shellfish ecology	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Underwater noise as a result of operational turbines and maintenance vessel traffic resulting in potential effects on fish and shellfish receptors	N/A	Negligible	Low to medium	Negligible (not significant in EIA terms)	None	N/A	None
Introduction of turbine foundations and scour/cable protection (hard substrates and structural complexity) leading to effects on fish and shellfish receptors by creating reef habitat	N/A	Minor	Low to medium	Minor beneficial (not significant in EIA terms)	None	N/A	None
EMF emitted by array and export cables during the operational phase causing behavioural responses in fish and shellfish receptors	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Temporary habitat loss and disturbance from maintenance operations (e.g. jack up operations and cable reburial)	N/A	Negligible	Low to medium	Negligible adverse (not significant in EIA terms)	None	N/A	None
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect fish and shellfish	PEMMP	Negligible	Low to medium	Negligible (not significant in EIA terms)	None	N/A	None

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Potentially reduced fishing pressure within the Hornsea Three array area offering some protection and possible local enhancement within the Hornsea Three array area and potentially increased fishing pressure outside the Hornsea Three array \rea	N/A	Negligible to minor	Not sensitive to low	Negligible to minor beneficial (not significant in EIA terms)	None	N/A	None
Decommissioning Phase							
Temporary habitat loss/disturbance due to decommissioning of turbine foundations and array, substation interconnector and export cables	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Temporary increases in SSC and associated sediment deposition from removal of array and substation interconnector cables, export cables and turbine foundations	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Seabed disturbances within the Hornsea Three offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on fish and shellfish ecology	N/A	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement	To be confirmed in the Environmental Statement
Decommissioning activities producing subsea noise resulting in potential effect on fish and shellfish receptors	N/A	Negligible	Low to medium	Negligible (not significant in EIA terms)	None	N/A	None
Effects on fish and shellfish receptors due to removal of foundations and cable protection leading to loss of hard substrates and structural complexity	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Permanent habitat loss/alteration due to presence of scour/cable protection left *in situ* post decommissioning with potential effects on fish and shellfish ecology	N/A	Minor	Low to medium	Minor adverse (not significant in EIA terms)	None	N/A	None
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect fish and shellfish ecology	COCP	Negligible	Low to medium	Negligible (not significant in EIA terms)	None	N/A	None

3.18 References

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