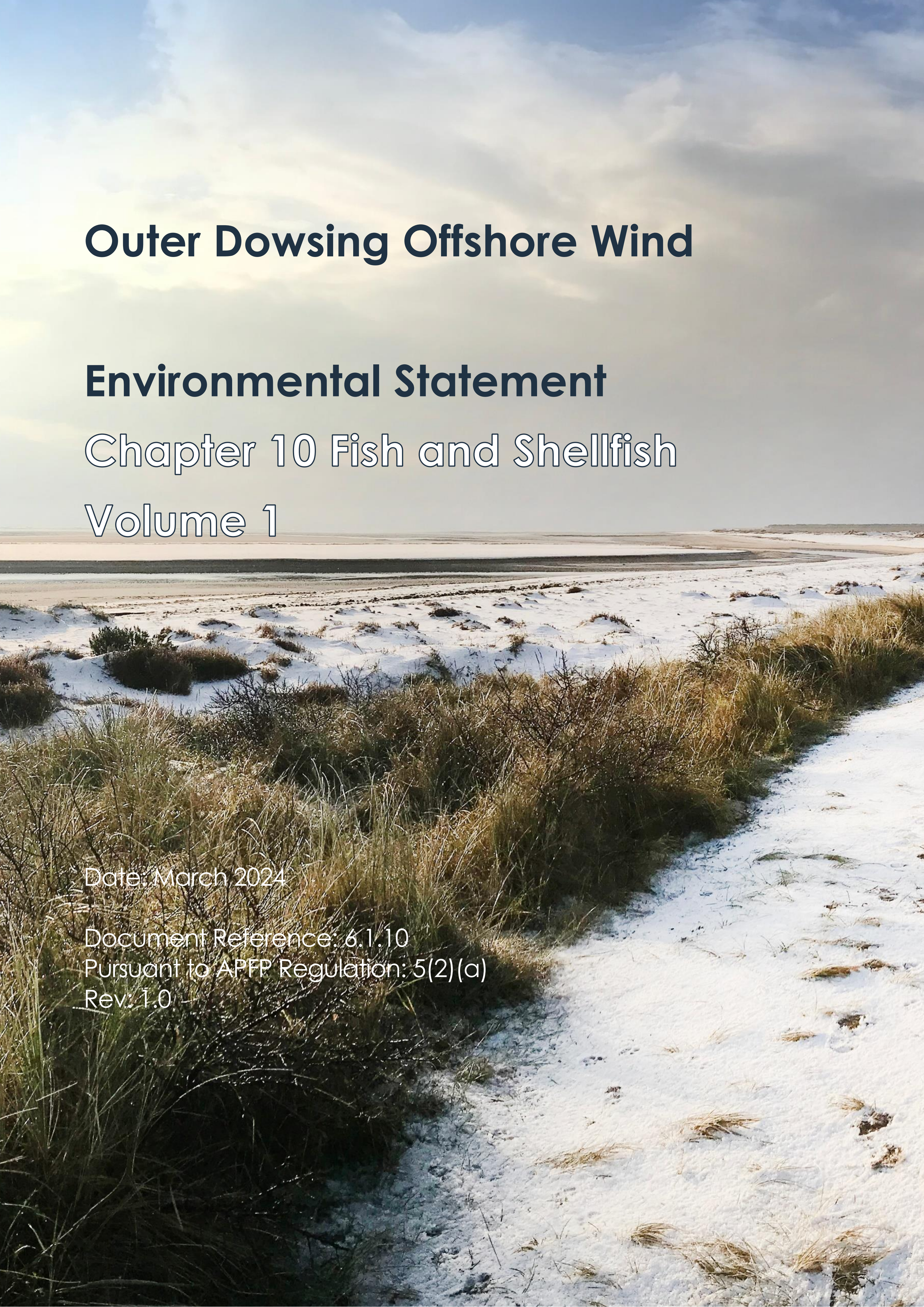

Outer Dowsing Offshore Wind

Environmental Statement

Chapter 10 Fish and Shellfish

Volume 1

Date: March 2024

Document Reference: 6.1.10
Pursuant to APFP Regulation: 5(2)(a)
Rev: 1.0

Company:	**Outer Dowsing Offshore Wind**	Asset:	**Whole Asset**
Project:	**Whole Wind Farm**	Sub Project/Package:	Whole Asset
Document Title or Description:	Volume 1 Chapter 10 Fish and Shellfish		
Internal Document Number:	PP1-ODOW-DEV-CS-REP-0118	3rd Party Doc No (If applicable):	N/A

Outer Dowsing Offshore Wind accepts no liability for the accuracy or completeness of the information in this document nor for any loss or damage arising from the use of such information.

Rev No.	**Date**	**Status / Reason for Issue**	**Author**	**Checked by**	**Reviewed by**	**Approved by**
1	March 2024	Environmental Statement	GoBe	GoBe	Shepherd and Wedderburn	ODOW

Table of Contents

Table of Tables

Table of Figures

- Figure 10.3 Spawning Grounds 1998 2010 (Document Reference: 6.2.10.3)
- Figure 10.4 Spawning Grounds 1998 2010 (Document Reference: 6.2.10.4)
- Figure 10.5 Nursery Grounds 1998 2010 (Document Reference: 6.2.10.5)
- Figure 10.6 Nursery_Grounds_1998_2010 (Document Reference: 6.2.10.6)
- Figure 10.7 Nursery_Grounds_1998_2010 (Document Reference: 6.2.10.7)
- Figure 10.8 Nursery_Grounds_1998_2010 (Document Reference: 6.2.10.8)
- Figure 10.9 Nursery_Grounds_1998_2010 (Document Reference: 6.2.10.9)
- Figure 10.10 Herring Spawning EUSeaMap2021 (Document Reference: 6.2.10.10)
- Figure 10.11 Herring EUSeaMap2021 (Document Reference: 6.2.10.11)
- Figure 10.12 Herring BGS Site Data (Document Reference: 6.2.10.12)
- Figure 10.13 Herring Site Data (Document Reference: 6.2.10.13)
- Figure 10.14 Herring IHLS (Document Reference: 6.2.10.14)
- Figure 10.15 IHLS 2009 2013 (Document Reference: 6.2.10.15)
- Figure 10.16 IHLS 2013 2017 (Document Reference: 6.2.10.16)
- Figure 10.17 IHLS 2019 2021 v1 (Document Reference: 6.2.10.17)
- Figure 6.2.10.18 Sandeel Spawning EUSeaMap2021 (Document Reference: 6.2.10.18)
- Figure 10.19 Sandeel EUSeaMap2021 (Document Reference: 6.2.10.19)
- Figure 10.20 Sandeel BGS Site Data (Document Reference: 6.2.10.20)
- Figure 10.21 Sandeel Site Data (Document Reference: 6.2.10.21)
- Figure 10.22 Designated Sites v2 (Document Reference: 6.2.10.22)
- Figure 10.23 Herring Noise Jacket 3500kJ v1 (Document Reference: 6.2.10.23)
- Figure 10.24 Herring Noise Monopile 6600kJ v1 (Document Reference: 6.2.10.24)
- Figure 10.25 Sandeel Noise Jacket 3500kJ v1 (Document Reference: 6.2.10.25)
- Figure 10.26 Sandeel Noise Monopile 6600kJ v1 (Document Reference: 6.2.10.26)
- Figure 10.27 Herring Noise Simultaneous Jacket 3500kJ v1 (Document Reference: 6.2.10.27)
- Figure 10.28 Herring Noise Simultaneous Monopile 6600kJ v1 (Document Reference: 6.2.10.28)
- Figure 10.29 Sandeel Noise Simultaneous Jacket 3500kJ v1 (Document Reference: 6.2.10.29)
- Figure 10.30 Sandeel Noise Simultaneous Monopile 6600kJ v1 (Document Reference: 6.2.10.30)
- Figure 10.31 Fleeing Noise Simultaneous Jacket 3500kJ v1 (Document Reference: 6.2.10.31)

Table of Appendices

Acronyms & Definitions

Abbreviations / Acronyms

Abbreviation / Acronym	Description
AC	Alternating Current
ANS	Artificial Nesting Structures
AoS	Area of Search
BEGG	Business, Enterprise and Regulatory Reform
BEIS	Department of Business, Energy and Industrial Strategy
BGS	British Geological Survey
BMAPA	British Marine Aggregate Producers Association
BNG	Biodiversity Net Gain
CBRA	Cable Burial Risk Assessment
CBS	Cost Breakdown Structure
CEA	Cumulative Effects Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture
CIA	Cumulative Impact assessment
CIEEM	Chartered Institute of Ecology and Environmental Management
CNS	Central North Sea
CPUE	Catch Per Unit Effort
CSIP	Cable Specification and Installation Plan
DC	Direct Current
DCO	Development Consent Order
DDV	Drop Down Video
DECC	Department of Energy & Climate Change, now the Department for Energy Security and Net Zero (DESNZ)
DESNZ	Department for Energy Security and Net Zero, formerly Department of Business, Energy and Industrial Strategy (BEIS), which was previously Department of Energy & Climate Change (DECC).
DP	Decommissioning Programme
EA	Environment Agency
ECC	Export Cable Corridor
EDMS	Electronic Document Management System
eDNA	Environmental Deoxyribonucleic Acid
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIAFCA	Eastern Inshore Fisheries & Conservation Authority
EMF	Electromagnetic Field
EMODnet	European Marine Observation and Data Network
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Technical Group

Abbreviation / Acronym	Description
EU	European Union
EUNIS	European Nature Information System
GBS	Gravity Base Structure
GES	Good Environmental Status
GT R4 Ltd	The Applicant. The special project vehicle created in partnership between Corio Generation (a wholly owned Green Investment Group portfolio company), Gulf Energy Development and TotalEnergies
HDD	Horizontal Directional Drilling
HRA	Habitats Regulation Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IBTS	International Bottom Trawl Surveys
ICES	International Council for the Exploration of the Sea
iE	Induced Electric
IFI	Issued for Information
IFISH	Integrated Fisheries System Holding
IHLS	International Herring Larvae Survey
INNS	Invasive Non-Native Species
IUCN	Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
JUV	Jack-Up Vessel
LWT	Lincolnshire Wildlife Trust
MBES	Multi-beam Echo Sounder
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zone
MDR	Master Document Register
MDS	Maximum Design Scenario
MFE	Mass Flow Excavator
MHWS	Mean High Water Spring
MMMP	Marine Mammal Mitigation Programme
MMO	Marine Management Organisation
MPA	Marien Protected Area
MPCP	Marine Pollution Contingency Plan
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
NPS	National Policy Statement
NSIBTS	North Sea International Bottom Trawl Survey
NSSS	North Sea Sandeel Survey
OBR	Opercular Beat Rate
ODOW	Outer Dowsing Offshore Wind, trading name of GT R4 Limited
O&M	Operation and Maintenance
OMPM	Opercular Movements Per Minute
ORCP	Offshore Reactive Compensation Platform

Abbreviation / Acronym	Description
OSPAR	Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic)
OSS	Offshore Substation
OWF	Offshore Wind Farm
PAH	Polycyclic Aromatic Hydrocarbons
PEIR	Preliminary Environmental Information Report
PEL	Probable Effect Limit
PEMP	Project Environmental Management Plan
PSA	Particle Size Analysis
PTS	Permanent Threshold Shift
rMCZ	Recommended Marine Conservation Zone
RMS	Route Mean Square
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SBP	Sub-Bottom Profiler
SEL	Sound Exposure Level
SoS	Secretary of State
SoW	Scope of Work
SPA	Special Protection Area
SPL	Sound Pressure Level
SPMP	Scour Protection Management Plan
SSC	Suspended Sediment Concentration
SSS	Side Scan Sonar
SSSI	Site of Special Scientific Interest
TE	TotalEnergies
TTS	Temporary Threshold Shift
TCA	Trade and Cooperation Agreement
TCE	The Crown Estate
TSHD	Trailer Suction Hopper Dredger
UHRS	Ultra-High Resolution Seismic
UK	United Kingdom
UWN	Under Water Noise
UXO	Unexploded Ordnance
VER	Valued Ecological Receptor
VMS	Vessel Monitoring System
WCS	Worst Case Scenario
WTG	Wind Turbine Generator
ZoI	Zone of influence

Terminology

Term	Definition
AfL array area	The area of the seabed awarded to GT R4 Ltd. through an Agreement for Lease (AfL) for the development of an offshore windfarm, as part of The Crown Estate's Offshore Wind Leasing Round 4.
Array area	The area offshore within which the generating station (including Wind Turbine Generators (WTG) and inter array cables), offshore accommodation platforms, offshore transformer substations and associated cabling will be positioned.
Baseline	The status of the environment at the time of assessment without the development in place.
Biodiversity Net Gain (BNG)	An approach to development that leaves biodiversity in a measurably improved state than it was previously. Where a development has an impact on biodiversity, developers are encouraged to provide an increase in appropriate natural habitat and ecological features over and above that being affected, to ensure that the current loss of biodiversity through development will be halted and ecological networks can be restored.
Cumulative effects	The combined effect of the Project acting additively with the effects of other projects, on the same single receptor/resource.
Cumulative impact	Impacts that result from changes caused by other past, present, or reasonably foreseeable actions together with the Project.
Deemed Marine Licence (dML)	A marine licence set out in a Schedule to the Development Consent Order and deemed to have been granted under Part 4 (marine licensing) of the Marine and Coastal Access Act 2009.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for a Nationally Significant Infrastructure Project (NSIP).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the sensitivity of the receptor, in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Regulations, including the publication of an Environmental Statement (ES).
EIA Directive	European Union 2011/92/EU (as amended by Directive 2014/52/EU).
EIA Regulations	Infrastructure Planning (Environmental Impact Assessment) Regulations 2017.
Environmental Statement (ES)	The suite of documents that detail the processes and results of the EIA.
Evidence Plan	A voluntary process of stakeholder consultation with appropriate Expert Topic Groups (ETGs) that discusses and, where possible, agrees the detailed approach to the Environmental Impact Assessment (EIA) and information to support Habitats Regulations Assessment (HRA) for those relevant topics included in the process, undertaken during the pre-application period.
Export cables	Cables which connect the Offshore Reactive Compensation Platform (ORCP) and Offshore Substations (OSS) with the Onshore Substation (OnSS) to

Term	Definition
	transmit power from the windfarm to shore. Cables can be Onshore, Landfall and Offshore.
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
High Voltage Direct Current (HVDC)	High voltage direct current is the bulk transmission of electricity by direct current (DC), whereby the flow of electric charge is in one direction.
Impact	An impact to the receiving environment is defined as any change to its baseline condition, either adverse or beneficial.
Inter-array cables	Cables which connect the wind turbines to each other and to the offshore substation(s).
Interlink cables	Cables which connect the Offshore Substations (OSS) to one another.
Landfall	The location at the land-sea interface where the offshore export cables and fibre optic cables will come ashore.
Maximum Design Scenario	The project design parameters, or a combination of project design parameters, that are likely to result in the greatest potential for change in relation to each impact assessed
Mitigation	Mitigation measures are commitments made by the Project to reduce and/or eliminate the potential for significant effects to arise as a result of the Project. Mitigation measures can be embedded (part of the project design) or secondarily added to reduce impacts in the case of potentially significant effects.
National Policy Statement (NPS)	A document setting out national policy against which proposals for Nationally Significant Infrastructure Projects (NSIPs) will be assessed and decided upon
NSIP Reform Action Plan	An Action Plan launched in February 2023 by Department for Levelling Up, Housing & Communities to reform the NSIP regime to ensure the effectiveness and resilience of the planning regime for the growing pipeline of critical infrastructure projects.
Onshore Infrastructure	The combined name for all onshore infrastructure associated with the Project from landfall to grid connection.
Offshore Export Cable Corridor (ECC)	The Offshore Export Cable Corridor (Offshore ECC) is the area within the Order Limits within which the export cables running from the array to landfall will be situated.
Offshore Reactive Compensation Station (ORCP)	A structure attached to the seabed by means of a foundation, with one or more decks and a helicopter platform (including bird deterrents) housing electrical reactors and switchgear for the purpose of the efficient transfer of power in the course of HVAC transmission by providing reactive compensation
Offshore Substation (OSS)	A structure attached to the seabed by means of a foundation, with one or more decks and a helicopter platform (including bird deterrents), containing— (a) electrical equipment required to switch, transform, convert electricity generated at the wind turbine generators to a higher voltage and provide reactive power compensation; and (b) housing accommodation, storage, workshop auxiliary equipment, radar and facilities for operating, maintaining and controlling the substation or wind turbine generators
Outer Dowsing Offshore Wind (ODOW)	The Project
Order Limits	The area subject to the application for development consent. The limits shown on the works plans within which the Project may be carried out

Term	Definition
The Planning Inspectorate	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs)
Pre-construction and post-construction	The phases of the Project before and after construction takes place.
Preliminary Environmental Information Report (PEIR)	The PEIR was written in the style of a draft Environmental Statement (ES) and provided information to support and inform the statutory consultation process during the pre-application phase.
The Project	Outer Dowsing Offshore Wind, an offshore wind generating station together with associated onshore and offshore infrastructure
Project Design Envelope	A description of the range of possible elements that make up the Project's design options under consideration, as set out in detail in the project description. This envelope is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact engineering parameters are not yet known. This is also often referred to as the "Rochdale Envelope" approach
Receptor	A distinct part of the environment on which effects could occur and can be the subject of specific assessments. Examples of receptors include species (or groups) of animals or plants, people (often categorised further such as 'residential' or those using areas for amenity or recreation), watercourses etc.
Statutory consultee	Organisations that are required to be consulted by the Applicant, the Local Planning Authorities and/or The Planning Inspectorate during the pre-application and/or examination phases, and who also have a statutory responsibility in some form that may be relevant to the Project and the DCO application. This includes those bodies and interests prescribed under Section 42 of the Planning Act 2008
Strategic Compensation	Collaborative approach by developers and/or government departments to secure compensation for adverse effects on the conservation objectives of a Marine Protected Area.
Study area	Area(s) within which environmental impact may occur – to be defined on a receptor-by-receptor basis by the relevant technical specialist
Subsea	Subsea comprises everything existing or occurring below the surface of the sea
Transboundary impacts	Transboundary effects arise when impacts from the development within one European Economic Area (EEA) state affects the environment of another EEA state(s)
Trenched technique	Trenching is a construction excavation technique that involves digging a narrow trench in the ground for the installation, maintenance, or inspection of pipelines, conduits, or cables
Trenchless technique	Trenchless technology is an underground construction method of installing, repairing, and renewing underground pipes, ducts and cables using techniques which minimize or eliminate the need for excavation. Trenchless technologies involve methods of new pipe installation with minimum surface and environmental disruptions. These techniques may include Horizontal Directional Drilling (HDD), thrust boring, auger boring, and pipe ramming, which allow ducts to be installed under an obstruction without breaking open the ground and digging a trench
The Applicant	GT R4 Ltd. The Applicant making the application for a DCO. The Applicant is GT R4 Limited (a joint venture between Corio

Term	Definition
	Generation, TotalEnergies and Gulf Energy Development (GULF)), trading as Outer Dowsing Offshore Wind. The Project is being developed by Corio Generation (a wholly owned Green Investment Group portfolio company), TotalEnergies and GULF
Wind turbine generator (WTG)	A structure comprising a tower, rotor with three blades connected at the hub, nacelle and ancillary electrical and other equipment which may include J-tube(s), transition piece, access and rest platforms, access ladders, boat access systems, corrosion protection systems, fenders and maintenance equipment, helicopter landing facilities and other associated equipment, fixed to a foundation

Document Number	Title
5.1	Consultation Report
6.1.3	Project Description
6.1.5	EIA Methodology
6.1.6	Technical Consultation
6.1.7	Marine Physical Processes
6.1.8	Marine Water and Sediment Quality
6.1.9	Benthic Subtidal and Intertidal Ecology
6.1.14	Commercial Fisheries
6.1.18	Marine Infrastructure and Other Users
6.1.2	Needs, Policy, and Legislative Context
6.3.3.2	Onshore Crossing Schedule
6.3.7.1	Physical Processes Technical Baseline
6.3.7.2	Physical Processes Modelling Report
6.3.10.1	Fish and Shellfish Ecology Technical Baseline
7.1	Report to Inform Appropriate Assessment
8.5	Outline Cable Specification and Installation Plan

10 Fish and Shellfish

10.1 Introduction

1. This chapter of the Environmental Statement (ES) presents the results of the Environmental Impact Assessment (EIA) process for the potential impacts of Outer Dowsing Offshore Wind ('the Project') on Fish and Shellfish Ecology. Specifically, this chapter considers the potential impact of the Project seaward of Mean High Water Springs (MHWS) during the construction, operation and maintenance, and decommissioning phases.
2. GT R4 Limited (trading as Outer Dowsing Offshore Wind), hereafter referred to as the 'Applicant', is proposing to develop the Project. The Project array area will be located approximately 54km from the Lincolnshire coastline in the southern North Sea. The Project will include both offshore and onshore infrastructure including an offshore generating station (windfarm), export cables to landfall, Offshore Reactive Compensation Platforms (ORCPs), onshore cables, connection to the electricity transmission network, ancillary and associated development and areas for the delivery of up to two Artificial Nesting Structures (ANS) and the creation of a biogenic reef (if these compensation measures are deemed to be required by the Secretary of State) (see Volume 1, Chapter 3: Project Description (document reference 6.1.3) for full details).
3. This chapter summarises the information contained within Volume 3, Appendix 10.1: Fish and Shellfish Ecology Technical Baseline (document reference 6.3.10.1).
4. This chapter should be read in conjunction with the following ES chapters and documents:
    - Volume 1, Chapter 3: Project Description (document reference 6.1.3);
    - Volume 1, Chapter 7: Marine Physical Processes (document reference 6.1.7);
    - Volume 1, Chapter 8: Marine Water and Sediment Quality (document reference 6.1.8);
    - Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology (document reference 6.1.9); and
    - Volume 1, Chapter 14: Commercial Fisheries (document reference 6.1.14).

10.2 Statutory and Policy Context

5. This section highlights legislation as well as national and local policy that is relevant to fish and shellfish ecology and provides information regarding the legislative context surrounding the assessment of potential effects in relation to fish and shellfish ecology. Full details of all Needs Policy and Legislation Context to the Project application are provided within Volume 1, Chapter 2: Need, Policy and Legislative Context (document reference 6.1.2). The Applicant has ensured that the assessment adheres to the relevant legislation.
6. In undertaking the assessment, the following Needs Policy and Legislation Context has been considered:
    - The Conservation of Habitats and Species Regulations 2017 and

- The Conservation of Offshore Marine Habitats and Species Regulations 2017 (collectively referred to herein as the "Habitats Regulations");
- Overarching National Policy Statement (NPS) for Energy (NPS EN-1; Department for Energy and Climate Change (DECC), 2024);
- National Policy Statement for Renewable Energy Infrastructure (NPS EN-3; DESNZ, 2024);
- National Policy Statement for Electricity Networks Infrastructure EN-5 (DESNZ, 2024);
- The United Kingdom (UK) Marine Policy Statement (MPS; HM Government, 2011); and
- East Inshore and East Offshore Marine Plans (MMO, 2014).

7. The assessment of potential changes to fish and shellfish ecology has been made with consideration to the specific policies set out in the NPS EN-1 (2023) and EN-3 (2023). Key provisions are set out in Table 10.1 below along with details as to how these have been addressed within the EIA.

Table 10.1: National Policy Statements of relevance to fish and shellfish ecology.

Legislation/policy	Key provisions	Section where comment addressed
NPS EN-1 (2023)	"Many Sites of Special Scientific Interests (SSSIs) are also designated as sites of international importance and will be protected accordingly. Those that are not, or those features of SSSIs not covered by an international designation, should be given a high degree of protection. Most National Nature Reserves are notified as SSSIs." Paragraph 5.4.7 of National Policy Statement (NPS) EN-1). "Development on land within or outside a SSSI, and which is likely to have an adverse effect on it (either individually or in combination with other developments), should not normally be permitted. The only exception is where the benefits (including need) of the development in the location proposed clearly outweigh both its likely impact on the features of the site that make it of special scientific interest, and any broader impacts on the national network of SSSIs." Paragraph 5.4.8 of NPS EN-1).	Designated sites within the region have been identified in Section 10.4. The Humber Estuary has been included as it is designated as a Special Area of Conservation (SAC), a Special Protection Area (SPA), a Ramsar Site and an Site of Special Scientific Interest (SSSI).
	"Marine Conservation Zones (MCZs) (Marine Protected Areas in Scotland) introduced under the Marine and Coastal Access Act 2009, are areas that have been designated for the purpose of conserving marine flora and fauna, marine habitats or types of marine habitat or features of geological or geomorphological interest. The protected feature or features and the conservation objectives for the MCZ are stated in the designation order for the MCZ. If a proposal is likely to have significant impacts on an MCZ, an MCZ Assessment should be undertaken as per the requirements under section 126 of the Marine and Coastal Access Act 2009." (paragraph 5.4.9 of NPS EN-1).	One Marine Conservation Zone (MCZ) relevant to fish and shellfish was identified – Holderness Offshore MCZ. This is discussed in Section 10.4. An assessment of potential impacts to MCZs is provided in Volume 3, Appendix 9.3 (document reference 6.3.9.3).
	"Many individual wildlife species receive statutory protection under a range of legislative provisions. Other species and habitats have been identified as being of principal importance for the conservation of biodiversity in England and Wales, as well as for their continued benefit	All species receptors, including those of principal importance for the conservation of biodiversity in the North Sea, are summarised in Table 10.6 (full description in 3 (document reference 6.3.9.3).

Legislation/policy	Key provisions	Section where comment addressed
	for climate mitigation and adaptation and thereby requiring conservation action." (paragraph 5.4.16 of NPS EN-1) The Secretary of State should ensure that species and habitats identified as being of importance for the conservation of biodiversity are protected from the adverse effects of development by using requirements, planning obligations, or licence conditions where appropriate. (paragraph 5.4.54 of NPS EN-1). The Secretary of State should refuse consent where harm to the habitats or species and their habitats would result, unless the benefits (including need) of the development outweigh that harm. In this context the Secretary of State should give substantial weight to any such harm to the detriment of biodiversity features of national or regional importance or the climate resilience and the capacity of habitats to store carbon, which it considers may result from a proposed development. (paragraph 5.4.55 of NPS EN-1).	
	"Where the development is subject to Environmental Impact Assessment (EIA) the applicant should ensure that the Environmental Statement (ES) clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance (including those outside England), on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity, including irreplaceable habitats. (paragraph 5.4.17 of NPS EN-1).	The potential effects of the Project have been assessed regarding international, national and local sites designated for ecological features of conservation importance (see Section 10.6).
	"The applicant should show how the project has taken advantage of opportunities to conserve and enhance biodiversity and geological conservation interests." (Paragraphs 5.4.19 NPS EN-1). "Applicants should consider wider ecosystem services and benefits of natural capital when designing enhancement measures." (Paragraphs 5.4.20 NPS EN-1). "As set out in Section 4.7, the design process should embed opportunities for nature inclusive design. Energy infrastructure projects have the	Consideration has been given to the use of ecoengineering or methods to enhance biodiversity, and geological interests, where technologies exist which are sufficient to ensure the integrity of the infrastructure (Volume 1, Chapter 9,

Legislation/policy	Key provisions	Section where comment addressed
	potential to deliver significant benefits and enhancements beyond Biodiversity Net Gain (BNG), which result in wider environmental gains (see Section 4.6 on Environmental and BNG). The scope of potential gains will be dependent on the type, scale, and location of each project.” (Paragraphs 5.4.21 NPS EN-1).	Benthic Subtidal and Intertidal Ecology (document reference 6.1.9)).
	“The design of energy Nationally Significant Infrastructure Project (NSIP) proposals will need to consider the movement of mobile/migratory species such as birds, fish and marine and terrestrial mammals and their potential to interact with infrastructure. As energy infrastructure could occur anywhere within England and Wales, both inland and onshore and offshore, the potential to affect mobile and migratory species across the United Kingdom (UK) and more widely across Europe (transboundary effects) requires consideration, depending on the location of development.” (Paragraphs 5.4.22 NPS EN-1).	The potential for transboundary effects on Annex II migratory fish species listed as features of European sites in European Economic Area (EEA) States and on fish and shellfish receptors in EEA States have been assessed in Section 10.9 of this chapter.
NPS EN-1	“Applicants should include appropriate avoidance, mitigation, compensation and enhancement 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; ▪ the timing of construction has been planned to avoid or limit disturbance; ▪ 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	Designed-in measures to be adopted as part of the Project are presented in Table 10.8.

Legislation/policy	Key provisions	Section where comment addressed
	▪ opportunities will be taken to enhance existing habitats rather than replace them, and where practicable, create new habitats of value within the site landscaping proposals. Where habitat creation is required as mitigation, compensation, or enhancement the location and quality will be of key importance. In this regard habitat creation should be focused on areas where the most ecological and ecosystems benefits can be realised; ▪ mitigations required as a result of legal protection of habitats or species will be complied with.(paragraph 5.4.35 of NPS EN-1)	
	"In the marine environment, applicants should consider noise impacts on protected species, both at the individual project level and in-combination with other marine activities." (paragraph 5.12.11 of NPS EN-1) "Applicants should submit a detailed impact assessment and mitigation plan as part of any development plan, including the use of noise mitigation and noise abatement technologies during construction and operation." (paragraph 5.12.12 of NPS EN-1)	A full assessment of underwater noise on fish and shellfish receptors is provided in Section 10.6. The assessment of underwater noise impacts in-combination with other marine activities is provided in Section 10.7. A piling Marine Mammal Mitigation Programme (MMMP) will be developed and implemented during construction following the principles set out in the Outline MMMP (document reference 8.5). Whilst the implementation of a MMMP is not aimed at fish and shellfish receptors, the measures detailed within it (such as soft start procedures) will provide benefit to mobile fish receptors. Embedded mitigation in relation to fish and shellfish ecology is provided in Table 10.8.
NPS EN-3 (2023)	"Applicants must undertake a detailed assessment of the offshore ecological, biodiversity and physical impacts of their proposed development, for all phases of the lifespan of that development, in	Construction, Operation and Maintenance (O&M) and decommissioning phases of the

Legislation/policy	Key provisions	Section where comment addressed
	accordance with the appropriate policy for offshore windfarm EIAs, Habitats Regulations Assessment (HRAs) and MCZ assessments." (paragraph 2.8.101 of NPS EN-3, also see Sections 4.3 and 5.4 of EN-1). "Applicants need to consider environmental and biodiversity net gain as set out in Section 4.6 of EN-1 and the Environment Act 2021." (paragraph 2.8.102 of NPS EN-3).	Project have been assessed in Section 10.6.
	"Applicants should consult at an early stage of pre-application with relevant statutory consultees and energy not-for-profit organisations/non-governmental organisations, as appropriate, on the assessment methodologies, baseline data collection, and potential avoidance, mitigation and compensation options should be undertaken." (paragraph 2.8.94 of NPS EN-3).	Consultation with relevant statutory and non-statutory stakeholders has been carried out from the early stages of the Project (see Section 10.3 for a summary of consultation regarding fish and shellfish).
	"Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore windfarms should be referred to where appropriate" (paragraph 2.8.96 of NPS EN-3).	Relevant data collected as part of post-construction monitoring from other Offshore Wind Farm (OWF) projects has informed the assessment (see Table 10.5).
	"Applicants should assess the potential of their proposed development to have net positive effects on marine ecology and biodiversity as well as negative." (paragraph 2.11.40)	The assessment methodology includes the provision for assessment of both positive and negative effects (see Table 10.11).
	"Careful design and siting of the development is likely to be the primary form of impact mitigation, along with the choice of construction and installation techniques" (paragraph 2.11.45 of NPS EN-3).	Embedded mitigation relevant to the fish and shellfish ecology chapter is detailed in Table 10.8.
	"Applicants must develop an ecological monitoring programme to monitor impacts during the pre-construction, construction and operational phases to identify the actual impacts caused by the project and compare them to what was predicted in the EIA/HRA.". (paragraph 2.8.221 of NPS EN-3).	The requirement for fish and shellfish monitoring has been considered within the impact assessments in Section 10.6. In summary, no fish and shellfish monitoring for the construction, O&M or

Legislation/policy	Key provisions	Section where comment addressed
		decommissioning phases of the Project is considered necessary.
	"The Secretary of State should consider the effects of a proposed development on marine ecology and biodiversity, considering all relevant information made available by the applicant." (paragraph 2.8.292 of NPS EN-3).	Designated sites within the region have been identified in Section 10.4 as appropriate, and any potential impacts to features of the sites have been assessed in Section 10.6.
	"The applicant should identify fish species that are the most likely receptors of impacts with respect to: ▪ spawning grounds ▪ nursery grounds ▪ feeding grounds ▪ over-wintering areas for crustaceans ▪ migration routes ▪ protected areas" (paragraph 2.8.140 of NPS EN-3).	The key receptors of impacts are listed in Table 10.6. Consideration of receptors with regards to spawning grounds, nursery grounds, feeding grounds, over-wintering areas and migration routes has been given, with those receptors of potential sensitivity to impacts from the development of the Project assessed within Section 10.6.
	"Applicant assessments should identify potential implications of underwater noise from construction and unexploded ordnance including, where possible, implications of predicted construction and soft start noise levels in relation to mortality, Permanent Threshold Shift (PTS), Temporary Threshold Shift (TTS) and disturbance and addressing both sound pressure and particle motion) and Electromagnetic Field (EMF) on sensitive fish species." (paragraph 2.8.141 of NPS EN-3).	Potential implications from underwater noise and EMF on fish and shellfish receptors have been assessed in Section 10.6, Impacts 1 and 10.
	"Applicants should undertake a review of up-to-date research and present all potential avoidance reduction and mitigation options presented for all receptors." (paragraph 3.8.205 of NPS EN-3). "EMF in the water column during operation, is in the form of electric and magnetic fields, which are reduced by use of armoured cables for inter-array and export cables." (Paragraph 2.8.235 of NPS EN-3	The development impacts of EMF on fish and shellfish receptors have been considered in Section 10.6, Impact 10. Where possible, cables will be buried but, if not, cable protection will be installed (see Table 10.8).

Legislation/policy	Key provisions	Section where comment addressed
	"Burial of the cable increases the physical distance between the maximum EMF intensity and sensitive species. However, what constitutes sufficient depth to reduce impact may depend on the geology of the seabed." (Paragraph 2.8.236 of NPS EN-3 "It is unknown whether exposure to multiple cables and larger capacity cables may have a cumulative impact on sensitive species. It is therefore important to monitor EMF emissions which may provide the evidence to inform future EIAs." (paragraph 2.8.237 of NPS EN-3).	
	"Construction of specific elements can also be timed to reduce impacts on spawning or migration. Underwater noise mitigation can also be used to prevent injury and death of fish species." (paragraph 2.8.239 of NPS EN-3).	Due consideration to the potential for impacts from underwater noise on spawning and migration of relevant species is given in in Section 10.6
NPS EN-5 (2023)	"Adverse impacts on Marine Protected Areas (MPAs) have caused. consenting delays, and in some cases a need for compensatory measures under the Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Habitats and Species Regulations 2017, or measures of equivalent environmental benefit under the Marine and Coastal Access Act 2009. Therefore, applicants should consider and address routing and avoidance/minimisation of environmental impacts both onshore and offshore at an early stage in the development process. Applicants should also facilitate delivery of strategic compensation measures where appropriate." (paragraph 2.14.1 of NPS EN-5).	Designated nature conservation sites within the Project study area have been detailed in Appendix 10.1 (document reference 6.3.10.1) and are summarised in Section 10.4. The potential for impacts to fish and shellfish features of MPAs have been assessed in Section 10.6
	"In the assessments of their designs, applicants should demonstrate; ▪ how environmental, community and other impacts have been considered and how adverse impacts have followed the mitigation hierarchy i.e. avoidance, reduction and mitigation of adverse impacts through good design;	A Project Environmental Management Plan (PEMP) will be produced, in line with the Outline PEMP (document 8.4) prior to construction and followed to cover all phases of the Project (see Table 10.8: Embedded mitigation relating to fish and shellfish ecology).

Legislation/policy	Key provisions	Section where comment addressed
	▪ how the mitigation hierarchy has been followed, in particular to avoid the need for compensatory measures for coastal, inshore and offshore developments affecting SACs SPAs, and Ramsar sites and MCZs (as set out in EN-3 2.8)." (paragraph 2.14.2 of NPS EN-5).	

8. Guidance has been provided, within the Marine Strategy Framework Directive (MSFD, which has been considered in this assessment. The relevance of the MSFD to the Project is described in Chapter 2 (document reference 6.1.2).
9. The overarching aim of the MSFD is to achieve ''Good Environmental Status'' (GES), across Europe's marine environment. Annex I of the MSFD identifies 11 high level qualitative descriptors for determining GES, with those relevant to the fish and shellfish ecology assessment for the Project outlined in Table 10.2, with a brief description of how and where these have been addressed in this assessment.

Table 10.2: Summary of the MSFDs high level descriptors of GES relevant to fish and shellfish ecology and consideration in the Project assessment.

Legislation/Policy	Key provisions	Section where comment addressed
Marine Strategy Framework Directive (MSFD)	Descriptor 1 – Biological diversity: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic, and climatic conditions.	The effects on biological diversity have been described and considered within the Impact Assessment for the Project alone (Section 10.6) and the Cumulative Impact Assessment (CIA) (Section 10.7).
MSFD	Descriptor 2 – Non-indigenous species: Non-indigenous species introduced by human activity are at levels that do not adversely alter the ecosystems.	Impacts from Invasive Non-Native Species (INNS) were scoped out in the scoping stage (Outer Dowsing Offshore Wind, 2022).
MSFD	Descriptor 3 – Commercial species: Population of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.	Potential effects on commercial fish and shellfish species have been described and considered within the Impact Assessment for the Project alone (Section 10.6) and the Cumulative Impact Assessment (CIA) (Section 10.7).
MSFD	Descriptor 4 – Elements of marine food web: All elements of marine food webs, to the extent 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, inclusive of the interlinkages with interdependent ecological receptors described in other chapters is integral within this chapter and the wider Environmental Statement (ES) with inter relationships described where appropriate.
MSFD	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, inclusive of any risk to ecological integrity, has been described and considered within the Impact Assessment for the Project alone (Section 10.6) and the CIA (Section 10.7).

Legislation/Policy	Key provisions	Section where comment addressed
MSFD	Descriptor 7 – Permanent alteration of hydrographical conditions does not adversely affect the marine ecosystems.	The effects on hydrographical conditions have been assessed in Chapter 7 (document reference 6.1.7), which concluded no significant effects. Therefore, the potential for impacts on fish and shellfish receptors from the alteration of hydrographical conditions have not been considered in this assessment.
MSFD	Descriptor 8 – Contaminants: Concentrations of contaminants are at levels not giving rise to pollution effects.	The effects of contaminants on fish and shellfish and species have been assessed in Section 10.6, Impact 4.
MSFD	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 and species have been assessed in Section 10.6, Impact 4.
MSFD	Descriptor 10 – Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	A Project Environmental Management Plan (PEMP) will be produced prior to construction and followed to cover all phases of the Project (see Table 10.8: Embedded mitigation relating to fish and shellfish ecology.). The PEMP will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details (e.g., EA and Maritime and Coastguard Agency (MCA)). A Decommissioning Programme (DP) will be developed to cover the decommissioning phase.

Legislation/Policy	Key provisions	Section where comment addressed
MSFD	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 have been assessed in Section 10.6, Impact 1.

10. The assessment of potential changes to fish and shellfish ecology has also been made with consideration to the specific policies set out in the East Inshore and East Offshore Marine Plans (Department for Environment, Food and Rural Affairs (Defra), 2014). Key provisions are set out in Table 10.3 along with details as to how these have been addressed within the EIA.

Table 10.3: East Marine Plan Policies of relevance to fish and shellfish ecology.

Legislation/policy	Key provisions	Section where comment addressed
East Inshore and East Offshore Marine Plans	Policy 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 10.7.
	Policy BIO1- Appropriate weight should be attached to biodiversity, reflecting the need to protect biodiversity as a whole, taking account of the best available evidence including on habitats and species that are protected or of conservation concern in the East marine plans and adjacent areas (marine, terrestrial).	Due consideration to the baseline characterisation of the site has been given in Appendix 10.1 (document reference 6.3.10.1), which is informed by the best available evidence, inclusive of consideration of protected or conservation species. This is summarised in Section 10.4. Potential impacts on protected or conservation species have been assessed in Sections 10.6 and 10.7.
	Policy BIO2- Where appropriate, proposals for development should incorporate features that enhance biodiversity and geological interests.	Consideration has been given to the use of ecoengineering or methods to enhance biodiversity, and geological interests, with the inclusion of ecological scour and cable protection within the project design which could be used if this is considered appropriate following consultation with Natural England (see document 6.1.3 for more detail).
	Policy FISH2- Proposals should demonstrate, in order of preference: ▪ that they will not have an adverse impact upon spawning and nursery areas and any associated habitat; ▪ how, if there are adverse impacts upon the spawning and nursery areas and any associated habitat, they will minimise them;	Potential impacts on fish and shellfish receptors have been assessed in Sections 10.6 and 10.7, and embedded mitigation detailed in Table 10.8. To summarise, there are no significant effects concluded on fish and shellfish receptors, therefore no additional mitigation measures (other than the embedded mitigation) are proposed.

Legislation/policy	Key provisions	Section where comment addressed
	▪ how, if the adverse impacts cannot be minimised they will be mitigated; ▪ the case for proceeding with their proposals if it is not possible to minimise or mitigate the adverse impacts.	
	Policy SOC3- Proposals that may affect the terrestrial and marine character of an area should demonstrate, in order of preference: ▪ that they will not adversely impact the terrestrial and marine character of an area; ▪ how, if there are adverse impacts on the terrestrial and marine character of an area, they will minimise them; ▪ how, where these adverse impacts on the terrestrial and marine character of an area cannot be minimised, they will be mitigated against; ▪ the case for proceeding with the proposal if it is not possible to minimise or mitigate the adverse impacts.	The current marine character regarding fish and shellfish ecology aspects of the site has been detailed in Appendix 10.1 (document reference 6.3.10.1). Due regard has also been given to the Seascape Character Assessment (MMO, 2012) of the marine plan areas. Potential impacts that may affect the fish and shellfish ecology marine character of the Marine Plan areas (namely fish and shellfish spawning and nursery grounds and habitats) have been assessed in Section 10.6. Potential effects on the fishing heritage character of the marine plan areas have been assessed in Chapter 14 (document reference 6.1.14). To summarise, there are no significant effects concluded on fish and shellfish receptors, therefore no additional mitigation measures are proposed (other than those provided as embedded mitigation measures in Table 10.8).
	Policy 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 Project study area have been detailed in Appendix 10.1 (document reference 6.3.10.1) and are summarised in Section 10.4. The potential for impacts to fish and shellfish features of MPAs have been assessed in Section 10.6. The potential for hindrance of the conservation objectives of Marine

Legislation/policy	Key provisions	Section where comment addressed
		Conservation Zones (MCZs) has been assessed in Volume 3, Appendix 9.4: Marine Conservation Zone Assessment (document reference 6.3.9.4). The potential for significant effects on the National Site Network has been assessed in Part 7, Document 7.2: Habitat Regulations Assessment.

10.3 Consultation

11. Consultation is a key part of the Development Consent Order (DCO) application process. Consultation regarding fish and shellfish ecology has been conducted through the Evidence Plan Process (EPP), Expert Topic Group (ETG) meetings, public information events, the EIA scoping process (Outer Dowsing Offshore Wind, 2022) and the Preliminary Environmental Information Report (PEIR) process (Outer Dowsing Offshore Wind, 2023). An overview of the consultation undertaken for the Project is presented in Volume 1, Chapter 6 (document reference 6.1.6) and wider consultation is presented in the Consultation Report (document reference 5.1).
12. A summary of the key issues raised during consultation to date, specific to fish and shellfish ecology, is outlined in Table 10.4 below, together with how these issues have been considered in the production of this ES.

Table 10.4: Summary of consultation relating to fish and shellfish ecology.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Pre-scoping Evidence Plan meeting		
Marine Ecology & Coastal Processes Expert Topic Group (ETG) (11 January 2022)	Centre for Environment, Fisheries and Aquaculture (Cefas) noted there were no proposed fisheries surveys, and queried what data are being used. Confirmed that the age of data from Triton Knoll is becoming outdated for fisheries.	Further developer surveys which overlap with the Project study area as well as site-specific survey data have been used to characterise the fish and shellfish baseline environment. See Appendix 10.1 (document reference 6.3.10.1) for the detailed fish and shellfish technical baseline and Section 10.4 of this chapter for a summary of the baseline.
Marine Ecology & Coastal Processes ETG (11 January 2022)	Cefas is not comfortable with the scoping out of direct damage impacts due to herring and sandeel and requested that these are scoped in.	Impacts from direct damage have been scoped into the assessment. See Section 10.6, Impacts 5 and 15 of this chapter for an assessment of the potential impacts from direct damage on fish and shellfish receptors.
Scoping Opinion		
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 2.1.4	The Inspectorate notes the intention to seek consent for Unexploded Ordnance (UXO) removal through a future Marine Licence application but that the effects of removal of UXO will be considered as part of the EIA process for the Development Consent Order (DCO) application. The Environmental Statement (ES) should address any cumulative effects from the construction of the Proposed Development with the likely effects from the UXO clearance.	Consideration of underwater noise effects on fish and shellfish receptors from piling and UXO clearance can be found within Section 10.6.
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.1	Accidental pollution–- Construction, Operations and Maintenance (O&M) and Decommissioning The Scoping Report proposes to scope out accidental pollution resulting from all phases of the Proposed Development. The Inspectorate agrees that such	Details on proposed embedded mitigation and their securement are provided in Table 10.8.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	effects are capable of being mitigated through standard management practices and can be scoped out of the assessment. The ES should provide details of the proposed mitigation measures to be included in the PEMP/Project Environmental Management Plan (PEMP) and its constituent Marine Pollution Contingency Plan (MPCP). The ES should also explain how such measures will be secured.	
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.2	Direct disturbance resulting from O&M activities–-O&M The Scoping Report states that this is to be scoped out based on the limited spatial extent and length of time of disturbing activities during O&M. The Inspectorate accepts that maintenance activities are likely to be of lower impact than construction; however, in the absence of any information as to the nature, duration, frequency, and extent of O&M activities, the Inspectorate is unable to agree to scope out such effects at this stage. The ES should include an assessment of the effects or provide evidence demonstrating agreement with the relevant consultation bodies that significant effects are not likely to occur.	Impacts from direct disturbance on fish and shellfish receptors during the operation and maintenance phase have been assessed in Section 10.7, Impact 9 of this chapter.
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.3	Impacts on fishing pressure due to displacement–-Construction, O&M and Decommissioning The Scoping Report states that information will be collected as part of the Commercial Fisheries aspect chapter of the ES; however, as operational disturbance will be limited in spatial extent, with the risk of	Impacts on fishing pressure due to displacement have been scoped out of the assessment as potential impacts on commercial fisheries have been assessed within Chapter 14 (document reference 6.1.14).

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	displacement considered minor, the Applicant proposes to scope out assessment of impacts from fishing pressure due to displacement. On the basis that potential impacts on fishing pressure will be included and assessed in the Commercial Fisheries aspect chapter of the ES, the Inspectorate is content for this matter to be scoped out of the Fish and Shellfish Ecology assessment.	
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.4	<u>Cumulative effects</u> The Scoping Report states that, impacts scoped into the assessment for the Project alone, are generally spatially restricted to within the near field of the array and the offshore Export Cable Corridor (ECC) and that, with the exception of those impacts identified in Table 7.4.4, it is proposed that all other impacts with limited spatial extent, where not having an effect on a designated species, site or feature, are scoped out of further assessment in the ES. The Inspectorate agrees that where there are no likely significant effects on fish and shellfish receptors that could occur alone or cumulatively with other projects or plans, these can be scoped out of the assessment.	Impacts from cumulative underwater noise impacts and cumulative increases in Suspended Sediment Concentration (SSC) and sediment deposition on fish and shellfish receptors have been assessed in Section 10.7 of this chapter. Impacts with limited spatial extents have been scoped out of the cumulative impacts assessment as agreed.
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.5	<u>Transboundary effects</u> Transboundary effects on fish and shellfish receptors are proposed to be scoped out on the basis that the impacts of the Proposed Development are localised in nature (including those giving rise to the greatest footprint of effect such as underwater noise from piling). The Scoping Report includes a discussion about	The potential for transboundary effects on Annex II migratory fish species listed as features of European sites in other EEA States and on fish and shellfish receptors in EEA States have been assessed in Section 10.9 of this chapter.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	migratory fish, including United Kingdom (UK) designated sites and migratory species of conservation concern; however, the Scoping Report does not discuss whether the Proposed Development would have the potential to impact Annex II migratory fish species listed as features of European sites in other European Economic Area (EEA) States. The ES should clarify whether activities associated with the Proposed Development could have the potential to impact Annex II migratory fish species listed as features of European sites in other EEA States and assess transboundary effects on fish and shellfish receptors in EEA States, where likely significant effects could occur or provide further justification to support the scoping out of transboundary effects.	
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.6	<u>Baseline data and site surveys</u> The Scoping Report identifies extensive baseline data for fish and shellfish available from existing literature and surveys and thus no additional site-specific fish and shellfish surveys are proposed, although site-specific geophysical survey and grab samples which will be analysed for spawning habitat potential for species such as herring (*Clupea harengus*) and sandeel. Whilst the Inspectorate acknowledges the numerous data sources available to inform the fish and shellfish assessment, it notes that, with the exception of one, the OWF data listed sources do not cover the array or cable corridor Area of Search (AoS) and a number are over 10 years old. The Applicant should ensure that the	Although the Marine Management Organisation (MMO) were content that there was no requirement for new fish characterisation surveys to be undertaken (comment ID 3.4.4 detailed below), site-specific surveys (inclusive of grab sampling, epibenthic trawls and Environmental DNA (eDNA) sampling) have been undertaken to ground truth existing data sources. These surveys are summarised in Table 10.5, and have been used to inform the baseline within Appendix 10.1 (document reference 6.3.10.1), and the assessments undertaken in Section 10.6.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	baseline data used in the ES assessments are sufficiently up-to-date to provide a robust baseline. The ES should provide evidence to justify that the largely desk-based data constitutes a robust characterisation of the receiving environment, with reference to the date, seasonal period and geographic coverage of the data. It is recommended the Applicant makes use of the EPP to seek to agree the use and extent of existing data with relevant consultation bodies.	
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.7	<u>Nursery and spawning ground assessment and figures</u> The key to the nursery and spawning grounds for individual species on Figures 7.4.3 and 7.4.4 is not clear. The Applicant should ensure clear figures are provided in the ES. The Applicant's attention is directed to the comments of the Marine Management Organisation (MMO) at Appendix 2 of this Opinion with regards to the assessment of herring and sandeel potential spawning habitat and recommendations for the assessment methodology, together with the comments of Natural England with regards to potential mitigation for herring. The Applicant should seek to agree the baseline data and assessment methodology for the assessment of effects on fish spawning grounds with the relevant consultation bodies, including the MMO, Natural England and the Environment Agency (EA), as part of the EPP.	Nursery and spawning ground figures have been revised accordingly. Please see Volume 2, Figures 10.2 to 10.9. The baseline data and assessment methodology has been agreed with stakeholders through the evidence plan process.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.8	<u>Noise propagation modelling</u> The Scoping Report contains very limited information with regards to the noise modelling proposed to inform the fish and shellfish ecology assessment, although the Inspectorate notes and welcomes the intention to discuss the model and parameters as part of the EPP. The ES, and/or accompanying appendices, should provide details of the noise modelling used to inform the impact assessment.	Further details on noise modelling used to inform the impact assessment can be found in Volume 3, Appendix 3.2: Underwater Noise Assessment (document reference 6.3.3.2).
Scoping Opinion (The Inspectorate, 9 September 2022) Comment ID: 3.4.9	<u>Impacts on prey availability</u> The ES should assess impacts on prey availability for birds at designated sites, where significant effects are likely to occur. Appropriate cross-references should be included between aspect chapters.	Impacts on key prey species of birds at designated sites (such as sandeel) have been assessed within Section 10.6. Indirect impacts on bird species due to impacts on prey availability are assessed in Volume 1, Chapter 12: Intertidal and Offshore Ornithology (document reference 6.1.12).
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.1	<u>Baseline data and site surveys</u> Table 7.4.1. outlines the list of existing data sources and literature that will be used to inform the fish ecology baseline. The sources are generally appropriate to characterise the study area, however, please note comments 3.4.2-3.4.4 below.	See below for responses to comments 3.4.2-3.4.4.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.2	<u>Baseline data and site surveys</u> The PEIR should recognise the limitations of the data collected for fish characterisation surveys (e.g., Lynn, Inner Dowsing and Lincs OWFs, Hornsea Zonal Characterisation, and Triton Knoll OWF) which are now in excess of 10 years old. These surveys were carried out prior to the placement and operation of OWF infrastructure. Factors such as loss of habitat,	Site-specific surveys (inclusive of grab sampling, epibenthic trawls and eDNA sampling) have been undertaken to ground truth existing data sources. These surveys are summarised in Table 10.5, and have been used to inform the baseline within Appendix 10.1 (document reference 6.3.10.1), and the assessments undertaken in Section 10.6.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	introduction of hard substrates, and temporal and natural variations in fish assemblages may have changed over this period.	
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.3	<u>Baseline data</u> When using any fisheries data collected from past surveys, it is important that the data are interpreted and presented appropriately and that all survey limitations are acknowledged. Any catch data should be presented in the ES and ES in standardised units, e.g., Catch Per Unit Effort (CPUE). The survey methods, timings and limitations of survey and gear types as well as gear selectivity should be discussed or acknowledged within the PEIR especially with regard to the influence on species and life stages captured by individual gear types/sampling methods. For example, a 2m epibenthic beam trawl will not adequately target large/adult fish, or pelagic fish; otter trawls and epibenthic beam trawls will not adequately target sandeels; and the season in which a survey is undertaken may influence species abundance in that particular area.	This is noted. Abundance data used to inform the baseline environment in Section 10.4. are only referenced to as presence/absence to avoid any concern with relative abundances. Limitations of data sources are addressed in Section 10.5.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.4	<u>Baseline data and site surveys</u> Despite the age of some data sources, the MMO is generally content that there is no requirement for new fish characterisation surveys to be undertaken, as the various sources of data proposed to inform the desk-based assessment will be adequate to provide a general description of the fish species typically found in the Project study area. We note that a site-specific benthic	Site-specific surveys (inclusive of grab sampling, epibenthic trawls and eDNA sampling) have been undertaken to ground truth existing data sources. These surveys are detailed in Table 10.5, and have been used to inform the baseline within Appendix 10.1 (document reference 6.3.10.1). They are summarised in Section 10.4 and have been used to inform the assessments presented in Section 10.6.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	survey of the study area will be undertaken which will include grab sampling of seabed sediments which will be used for Particle Size Analysis (PSA). PSA data can then be used to determine sandeel habitat suitability and herring spawning habitat suitability.	
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.5	The MMO agrees with the potential impacts that have been identified and scoped in for fish ecology and fisheries receptors in relation to construction, operation and maintenance (O&M), decommissioning and cumulative impacts. Given the location of the project in relation to the nearest international boundaries, the MMO agrees that transboundary impacts can be scoped out for further assessment.	Potential impacts from transboundary effects on fish and shellfish receptors have been scoped into the assessment following scoping responses from the Inspectorate. These are assessed in Section 10.9.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.6	Impacts arising from accidental pollution during the construction, O&M and decommissioning phases have been scoped out of further assessment, on the basis that a PEMP will be implemented to manage and mitigate any pollution events. The MMO does not support the scoping out of impacts arising from direct disturbance resulting from O&M activities. The justification that the impacts will be limited in spatial extent and length of time cannot be supported until the spatial extent of the impacts in relation to specific species and/or habitats has been assessed.	This is noted and impacts from accidental pollution are scoped out of the assessment. Impacts arising from direct disturbance resulting from O&M activities have been scoped into the assessment and are assessed in Section 10.6, Impact 9.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.7	The MMO has no objection to impacts on fishing pressure due to displacement being scoped out during all phases of the Project Construction, O&M, and Decommissioning, in relation to Fish Ecology.	Potential impacts to fishing pressure are scoped out of this assessment. Potential impacts to commercial fisheries as a result of the development are assessed in Chapter 14 (document reference 6.1.14).

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.8	The Scoping Report recognises that there are a number of herring spawning grounds in the vicinity of the study area. However, it is unclear how many years of International Herring Larvae Survey (IHLS) data were used to provide the larvae heat map shown in Figure 7.4.2. This should be clearly stated in the PEIR. An assessment of herring potential spawning habitat should be undertaken to inform the EIA, using the method described in MarineSpace (2013a). The assessment should be supported by 10 years of IHLS data (up to 2021 data are available). The applicant is intending to undertake a programme of geophysical and benthic sampling across the Project study area in order to characterise the seabed. PSA data from these surveys can be used to inform the potential herring spawning habitat assessment following the MarineSpace (2013a) method.	The herring larvae heat maps have used IHLS data from 2009/2010 – 2022/2023. Description of the PSA data can be found in Section 10.4, along with classifications for herring spawning habitat using Reach *et al*. (2013).
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.9	The commercial and ecological importance of sandeel as prey for fish, birds and marine mammals has been recognised in the Scoping Report and it is acknowledged that the study area overlaps with sandeel habitat. Sandeel spawn in the same areas that they inhabit, show site fidelity to defined areas of seabed and do not tend to travel to other locations to spawn. As with herring, an assessment of sandeel habitat suitability habitat should be undertaken to inform the EIA, using the method described in MarineSpace (2013b) using site specific PSA data that will be collected during the benthic surveys. Any	Description of the PSA data can be found in Section 10.4, along with classifications for herring spawning habitat using Latto *et al*. (2013), these are presented in Volume 2, Figures 10.19 to 10.21. Presence of sandeel in site-specific grab sampling, camera transects and epibenthic trawls is discussed in Section 10.4, and presented in Volume 2, Figures 10.18.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	catches of sandeel observed in benthic grabs can provide anecdotal evidence of their presence in the array and export cable route areas.	
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.10	The Scoping Report states a cable burial risk assessment will be undertaken for cable protection and states that all cables will be buried where possible to reduce the risk of EMF impacts on sensitive receptors. The MMO supports these embedded mitigation measures and recommend that all cables are buried to a minimum depth of 1.5m (subject to local geology and obstructions) to minimise the effects of EMF, as recommended in the Department of Energy and Climate Change report (2011).	This is welcomed by the Project, and embedded mitigation measures with relevance to fish and shellfish ecology have been summarised in Table 10.8.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.11	The MMO supports the use of soft-start procedures on commencement of piling. A 20-minute soft-start in accordance with Joint Nature Conservation Committee (JNCC) protocol for minimising the risk to injury to marine mammals and other fauna from piling noise (JNCC, 2010). Should piling cease for a period greater than 10 minutes, then the soft-start procedure must be repeated.	A piling MMMP will be developed and implemented during construction, following the principles set out in the Outline MMMP (document reference 8.5). This is included in Table 10.8. Whilst the implementation of a MMMP is not aimed at fish and shellfish receptors, the measures detailed within it (such as soft start procedures) will provide benefit to mobile fish receptors.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.12	The MMO notes that the applicant is proposing to undertake underwater noise modelling. We recommend that fish are treated as stationary receptors in any modelling used to make predictions for noise propagation on fish spawning and nursery grounds. The MMO does not support the use of a fleeing animal model for fish due to the reasons outlined below, in paragraph 3.4.13.	Underwater noise modelling has been carried out on fish as both stationary and fleeing receptors to ensure the full range of responses are modelled. This approach was agreed with stakeholders in the Marine Ecology & Coastal Processes ETG 12/10/22. The assessment of potential impacts from underwater noise on fish and shellfish receptors has been undertaken in Section 10.6, Impact 1.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.13	Fish respond to loud noise and vibration, through observed reactions including schooling more closely; moving to the bottom of the water column; swimming away; and burying in substrate (Popper *et al*., 2014). However, this is not the same as fleeing, which would require a fish to flee directly away from the source over the distance shown in the modelling. We are not aware of scientific or empirical evidence to support the assumption that fish will flee in this manner. The assumption that a fish will flee from the source of noise is overly simplistic as it overlooks factors such as fish size and mobility, biological drivers, and philopatric behaviour which may cause an animal to remain/return to the area of impacts. This is of particular relevance to herring, as they are benthic spawners which spawn in a specific location due to its substrate composition.	Underwater noise modelling has been carried out on fish as both stationary and fleeing receptors to ensure the full range of responses are modelled. This approach was agreed with stakeholders in the Marine Ecology & Coastal Processes ETG 12/10/22. The assessment of potential impacts from underwater noise on fish and shellfish receptors has been undertaken in Section 10.6, Impact 1.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.14	Eggs and larvae have little to no mobility, which makes them vulnerable to barotrauma and developmental effects. Accordingly, they should also be assessed and modelled as a stationary receptor, as per the Popper *et al*. (2014) criteria.	Eggs and larvae have been assessed and modelled as a stationary receptor within the underwater noise assessment in Section 10.6, Impact 1.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.15	It should be clearly stated in the PEIR whether simultaneous piling is proposed to be undertaken, i.e., the installation of more than one pile at a time, for the installation of Wind Turbine Generators (WTGs) or other offshore platform structures. If simultaneous piling is proposed, then underwater noise modelling for impacts to fish must be based on this scenario.	Both simultaneous piling and sequential piling events within 24-hours are included in the project design. Therefore, potential impacts from the simultaneous piling of foundations and sequential piling events in 24-hours on fish and shellfish receptors have been assessed within Section 10.6, Impact 1.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.4.16	For the assessment of potential impacts to herring, ten years of IHLS data (2011– 2021) should be presented in the form of a 'heat map' which should be overlaid with the mapped noise contours from the modelling. This will provide a better understanding of the likely extent of noise propagation into herring spawning grounds and allow for a more robust assessment of impacts to be made.	Ten full years of IHLS data (2009/2010-2022/2023) are used to inform the baseline and assessment in Section 10.6. These data are presented in the form of a 'heat maps' (Volume 2, Figures 10.14 to 10.17).
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.5.1	As stated above, the ES should recognise the limitations of the data collected for fish characterisation surveys (e.g., Lynn, Inner Dowsing and Lincs OWFs, Hornsea Zonal Characterisation, and Triton Knoll OWF) which are now in excess of 10 years old. Further to this point, some cephalopods, such as squids, have shown expanding spatial ranges through the North Sea in recent years (van der Kooij *et al*., 2016). Given the timeliness of the data sources, it is unlikely that such shellfish groups will be identified in the surveys listed, though it is noted that commercial landings data have been used, which does provide recent data of squids, and 'mixed squids and octopi' grouped together.	Data limitations are addressed in Section 10.5 where it is noted that the methods of surveying for fish and shellfish species vary in their efficiency at capturing different species.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.5.2	Some surveys listed in Table 7.4.1 (such as the Hornsea One Benthic Subtidal Survey, and the Hornsea Project One Array Survey) uses epibenthic beam trawls. Whilst beam trawls may be suitable for capturing cuttlefish (typically *Sepia officinalis*), the gear type is unsuitable for capture of other shellfish (whelks *Buccinum undatum* are caught using specialised whelk pots, crabs *Cancer pagurus* and lobster *Homarus 43ammarus* are	Data limitations are addressed in Section 10.5 where it is noted that the methods of surveying for fish and shellfish species vary in their efficiency at capturing different species. Shellfish caught using epibenthic beam trawls are therefore only considered as indicative of presence/absence.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	caught using pots, scampi / Norway lobster / langoustine / Dublin prawn *Nephrops norvegicus* are caught using otter trawls etc.). As such, any shellfish caught using the epibenthic beam trawls should be considered as indicative of presence/absence only, rather than abundance in the area.	
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.5.3	It is appropriate for impacts arising from accidental pollution during the construction, O&M, and decommissioning phases be scoped out of further assessment, on the basis that a PEMP will be implemented to manage and mitigation any pollution events. However, the scoping out of impacts arising from direct disturbance resulting from O&M activities would be premature at this stage. The justification that the impact/s will be limited in spatial extent and length of time cannot be supported until the spatial extent of the impact/s in relation to specific species and/or habitats has been assessed.	Potential impacts from direct disturbance resulting from the operation of the project have been assessed in Section 10.6.
Scoping Opinion (MMO, 26 August 2022) Comment ID: 3.5.3	Given literature on detrimental effects of underwater noise to various squid species (Jones *et al*., 2020), the use of soft-start procedures is supported on commencement of piling. A 20-minute soft-start is recommended in accordance with JNCC's protocol for minimising the risk of injury to marine mammals and other fauna from piling noise (JNCC, 2010). Should piling cease for a period greater than 10 minutes, then the soft-start procedure must be repeated.	A piling MMMP will be developed and implemented during construction, following the principles set out in the Outline MMMP (document reference 8.5). This is included in Table 10.8. Whilst the implementation of a MMMP is not aimed at fish and shellfish receptors, the measures detailed within it (such as soft start procedures) will provide benefit to mobile fish receptors.
Scoping Opinion (Natural England, 30 August 2022)	Natural England advises Cefas is consulted to review and comment on the Fish and Shellfish section of the	Cefas were consulted via the MMO, to review and comment on the Fish and Shellfish section of the EIA

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Comment ID: 68.	EIA Scoping Report. Please insert information within this section referencing links to other chapters of the report, such as marine mammals and offshore ornithology. Natural England would like to emphasise the need for discussion and consideration for appropriate seasonal restrictions to reduce impacts to commercially/ecologically important fish species within the assessment.	Scoping Report. In addition, consultation with Cefas has been undertaken throughout the Evidence Plan Process. Where appropriate links to other relevant chapters have been made throughout this Chapter. Due consideration of mitigation measures has been made in the event that significant effects on Valued Ecological Receptor (VERs) are concluded following an assessment of impacts on fish and shellfish VERS, which is undertaken in Section 10.6.
Scoping Opinion (Natural England, 30 August 2022) Comment ID: 69.	Natural England advise that designated sites including Flamborough and Filey Coast and the Greater Wash SPAs should be scoped in and the impacts on prey availability referred to/signposted in the Designated Sites section of the report.	Impacts on key prey species of birds at designated sites (such as sandeel) have been assessed within Section 10.6. Indirect impacts on bird species due to impacts on prey availability are assessed in Chapter 12 (document reference 6.1.12).
Scoping Opinion (Lincolnshire Wildlife Trust, 25 August 2022)	Lincolnshire Wildlife Trust (LWT) strongly disagrees with the statement that 'given the significant extent of publicly available data covering fish and shellfish species in the area to enable a robust characterisation of the receiving environment, including identification of relevant valued fish and shellfish receptors, additional site-specific fish and shellfish ecology surveys are not proposed to be undertaken'. LWT would urge that new, site-specific data be collected, as the sources provided are invalid and inappropriate.	The MMO agreed that the baseline datasets identified in the Scoping Report (Outer Dowsing Offshore Wind, 2022) were appropriate for characterisation and the MMO confirmed no need for site-specific surveys. Notwithstanding this, site-specific surveys were undertaken to provide validation of the existing datasets, these include epibenthic trawls, and eDNA sampling. Information on these surveys can be found in Table 10.5.
Scoping Opinion (Lincolnshire Wildlife Trust, 25 August 2022)	While LWT supports the use of current data from International Council for the Exploration of the Sea (ICES), UK Fisheries, Cefas, and European Marine Observation and Data Network (EMODnet), these	The MMO agreed that the baseline datasets identified in the Scoping Report (Outer Dowsing Offshore Wind, 2022) were appropriate for characterisation and the MMO confirmed no need for site-specific surveys.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	datasets are mainly applicable to commercial fish stocks (Section 7.8) and will lack coverage of protected and vulnerable species (e.g., Allis shad, Atlantic salmon, European eel, porbeagle shark, sea lamprey, spotted ray, spurdog, thornback ray, tope shark *Galeorhinus galeus*, twaite shad, and blonde ray; Table 7.4.3). Furthermore, the Scoping Report states that data is 'largely drawn upon work undertaken in support of various windfarm projects in the vicinity of the study area'. However, these datasets are outdated (>5 years old; and in many cases 10–20 years old) and not site-specific to the relevant study area. For example, Table 7.4.1 lists several datasets that are over a decade old, including the six datasets from the Hornsea Project (surveys conducted between 2010 and 2012) and two datasets from the Triton Knoll Project (2008 to 2011). The material evidence provided for species present within the Project array and offshore ECC AoS mainly cite the six datasets taken from the Hornsea Project (2010 to 2012). Moreover, the principal evidence used to inform fish and shellfish species distributions in Table 7.4.2 is over 20 years old, having been published in 2001 following the Hornsea Zone surveys. These datasets are outdated and not appropriate for this use, as the dynamic nature of ecosystems requires up-to-date information for proper assessment.	Notwithstanding this, site-specific surveys were undertaken to provide validation of the existing datasets, these include epibenthic trawls, and eDNA sampling. These surveys are summarised in Table 10.5.
Scoping Opinion (Lincolnshire Wildlife Trust, 25 August 2022)	The estimated distance from the closest Hornsea Project array to the proposed the Project array is roughly 17km (according to the public shapefiles	Blonde ray, European eel and thornback ray have all been included in the impact assessment (see Table 10.6).

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	provided; 4coffshore.com). Given that several fish and shellfish species are demersal with relatively small home ranges (e.g., demersal and shellfish species listed in Table 7.4.2), localised data specific to the study areas will be needed to properly assess fish and shellfish distributions and associated disturbance impacts. For example, several of the threatened and red-listed species provided in Table 7.4.3 are demersal with localised home ranges (e.g., blonde ray, European eel, thornback ray), requiring the ecological assessment of the proposed project area to determine protected species distributions within the potential the Project array and ECC AoS.	
Scoping Opinion (Lincolnshire Wildlife Trust, 25 August 2022)	Lastly, LWT appreciates that fish and shellfish will be included in noise modelling assessments. However, LWT would advise that the same investigative scope of noise impacts on marine mammals be applied to fish and shellfish, including LWT recommendations for noise modelling practice detailed in the next response.	Detailed noise modelling has been undertaken and is presented in full in Appendix 3.2 (document reference 6.3.3.2). This underwater noise modelling has been used to inform the assessment of potential impacts on fish and shellfish receptors in Section 10.6.
Post-scoping Evidence Plan meeting		
Marine Ecology & Coastal Processes ETG (12 October 2022)	Cefas queried if all cumulative effects are being scoped out or ones specific to particular impact.	Cumulative impacts related to underwater noise and increases in suspended sediments and deposition have been assessed. See Section 10.7.
Marine Ecology & Coastal Processes ETG (12 October 2022)	Cefas welcome that a full ten-year dataset is being addressed.	Ten years of IHLS data (2009-2010-2022/2023) have been used to inform the assessment of impacts on spawning herring (Volume 2, Figures 10.14 to 10.17).
Marine Ecology & Coastal Processes ETG (2 December 2022)	Cefas queried if the Project would be modelling and presenting the 135dB Sound Exposure Level (SEL) contour from Hawkins *et al*. (2014). Natural England	Whilst Hawkins *et al.* (2014) present a possible threshold for behavioural impacts on fish, the use of this threshold for noise impact assessments is expressly

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	also confirmed via a post meeting note that they support the inclusion of this contour.	advised against by the authors of the paper. Specifically, this threshold is based on a study undertaken within a quiet loch on fish not involved in any particular activity (i.e. not spawning), and it is therefore not considered appropriate to use this threshold within a much noisier area such as the southern North Sea (which is subject to high levels of anthropogenic activity and consequently noise) as the fish within this area will be acclimated to the noise and would be expected to have a correspondingly lower sensitivity to noise levels. Also, as demonstrated by Skaret *et al.* (2005), herring are much less likely to respond to sound when engaged in life-history critical activities (e.g., feeding, spawning). The use of this threshold is not considered meaningful when attempting to describe the potential disturbance effects on spawning herring arising from piling activity. Notwithstanding this, the Project has agreed to display the 135dB SELss contour contextualised alongside 5dB increments and a literature review of the response of fish to underwater noise at various noise levels (Section 10.6).
Marine Ecology & Coastal Processes ETG (2 December 2022)	Cefas queried how the site-specific epibenthic trawl survey data was being used for sandeels and when the data was collected.	The surveys were undertaken in 2022, across the offshore ECC and array area. The data was used as presence/absence validation of the existing datasets listed in Table 10.5.
Marine Ecology & Coastal Processes ETG (17 March 2023)	Cefas confirmed that their stance remains, regarding the presentation of the Hawkins *et al.* (2014) behavioural threshold, due to the presence of	The Project confirmed that the potential behavioural impact ranges have been presented as 5dB increments from the piling source alongside a literature review of

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	spawning herring at Flamborough Head. Cefas stated that alternative evidence is welcomed but at the current point this remains their position.	impacts from underwater noise to fish species. See Section 10.6. As mentioned in response to the Marine Ecology & Coastal Processes ETG (2 December 2022), whilst Hawkins et al. (2014) present a possible threshold for behavioural impacts on fish, the use of this threshold for noise impact assessments is expressly advised against by the authors of the paper. The Project therefore do not support the use of this threshold to inform the underwater noise assessment.
Section 42 Responses		
Lincolnshire Wildlife Trust	We do not agree with the final decision to classify sandeel as having 'medium sensitivity' to increased SSC and deposition.	This is noted by the Applicant. Further justification for the assignment of this sensitivity score has been added to the assessments in Section 10.6 of this chapter.
Lincolnshire Wildlife Trust	Lincolnshire Wildlife Trust would like to point out that this comparison between the amount of suspended material following offshore windfarm development and natural resuspension of sediment is misleading and in direct conflict with the literature, which has shown that Suspended Particulate Matter (SPM) plumes in the wake of OWF construction can reach concentrations up to 5 times that of background concentrations. Given the intended impact to an important source habitat for *A. marinus* and the lack of evidence for recovery, LWT believes that this project does impose significant risk to the Southern North Sea sandeel population.	The Applicant acknowledges these concerns raised by the Lincolnshire Wildlife Trust and note that the modelled release of suspected sediments are based on Worst Case Scenarios (WCS), details of which are summarised in Chapter 7 (document reference 6.1.7), and Volume 3, Appendix 7.2: Physical Processes Modelling Report (document reference 6.3.7.2). A full assessment of the potential impacts on sandeel populations is undertaken in Section 10.6, Impact 2, and further justification for the sensitivity score of sandeel has been provided.
Lincolnshire Wildlife Trust	Dredging and Disposal of Dredged Material: Lincolnshire Wildlife Trust is particularly concerned with the statement that, 'any material dredged from	The Applicant acknowledge these concerns raised by the Lincolnshire Wildlife Trust and note that physical processes modelling is based on WCS, details of which

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	within the Special Area of Conservation (SAC) will be deposited back within the SAC' (Section 9.7.8). While LWT appreciates the reasoning behind this—likely an attempt to minimise harm to SAC sandbank features—we are nonetheless concerned with the redeposition of sediment across Annex 1 habitat (H1110 Sandbanks and/or H1170 Reefs), as this would greatly impact benthic and pelagic communities that rely on these unique and important ecosystems. Given the above concerns for direct impact and loss of important spawning habitat for sandeel, LWT would recommend minimising the need for dredging within the Inner Dowsing, Race Bank and North Ridge SAC, and any other unprotected Annex 1 sandbank, (avoidance) and mitigating the disposal of dredged material either outside of the SAC or outside of important spawning seasons. We anticipate a full evaluation of the impacts of dredging and sediment redeposition on these and other receptors in the ES, as well as due diligence towards the mitigation hierarchy for any projected impacts.	are summarised in Chapter 7 (document reference 6.1.7), Volume 3, Appendix 7.1: Physical Processes Technical Baseline (document reference 6.3.7.1) and Appendix 7.2 (document reference 6.3.7.2). The Project is seeking a defined disposal ground in parallel to the DCO application. The Applicant is committed to micro-siting infrastructure around Annex I habitat as far as practicable, to avoid direct significant impacts on these sensitive habitats where possible (as detailed within the Outline Biogenic Reef Mitigation Plan (document reference 8.22) and Outline Cable Specification and Installation Plan (document reference 8.5)). Impacts to benthic habitats are considered within Chapter 9 (document reference 6.1.9) and where impacts may arise to the SAC, within the Report to Inform Appropriate Assessment (RIAA) (document reference 7.1). A full assessment of the potential impacts of direct impact and loss of important spawning habitat for sandeel is undertaken in Section 10.6.
Marine Management Organisation	The MMO does not have any comments or concerns at this stage on the receptors that have been scoped out with regards to shellfish and defers to the Eastern Inshore Fisheries & Conservation Authority (EIFCA) for comments on potential impacts of the development on cockle and whelk features in The Wash.	This is noted by the Applicant.
Marine Management Organisation	The MMO notes the use of several data sources for shellfish and shellfisheries. These are a combination of	The Applicant confirms that the limitations of these datasets have been acknowledged in Section 10.5 of

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	desk sources and additional opportunistic surveys. However, the listed data sources do not cover the array or cable corridor, and several are over 10 years old, which could be considered outdated. Furthermore, as acknowledged by Outer Dowsing Offshore Wind (ODOW), the surveys conducted are not shellfish targeted surveys and are therefore only indicative of presence and absence of shellfish species. It is acknowledged that the report states "the MMO agreed that the baseline datasets identified in the Scoping Report (Outer Dowsing Offshore Wind, 2022) were appropriate for characterisation and the MMO confirmed no need for site-specific surveys." However, the MMO would expect more recent data to inform the baseline environment for shellfish receptors and shellfisheries.	the fish and shellfish ecology chapter. The Coull *et al*. (1998) and Ellis *et al. (*2012) data sources are widely accepted across the offshore wind industry. However, to substitute these data sources, site specific PSA data have been used to inform the locations of suitable spawning substrates for demersal spawning receptors such as herring and sandeel. Site-specific epibenthic trawls, and eDNA surveys have also been undertaken to inform the fish and shellfish baseline, and the assessment. Literature has also been drawn upon to further inform the baseline environment for shellfish receptors and shellfisheries (see Appendix 10.1: Fish and Shellfish Ecology Technical Baseline).
Marine Management Organisation	The MMO has no concerns regarding the scoping in/out of impacts or receptors for fish. The fish species present in and around the project's study area have been correctly identified, as have the spawning and nursery grounds found within the vicinity of the project. The potential impacts to fish receptors and commercial fisheries have been appropriately scoped in/out. As agreed at scoping stage, impacts arising from accidental pollution during the construction, operation and maintenance (O&M), and decommissioning phases have been scoped out of further assessment on the basis that a Project Environmental Management Plan	This is welcomed by the Applicant.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	(PEMP) will be implemented to mitigate pollution events.	
Marine Management Organisation	Impacts from direct disturbance during the O&M phase have now been scoped in, which is appropriate. Impacts arising from changes in fishing pressure due to displacement have been scoped out of further assessment for fish ecology, but scoped into the assessment for commercial fisheries, which is supported. Transboundary impacts have been scoped into the assessment in respect of Annex II migratory fish species listed as features of European sites in other EEA States. The assessment of impacts to fish from underwater noise and habitat disturbance for some species (primarily herring and sand eel) requires further consideration and some clarification is also needed to ensure the ES is robust and fit for the purpose of assessing the likelihood of significant impacts occurring to fish.	This is noted by the Applicant. Further consideration of potential impacts from underwater noise and habitat disturbance for some species (primarily herring and sandeel) has been incorporated into the Section 10.6 of this chapter and conclusions updated accordingly.
Marine Management Organisation	The MMO notes the increase in hammer energies being used to install monopiles at OWFs. Monopile hammer energies have typically been in the region of 4,000 – 5,000 kilojoules (kJ). It is noted that 6,000 – 7,000kJ is proposed. These higher hammer energies are likely to result in noise impacting a larger area. Whilst receptor-specific mitigation is recommended by the MMO when the evidence suggests that significant impacts to a particular species of fish are likely to occur, additional noise abatement measures may be required, such as	The Applicant reassures the MMO that due consideration to the potential for impacts on fish and shellfish receptors from underwater noise is given in Section 10.6 of this chapter. Where the assessment concludes that further mitigation is required, this is detailed in Section 10.6.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	bubble curtains (see Würsig *et al*. (1999)), or other alternative measures.	
Marine Management Organisation	The MMO would highlight that given the wider context of the current ramp up of offshore wind development at unprecedented scale in the North Sea it is vital that these discussions begin as soon as possible. To ensure adequate preparations are made and potential delays avoided, it is therefore in the applicant's interest to plan for noise abatement measures at the earliest opportunity and to incorporate such measures into any future MMMP.	The Applicant reassures the MMO that due consideration to the potential for impacts on fish and shellfish receptors from underwater noise are given in Section 10.6 of this chapter. Where the assessment concludes that further mitigation is required, this is detailed in Section 10.6.
Marine Management Organisation	In the benthic survey report for the array area (Appendix 9.1: Benthic Ecology Technical Report (Array). Document Number: 6.2.9.1, Rev. v1.0.), it is noted that 'numerous sandeels were observed on the video footage across the sand dominated sediments' and that 'sandeels were also the most prominently identified chordates in seabed photographs and video footage'. Raitt's sand eel (*Ammodytes marinus),* smooth sandeel (*Gymnammodytes semisquamatus*), lesser sandeel (*Ammodytes tobianus*) and greater sandeel (*Hyperoplus lanceolatus*) were all caught in the trawl surveys. With this in mind, it would be helpful to know the numbers of each sandeel species caught in the trawl surveys (and grab samples if applicable), and the locations of where sandeel were caught, or observed, the MMO recommends than an additional layer to the map of	This is noted, and the distribution of sandeel as informed by the site-specific benthic surveys have been presented in Volume 2, Figure 10.18, and used to inform the baseline in Appendix 10.1: Fish and Shellfish Ecology Technical Baseline (document reference 6.3.10.1), and the assessment within Section 10.6 of this chapter.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	sandeel habitat is provided (similar to that shown in Figure 10.2 but indicating those locations where sandeel were caught/observed). Given that two metre (m) beam trawls and grabs are not suitable fishing methods for targeting sandeels, it is interesting to see such high numbers caught, and whilst the data would only be an anecdotal indicator of their presence, it would be useful to plot the locations of sandeel catches and observations across the site to see if any further useful context could be gained relating to sediment type and seabed features, such as the noted absence of sandeels in areas where water depth exceeded 30m.	
Marine Management Organisation	It is recommended that the sandeel habitat assessment is supplemented with data from the North Sea Sandeel Survey (NSSS) carried out in Sandeel Area 1 in December each year. This targeted sandeel dredge survey has been carried out since December 2004 and includes a number of stations in and around Outer Dowsing (see Annex 1). The NSSS data can be downloaded from ICES at Datras: Download (ices.dk).	The suggestion of this data source is welcomed by the Applicant and the data have been presented Volume 2, Figure 10.18
Marine Management Organisation	Vessel Monitoring System (VMS) data for bottom trawled gear is a further source of data that is recommended for the assessment to identify areas where high intensity fishing may be occurring in the project study area.	The suggestion of this data source is welcomed by the Applicant. Landings data from the MMO has been used to inform the fish and shellfish baseline in Appendix 10.1 (document reference 6.3.10.1), and the assessment of potential impacts to commercially important species undertaken in Section 10.6 of this chapter. VMS data have been used to inform the

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
		Chapter 14 (document reference 6.1.14) to identify areas of high intensity fishing activity.
Marine Management Organisation	The MMO notes that it has been recognised that sandeel play an important role in the North Sea's food web as prey for birds, marine mammals and piscivorous fish. The project array overlaps the Southern North Sea Harbour Porpoise SAC and the ECC overlaps the Greater Wash Special Protected Area (SPA) which incorporates red throated divers, little gull, common scoter, Sandwich tern, little tern and common tern as Annex I features. It is likely that some of these predatory receptors will rely on sandeel as part of their diet whilst foraging in the project area and may experience reduced foraging success and/or incur greater energy expenditure travelling to new feeding grounds as a result of localised impacts to fish populations during the construction of the windfarm, especially those receptors with relatively small and/or coastal restricted foraging areas. Given the ecological importance of sandeel to support marine predators in the study area and given the potential abundance of sandeel within the Order Limits and the suitability of the habitat, it is recommended that ODOW makes use of the additional data sources outlined above to ensure that the potential impacts to Annex I species resulting from regional adverse impacts to sandeel populations can be assessed in more detail.	This is noted by the Applicant, and the suggested data sources have been incorporated into the fish and shellfish ecology baseline in Appendix 10.1 (document reference 6.3.10.1) and have been used to inform the assessment of potential effects on sandeel as prey species for Annex 1 features in Section 10.6 of this chapter.
Marine Management Organisation	To complement the maps of herring spawning habitat suitability in Figures 10.10 – 10.13, International	This is welcomed by the Applicant.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	Herring Larvae Survey (IHLS) abundance data for the years 2009 – 2021 have been plotted as a cumulative data set (Figure 10.14) and by individual survey years (Figures 10.15 – 10.17). Figure 10.14 shows that consistent high larval abundances of between 28,500.1 – 93,250 /m² occur offshore from Flamborough head, (northwest of the project site), whilst lower larval abundances ranging from 6,000.1 – 12,750 /m² occur south of Flamborough Head, extending over a portion of the project array area and secondary zone of influence. In some years (2011-2012, 2016-2017 and 2019-2020) higher larval densities occurred within the array site, demonstrating the continued importance of this area as a herring spawning ground, and the local importance of the southern extent of the Central North Sea (CNS) herring spawning grounds to maintain overall stock resilience for the North Sea herring stock. The MMO welcomes this.	
Marine Management Organisation	Given the presence of herring spawning grounds within the project study area, the specific spawning habitat requirements of herring, and their sensitivity to underwater noise, the MMO requests that ODOW models and presents (in mapped form) additional noise modelling for the received levels of single strike sound exposure levels (SELss) at the Banks herring spawning grounds based on the 135 decibel (dB) (SELss) startle response (as per Hawkins *et al*. (2014)) in order to predict the range of effect for behavioural responses in herring. This is particularly important as Under Water	The Applicant maintains that the 135dB threshold is overly precautionary, and that as stated by Popper *et al* (2014) it is not appropriate to determine the potential for behavioural effects quantitively due to the range of behavioural responses, and external stimuli and life events that can influence them. Notwithstanding this, the Applicant has presented potential behavioural impact ranges as 5dB increments from the piling source and undertaken a literature review to inform the potential range and magnitude of effects on spawning herring. This is presented in Section 10.6 of this

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	Noise (UWN) generated by piling at Outer Dowsing has the potential to create an acoustic 'barrier' to herring as they follow their migration southwards through the central North Sea (Cushing, 2001).	chapter. Due consideration of the migration of herring has also been incorporated into Appendix 10.1 (document reference 6.3.10.1), and into Impact 1, Section 10.6.
Marine Management Organisation	It is recommended that for the ES the maps in Figures 10.24 – 10.34 should also state the pile diameter used in the modelling. Modelling should be based on the maximum pile diameter (14m for monopiles and 5m for pin piles).	This is noted, and Volume 2, Figure 10.23 to 10.37 have been updated accordingly.
Marine Management Organisation	It is noted that underwater noise modelling for UXO clearance has been carried out using the appropriate unweighted peak sound pressure (SPL_{peak}) explosions threshold for fish of 229 - 234dB peak (as per Popper *et al*., 2014) for charge weights of 0.5 kilogram (kg) – 800kg (+donor charge weight of 0.5kg). The maximum predicted impact range for a 800kg charge at 229dB is 930m.	This is noted, the Applicant confirms that a detailed assessment on the impacts to fish from UXO clearance will be included in an UXO marine licence application post-consent, identifying receptors within the study area with specific habitat requirements for part or all of their life cycles and their sensitive spawning periods. A high-level assessment, as informed by the underwater noise modelling has been undertaken in Section 10.6 of this chapter.
Marine Management Organisation	The MMO understands a separate UXO marine licence application will be submitted and recommends a more detailed assessment on the impacts to fish from UXO clearance to be presented for the UXO clearance within this application that identifies those fish within the study area with specific habitat requirements for part or all of their life cycles (e.g., herring, sandeel and oviparous elasmobranchs) and their sensitive spawning periods.	This is noted, the Applicant confirms that a detailed assessment on the impacts to fish from UXO clearance will be included in an UXO marine licence application post-consent, identifying receptors within the study area with specific habitat requirements for part or all of their life cycles and their sensitive spawning periods. A high-level assessment, as informed by the underwater noise modelling has been undertaken in Section 10.6 of this chapter.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Marine Management Organisation	The Applicant has proposed 'best practice' embedded mitigation measures, such as the use of soft-start techniques on commencement of piling, the implementation of a Project Environmental Management Plan (PEMP) and the burial of cables wherever possible, all of which is supported.	This is welcomed by the Applicant, and embedded mitigation measures as relevant to fish and shellfish ecology are summarised in Table 10.8 of this chapter.
Marine Management Organisation	However, no additional fisheries-specific mitigation has been proposed because no impacts were assessed above 'minor adverse' (not significant in EIA terms). Even with the additional monitoring requested the MMO may recommend a temporal piling restriction during the Banks herring spawning season, because the results of the UWN modelling already show an overlap of noise with the southern portion of the Banks spawning ground, in an area which continues to be utilised by herring in some years. However, this restriction is subject to the review of the final modelling in the ES. Please note any restriction, may be comparable to the piling restrictions for Triton Knoll OWF, located to the east of Outer Dowsing and within the project study area.	This is noted by the Applicant. The assessment of underwater noise impacts on fish and shellfish receptors is presented in Section 10.6 of this chapter. The Applicant notes that as informed by the IHLS data (presented as a heatmap to identify areas of actively spawning herring), the main spawning of Banks herring stock consistently occurs to the north of the Project, off Flamborough Head. The modelled underwater noise contours do not interact with any areas of high intensity spawning activity (Volume 2, Figures 10.23 t0 10.37), and therefore the spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning off of Flamborough Head. The Applicant maintains their position that there will be no significant population level effects on herring.
Marine Management Organisation	Concerning the effects of electro-magnetic fields (EMF) on electro-sensitive fish receptors such as elasmobranchs, eels and lampreys, it is noted that the intended average cable burial depth for array, inter and export cables will be between 0 - 3m. In line with the National Policy Statement EN3 (Department of Energy & Climate Change, 2011) the MMO recommends that where possible, cables are buried to a minimum depth	This is noted by the Applicant.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	of 1.5m (subject to local geology or seabed obstructions) as this will further increase the distance between electro sensitive fish receptors and EMF, as well as reduce the risk of snagging and damage to cables by other marine vessels e.g., anchors, bottom-towed gear. It is also noted that a Cable Burial Risk Assessment (CBRA) has been undertaken in respect of the sections of export cables which cross through Annex 1 sandbanks.	
Marine Management Organisation	The approach to the assessment of cumulative and inter-related impacts outlined in the Appendix 5.1: Offshore Cumulative Effects Assessment is appropriate and follows a standard approach of identifying the impacts which have potential to cause an effect. The study area for the range of effect is 12km around the array area and 15km around the ECC (for sedimentary impacts, based on physical processes). For underwater noise the range of effect is 100km due to the larger range of effect from noise generating activities such as piling. The MMO believes that all other offshore operations (OWFs, subsea cables and aggregate areas) within the study area in the planning, consented, construction and operational activities have been identified. It should be recognised that the range of effect for cumulative and inter-related effects may increase if the modelling shows an impact range exceeding 100km. With this in mind, there may be other offshore developments further afield that will require scoping	This is noted by the Applicant, the cumulative assessment of the fish and shellfish ES chapter has been updated in accordance with the latest underwater noise modelling. The cumulative effects of underwater noise are assessed in Section 10.7.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	into the assessment, should the UWN modelling show a range of effect of >100km.	
The National Federation of Fishermen's Organisation	We welcome the practice of undertaking site specific surveys to aid in characterisation of the fish and shellfish baseline.	This is welcomed by the Applicant; the site-specific surveys are detailed in Appendix 10.1 (document reference 6.3.10.1) and are summarised in Table 10.5 in this chapter.
The National Federation of Fishermen's Organisation	This practice is not common in many offshore wind development pre-construction processes, we commend such and recommend it becomes common practice for advising the baseline characteristics. We also welcome the use of site-specific use of eDNA sampling as a tool to further enhance the understanding of the fish and shellfish ecology in the area. The challenges associated with differing methodologies biasing data collection for specific species receptors is well described and the use of presence/absence instead of abundance indices is well reasoned.	This is welcomed by the Applicant
The National Federation of Fishermen's Organisation	However, we do have concerns with regards to the conclusions drawn and lack of mitigation proposed within the ES. Section 10.1.3 describes that the ES provided a contemporary and comprehensive analysis of the available data, we disagree. Except for the site-specific surveys, which are acknowledged to give only a temporal ‘snapshot’, the remaining data presented is not contemporary and over 10 years old in many cases. For example, whilst we have reservations on the over-reliance of offshore wind development EIAs on Ellis *et al*., 2012, this ES uses the	The Applicant welcomes the suggestion of additional publications to inform the baseline, these have been incorporated into Appendix 10.1 (document reference 6.3.10.1), and this chapter accordingly.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	more dated Ellis *et al*., 2010 to characterise baseline spawning and nursery areas. The same is observed with regards to relying on shellfish monitoring reports (Roach and Cohen, 2015) when a more contemporary, peer reviewed publication is available for the same study (see Roach *et al*., 2022).	
The National Federation of Fishermen's Organisation	The list of data sources (Table 10.2) describes the use of MMO landings statistics to advise the baseline. These data are not described in the Shellfish Ecology Technical Baseline, their inclusion and analysis would further inform the baseline.	This is noted by the Applicant, and MMO landings statistics have been incorporated into the fish and shellfish baseline as presented in Appendix 10.1 (document reference 6.3.10.1). These data have also been summarised in Table 10.5 of this chapter and used to inform the assessment where appropriate.
The National Federation of Fishermen's Organisation	Figure 10.4 portrays offshore wind developments that conducted data collection that was included to advise the baseline for the Outer Dowsing development. We would expect to see the sampling stations and type to be included here to assess their relevance to be included.	This is noted by the Applicant, and the sampling stations and type have been incorporated into Volume 2, Figure 10.1.4 accordingly.
The National Federation of Fishermen's Organisation	Table 10.7 needs to include scientific names of species for clarity – for example, what spider crab was sampled?	This is noted by the Applicant, and Table 10.7 in Appendix 10.1 (document reference 6.3.10.1) has been updated accordingly.
The National Federation of Fishermen's Organisation	Section 10.5.3 refers to the Cefas Yorkshire and Humber Lobster stock assessment, the appropriate assessment to use in this context would be the Cefas East Anglia Lobster stock assessment.	The Applicant welcomes the suggestion of the use of the Cefas East Anglia Lobster stock assessment to inform the baseline. This data source has been incorporated into Appendix 10.1 (document reference 6.3.10.1) accordingly.
The National Federation of Fishermen's Organisation	Hornsea One and Two have been scoped out of the cumulative assessments, whilst we acknowledge these developments are in the operational phase, there is	As the completion/commissioning of Hornsea Projects One and Two occurred prior to the data collection process for the Project, these projects are considered

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	likely to be an operational effect contributing to the cumulative impacts to receptors. If data from these developments are suitable to be used to advise the baseline, then they should be included in the cumulative assessment.	as part of the baseline. Furthermore, any impacts from the operation of these projects are anticipated to be highly localised and will therefore not contribute to a cumulative effect on fish and shellfish receptors. The Applicant therefore maintains their position that the operational Hornsea Projects One and Two are not considered in the cumulative assessment undertaken in Section 10.7 of this chapter.
The National Federation of Fishermen's Organisation	The reliance of offshore wind impact assessments on Coull *et al*, (1998) and in this case, Ellis *et al*, (2010), has been called into question in nearly all our responses to offshore development licensing and planning reports. These data are 25 and 13 years old respectively but seem to be used as a 'gold standard' to assess impacts on spawning and nursery grounds. We would expect to see a more precautionary use of these data, based on those papers' well described limitations.	The Applicant confirms that the limitations of these datasets have been acknowledged in Section 10.5 of this chapter. The Coull *et al. (*1998) and Ellis *et al. (*2010) (updated in 2012 to include fish nursery grounds (Ellis *et al*., 2012)) data sources are widely accepted across the offshore wind industry. Furthermore, to supplement these data sources, site specific PSA data have been used to inform the locations of suitable spawning substrates for demersal spawning receptors such as herring and sandeel and additional research publications and trawl survey data have also been reviewed to provide site-specific information (as summarised in Table 10.5 of this chapter, and detailed in Appendix 10.1 (document reference 6.3.10.1).
The National Federation of Fishermen's Organisation	Shellfish species have not been assessed to the same standards of the fish species and conclusions drawn have not been treated with any precaution. What are the distributions of the shellfish species and key spawning areas in relation to the study area? Minimal data for impacts to shellfish receptors has been presented, with the site-specific surveys limited to	The Applicant confirms that Appendix 10.1 (document reference 6.3.10.1) has been updated to present a more comprehensive baseline for shellfish receptors. The baseline has also been summarised in Table 10.5 of this chapter and has been used to inform the assessment within Section 10.6 accordingly.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	presence/absence. We would expect to see a more precautionary approach taken to assessing impacts to shellfish receptors in the absence of robust data to assess.	
The National Federation of Fishermen's Organisation	We are concerned with the lack of fish and shellfish species monitoring proposed. The proposed development completely overlaps key spawning and nursery grounds for several key species yet impacts to these receptors has been assessed as minor adverse at worse due to the impact being a localised effect. The evidence does not support this assumption. We acknowledge the difficulties with the lack of site-specific, contemporary data for all receptors, but we would expect to see some element of precaution taken when assessing impacts on fish and shellfish ecology, especially when that assessment is informed by studies which employed methodologies inappropriate to this task or is based on presence/absence as opposed to abundance/biomass estimates.	Site-specific surveys (inclusive of grab sampling, geophysical surveys, epibenthic trawls and eDNA sampling) have been undertaken to ground truth existing data sources. These surveys are summarised in Table 10.5and have been used to inform the baseline within the Appendix 10.1 (document reference 6.3.10.1), and the assessments undertaken in Section 10.6. The assessment of potential impacts to fish and shellfish receptors has been based on WCS and has assumed the presence of sensitive receptors within the defined study area to ensure a precautionary assessment. A comprehensive and precautionary assessment of the potential for impacts to sensitive fish and shellfish receptors from the project has been undertaken in Section 10.6. No significant effects on fish and shellfish populations have been concluded (see conclusions in Section 10.10), and therefore no fish and shellfish monitoring has been proposed.
Post Section 42 Evidence Plan meeting		
Marine Ecology & Coastal Processes ETG (7 August 2023)	In relation to assessing the potential impacts from increased SSC and deposition, Cefas recommended ODOW look at sediment climatology datasets, and provided a link to the following dataset ‘Monthly average non-algal Suspended Particulate Matter concentrations – Cefas’. Cefas noted that these data	The Applicant welcomes the provision of the dataset. These data have been incorporated into the physical processes modelling and assessment (Chapter 7 (document reference 6.1.7), Appendix 7.1 (document reference 6.3.7.1) and Appendix 7.2 (document reference 6.3.7.2), which is used to inform the

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
	are only for the surface but provides an idea of the variability within the area.	assessment of potential impacts on fish and shellfish receptors as presented in Section 10.6, Impact 2.
Marine Ecology & Coastal Processes ETG (7 August 2023)	Cefas explained that whilst the ES was right to look at population scale impacts, it is also necessary to consider regional scale impacts.	Regional scale impacts on prey species of Annex 1 species are addressed accordingly in Section 10.6 of this chapter. Occurrences of prey species (sandeel) have been mapped in relation to the Project in Volume 2, Figure 10.18, in order to assess the regional scale impacts on the populations.
Marine Ecology & Coastal Processes ETG (14 September 2023)	Cefas confirmed their position that a temporal piling restriction for herring is likely to be needed, subject to updated modelling and mitigation measures. It was also added that the 135dB threshold to spawning herring would be good to model with noise abatement too to see the different measures.	This is noted by the Applicant. The assessment of underwater noise impacts on fish and shellfish receptors is presented in Section 10.6 of this chapter. The Applicant notes that as informed by the IHLS data (presented as a heatmap to identify areas of actively spawning herring), the main spawning of Banks herring stock consistently occurs to the north of the Project, off of Flamborough Head. The modelled underwater noise contours do not interact with any areas of high intensity spawning activity (Volume 2, Figure 10.23 to 10.37), and therefore the spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning off of Flamborough Head. The Applicant maintains their position that there will be no significant population level effects on herring. The Applicant has presented potential behavioural impact ranges as 5dB increments from the piling source and undertaken a literature review to inform the potential range and magnitude of effects on spawning herring. This is presented in Section 10.6 of this chapter.

Date and consultation phase/ type	Consultation and key issues raised	Section where comment addressed
Marine Ecology & Coastal Processes ETG (8 November 2023)	Regarding underwater noise modelling for the ANS and ORCPs, Cefas noted that the noise modelling contours as presented in the meeting will be looked into post meeting. Cefas also requested that the noise modelling impact ranges are tabulated within the chapter.	The Applicant has tabulated the underwater noise modelling outputs in Table 10.17, Table 10.18, Table 10.19 and Table 10.20, in Section 10.6 of this chapter. No comments were received post-meeting.
Marine Ecology & Coastal Processes ETG (8 November 2023)	Cefas raised concerns that inter-annual variability will not be shown in the IHLS 10-year dataset, presented as a heatmap. Cefas proposed using annual maps to help show this in more resolution	The annual IHLS data have been presented as heat maps in Volume 2, Figures 10.1.18, 10.1.19 and 10.1.20.

13. As identified in Chapter 3 (document reference 6.1.3) and Volume 1, Chapter 4: Site Selection and Consideration Alternatives (document reference 6.1.4), the Project Design Envelope has been refined throughout the stages of the Project prior to DCO submission. This process has been reliant on stakeholder consultation feedback.

10.4 Baseline Environment

10.4.1 Study Area

14. The fish and shellfish study area is presented in Volume 2, Figure 10.1 and has been defined at three spatial scales. For primary impacts, the study area includes the array area and offshore ECC. For secondary impacts a wider study area has been used based on the Project specific hydrodynamic modelling undertaken (Appendix 7.2 (document reference 6.3.7.2)). This Zone of Influence (ZoI) encapsulates the maximum extent of measurable plumes predicted by the modelling. Finally, although the maximum impact range from underwater noise will be up to 23km from the array area, a precautionary 50km study area has been defined for underwater noise impacts on fish and shellfish receptors, to fully encapsulate maximum impact ranges for the 186dB re 1µPa^2s Sound Exposure Level (SEL) for recent UK offshore windfarm applications.
15. The largest ZoI from activities within the ECC would result from increased Suspended Sediment Concentrations (SSCs) and associated sediment deposition and smothering from foundation and cable installation works and seabed preparation works. The 'Sedimentary ZoI' is based on the project specific hydrodynamic modelling undertaken (Appendix 7.2 (document reference 6.3.7.2)). This ZoI encapsulates the maximum extent of measurable plumes predicted by the modelling, although the majority of suspended sediment is expected to be deposited much closer to the disturbance activity.
16. The current study area overlaps with the International Council for the Exploration of the Sea (ICES) rectangles 35F0, 35F1, 36F0 and 36F1 and provides a regional context on fish and shellfish ecology and is sufficient to cover potential effects outside of the array area and offshore ECC.

10.4.2 Compensation Areas

17. Areas for potential compensation measures associated with the Project have been provided in Volume 2, Figure 10.1, with the baseline conditions in these areas detailed in Volume 2, Appendix 10.1 (document reference 6.3.10.1). The compensation areas have been assessed accordingly within this chapter.

10.4.3 Data Sources

18. A detailed desktop review was carried out to establish the baseline of information available on fish and shellfish populations in the fish study area for the Project. Information was sought on fish and shellfish ecology in general and on spawning and nursery activity. The baseline characterisation utilises a broad combination of datasets and provides a robust temporal analysis and validation of regional monitoring datasets. In addition, the fish and shellfish ecology characterisation will be informed through site-specific benthic ecology surveys to be undertaken across the array area and offshore ECC. These surveys include Particle Size Analysis (PSA) of sediment samples, epibenthic trawls and eDNA data. Data collected from these surveys will be used to inform on spawning habitat suitability for demersal spawning fish such as herring and sandeel, as well as presence/absence validation of the existing datasets listed in Table 10.5.
19. A combination of datasets has been used within this characterisation and this ensures a robust temporal and spatial coverage of fish and shellfish ecology in the area. These datasets and their utilisation are listed in Table 10.5.
20. The data available from existing literature and relevant surveys provide an appropriate evidence base for fish and shellfish populations within the Project study area, sufficient for the purposes of EIA and it is intended that these are utilised to characterise the fish and shellfish receptors in the vicinity of the Project array area and offshore ECC.
21. Additional information on the fish and shellfish characterisation for the Project and full details on the data sources and the utilisation of each data source are provided in Appendix 10.1 (document reference 6.3.10.1).

Table 10.5: Data sources used to inform the Project baseline characterisation.

Data source	Data utilisation
Existing Data Sources	
Environmental Statements' (ESs'), and pre- and post-construction monitoring reports from other Offshore Wind Farm (OWF) developments within the defined study area: ▪ Triton Knoll OWF herring larvae survey (Linnane and Simpson, 2011), seasonal trawl surveys (Linnane *et al.*, 2011) and ES (RWE, 2012); ▪ Sheringham Shoal OWF herring spawning survey, and pre- and post-construction elasmobranch surveys (Brown & May Marine Ltd, 2009, 2010, 2015) and ES (Scira, 2006); ▪ Dudgeon OWF pre-construction adult fish surveys (Brown & May Marine Ltd, 2008a,b), baseline ecology study (Fugro, 2015) and ES (Royal Haskoning, 2009);	Site-specific fish and shellfish surveys for OWF Projects in the area. Used to provide a fish and shellfish ecology characterisation taken from previous OWF project surveys of the area.

Data source	Data utilisation
▪ Sheringham Shoal and Dudgeon Offshore Windfarm Extension Projects ES (Equinor, 2022); and ▪ Hornsea Project One, Hornsea Project Two and Hornsea Project Three (as cited in Ørsted, 2018) and Hornsea Project Four ES (Ørsted, 2021).	
British Geological Survey (BGS) Seabed Sediment datasets (BGS, 2015).	Particle Size Analysis (PSA) data presented to provide an indication on the location of suitable habitat and spawning grounds for sandeel and herring.
EUSea Map broadscale marine habitat data (2021).	Broadscale marine habitat data presented to provide an indication on the location of suitable habitat and spawning grounds for sandeel and herring.
Fisheries Sensitivity Maps in British Waters (Coull *et al*., 1998)	Used to provide information on likely spawning or nursery areas for commercial species.
Ellis *et al*. (2010) Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (MPAs).	Provided information on fish spawning and nursery grounds.
Ellis *et al*. (2012) Spawning and nursery grounds of selected fish species in UK waters. Scientific Series Technical Report.	
The International Herring Larval Survey (IHLS) data (International Council for the Exploration of the Sea (ICES), (1967-2015).	Time-series trawl data on herring distribution used to characterise the herring populations throughout the North Sea and English Channel.
Marine Management Organisation (MMO) UK Sea Fisheries Monthly Reports and Annual Statistics Reports.	Commercial fisheries specific data (national and regional coverage). Used to provide data related to fisheries landings and fishing effort within the area.
Screening spatial interactions between marine aggregate application areas and sandeel habitat (Latto *et al*., 2013).	Methodologies used to identify preferred spawning habitats of herring and sandeel within the study area.
Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Areas (Reach *et al*., 2013).	
The International Bottom Trawl Surveys (IBTS) (ICES, 1965-2022).	Time-series groundfish survey data collected throughout European seas used to characterise the fish assemblage.
ICES beam trawl surveys (ICES, 1995-2022).	
ICES North Sea International Bottom Trawl Survey (NSIBTS) data (ICES, 1965-2022).	

Data source	Data utilisation
ICES North Sea Sandeel Survey (NSSS)	Annual sand eel dredge survey data, used to provide an indication of the presence, abundance and distribution of sandeel across the North Sea.
Boyle and New (2018) ORJIP Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options.	The study report presents a spatial analysis of the International Herring Larval Survey (IHLS) herring larval data collected over a ten-year period. The methodology defined within this study was used to undertake a spatial analysis of the IHLS data in relation to the Project to identify areas of active spawning herring grounds with overlap with the array area and offshore ECC.
New Survey Data	
Site-specific Benthic Ecology Baseline Characterisation Surveys.	Site-specific survey data from the array area and the offshore ECC inclusive of benthic grabs; Drop Down Video (DDV); epibenthic trawls; PSA; sediment total carbon content; sediment contaminant analysis; and lab work, data analysis and reporting.
Site-specific Geophysical Survey.	Includes shallow geophysical, Ultra-High Resolution Seismic (UHRS), Side Scan Sonar (SSS), echo sounder (Multi-Beam Echosystem) (MBES), magnetometer, high frequency Sub-Bottom Profiler (SBP) and vibrocore collection. These surveys have been used to build a sediment profile of area.
Site-specific eDNA Survey.	Water column and sediment eDNA samples collected alongside the geophysical surveys, used to provide a snapshot of fish and shellfish species presence (from approximately the past 24 hours) at each sample location.

10.4.4 Existing Environment

22. This section describes the present conditions which constitute the existing baseline environment for Fish and Shellfish Ecology within the offshore study area. A detailed characterisation of the fish and shellfish baseline environment is provided in Appendix 10.1 (document reference 6.3.10.1) with a summary provided here. This ES chapter should therefore be read alongside the detailed fish and shellfish characterisation appendix. The baseline characterisation is informed by a wide range of data sources, as summarised in Table 10.5. Fish Ecology

23. The baseline description of the study area draws on site-specific data collected within the array area and ECC, regional datasets and industry specific monitoring undertaken for a number of regional Offshore Wind Farms (OWFs).

24. Sandeels were present within the site-specific grab macrofauna, epibenthic trawl datasets and the video analysis. Furthermore, the Project array site falls within sandeel spawning and nursery grounds; however, it should be noted that even optimal habitats may not be occupied by sandeel if populations are below the area's carrying capacity (Holland *et al,* 2005). Chordata species were observed at the more sand dominated stations and came in the form of sandeels, plaice *Pleuronectes platessa*, dragonet *Callionymus lyra*, pogge *Agonus cataphractus*, lesser weaver *Echiichthys vipera* and unidentified fish. Sandeels were the most prominently identified Chordata, with higher abundances noticed at sand dominated stations with minimal surface shell fragments.
25. Site-specific epibenthic trawls conducted identified 21 fish species and revealed a fish community characterised by demersal species including dab *Limanda limanda*, plaice, pogge and dragonet as well as the inshore species lesser weever and longspined bullhead *Taurulus bubalis*. Several commercially important species such as whiting *Merlangius merlangus*, ling *Molva molva* and common sole *Solea solea* were recorded at low abundances. The greater sandeel *Hyperoplus lanceolatus*, lesser sandeel *Ammodytes tobianus*,smooth sandeel *Gymnammodytes semisquamatus* and Raitt's sandeel *Ammodytes marinus* were all recorded in the epibenthic trawls.
26. eDNA sampling within the array area and offshore ECC, identified 28 fish species, 24 bony and four elasmobranch species. Using haplotype variation as a proxy for species abundance, the most abundant species across the site were Painted Goby *Pomatoschistus pictus*, the right-eye flounder family *Pleuronectidae*, sand goby *Pomatoschistus minutus*, sandeel, common sole, Atlantic mackerel *Scomber scombrus*, lesser weever fish and European sprat *Sprattus sprattus*. Out of the 21 fish species observed across the epibenthic beam trawl data, eight were also identified in the eDNA dataset. Multiple haplotypes of demersal species such as the lesser weever fish, hooknose *Agonus cataphractus*, solenette *Buglossidium luteum* and common sole were recorded across both datasets. Additionally, species of conservation interest were recorded, these included;
    - Tope shark (UK BAP Priority species and International Union for Conservation of Nature (IUCN) 'Critically Endangered' species);
    - Starry smooth-hound (classed as 'Near threatened' on the IUCN Red List);
    - Spotted ray (afforded protection as an Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic) (OSPAR) Threatened or Declining Species);
    - Atlantic herring *Clupea harengus* (UK BAP Priority species due to their 'National Scarcity');
    - Shad *Alosa* spp. (UK BAP Priority species);
    - Atlantic salmon *Salmo salar* (UK BAP Priority species and afforded protection as an OSPAR Threatened or Declining Species);
    - Brown trout *Salmo truttus* (Section 41 Priority species);
    - Sandeel (various species) (UK BAP Priority species); and
    - Atlantic mackerel *Scomber scombrus* (UK BAP Priority species).

27. Otter trawl and epibenthic beam trawl surveys conducted between 2010 and 2012 across the former Hornsea Zone (Hornsea Project One, Hornsea Project Two and Hornsea Three) (Ørsted, 2018) revealed a species assemblage typical of this area of the North Sea. The fish community was largely characterised by demersal species recorded in abundance during surveys, including whiting, dab, plaice, solenette and grey gurnard *Eutrigla gurnardus*. Less abundant species included lemon sole *Microstomus kitt*, common sole and Atlantic cod *Gadus morhua*. Surveys also recorded smaller demersal species such as the short-spined sea scorpion *Myoxocephalus scorpius*, lesser weaver, dragonet and Mediterranean scaldfish *Arnoglossus laterna*. Pelagic species were also recorded during surveys included Atlantic herring, sprat, European common squid *Alloteuthis subulata* and European squid *Loligo vulgaris*. A total of 84 species were recorded in the otter and epibenthic beam trawls undertaken within the Hornsea Four study area. Solonette dominated the trawls along with Mediterranean scaldfish, dab, place and lemon sole. Atlantic salmon, Atlantic cod, whiting and sandeel were also recorded in the area (Ørsted, 2021).

Shellfish Ecology

28. Site-specific grab samples identified brown shrimp *Crangon crangon* and pink shrimp *Pandalus* spp. Mobile Arthropoda such brown crab *Cancer pagurus*, harbour crab *Liocarcinus depurator* and spider crab *Inachus* spp. were all present within the samples. Camera transects showed homogenous sand with negligible hard substrate. Shellfish observed on the seabed stills and videos within the array area and offshore ECC were limited to sporadic sightings of brown crab, harbour crab, spider crab *Hyas* spp. and velvet swimming crab *Necora puber*. Site-specific epibenthic trawls additionally recorded hermit crab *Pagurus bernhardus*, queen scallop *Aequipecten opercularis*, king scallop and blue mussel *Mytilus edulis*.
29. Several shellfish species that are also known to be present and abundant within the study area, recorded in other offshore wind development and regional surveys include European lobster *Homarus gammarus* and Norway lobster *Nephrops norvegicus* (also known as Nephrops), with these species being particularly significant for commercial fisheries within the study area. Whilst Nephrops are likely present in the region, their known spawning and nursery area is located approximately 18km north-east of the array area.

Spawning and Nursery Grounds

30. This section describes fish species which have spawning and nursery areas that overlap, or are in close proximity to, the array area or ECC.
31. Spawning and nursery areas are categorised by Ellis *et al*. (2012) as either 'high' or 'low intensity' dependent on the level of spawning activity or abundance of juveniles recorded in these habitats. Coull *et al*, (1998) does not always provide this level of detail. The spatial extent of the spawning grounds and the duration of spawning periods indicated in these studies are therefore considered likely to represent the maximum theoretical extent of the areas and periods within which spawning could occur.

32. Due to the demersal spawning nature of herring and sandeel, and therefore their increased sensitivity to potential impacts from the development, herring and sandeel have been addressed separately below. The spawning and nursery grounds (Coull *et al.,* 1998; Ellis *et al.,* 2010) discussed and illustrated below are considered robust sources of information, as the physical drivers such as sediment type remain the same (EUSeaMap, 2021) and are supplemented by project specific PSA and geophysical survey data.
33. A 'high intensity' plaice spawning ground overlaps the study area (Ellis *et al.,* 2012). Plaice spawning sites are significant in size, and therefore the interaction between the sites and the study area is small. 'Low intensity' spawning grounds are present across the study area for whiting, cod, sandeel and sole (Ellis *et al.,* 2010). There are also spawning grounds present across the study area for lemon sole, mackerel, and sprat (Coull *et al.,* 1998) (Volume 2, Figure 10.2 to 10.4). A Banks (Central North Sea) herring spawning grounds intersects the Project array area and offshore ECC (Coull *et al*., 1998), and an inshore herring spawning ground is located to the south of the offshore ECC (Coull *et al*., 1998). A Nephrops spawning ground lies to the east of the array area (Coull *et al.,* 1998). These spawning grounds are significant in size, spanning large areas across the southern North Sea and the Channel. As these species' spawning sites are significant in size, the interaction between the sites and the study area is small.
34. The fish and shellfish ecology study area coincides with 'high intensity' nursery grounds for cod, herring and whiting (Coull *et al.,* 1998). 'Low intensity' nursery grounds are present across the study area for anglerfish *Lophius piscatorius*, blue whiting *Micromesistius poutassou*, cod, European hake *Merluccius merluccius*, herring, ling, mackerel *Scomber scombrus*, plaice, sandeel, sole, spurdog *Squalus acanthias*, thornback ray *Raja clavata*, tope shark *Galeorhinus galeus* and whiting (Ellis *et al.,* 2010). There are also nursery grounds present across the study area for lemon sole, Nephrops and sprat (Coull *et al.,* 1998). These nursery grounds are significant in size, spanning large areas across the southern North Sea and the Channel. As these species' nursery grounds are significant in size, the interaction between the sites and the study area is small (Volume 2, Figures 10.6 to 10.9).

Herring

35. The Banks (Central North Sea) herring spawning grounds intersect the Project array area and offshore ECC (Coull *et al*., 1998), and an inshore herring spawning ground is located to the south of the offshore ECC (Coull *et al*., 1998).
36. Areas of potential herring spawning habitat have been identified using site specific PSA data (GEOxyz, 2022a, b), BGS sediment data (BGS, 2015) and broadscale habitat mapping (EUSeaMap, 2021). These data have been classified in accordance with the Reach *et al.,* (2013) classifications to further refine the understanding of areas of potential herring spawning habitat within the proposed development site. Areas of potential herring spawning habitat are shown in Volume 2, Figures 10.10 to 10.13.

37. Site specific PSA data (GEOxyz, 2022a, b) collected within the array area were primarily characterised by sandy gravel and gravelly sand, which are characterised as ‘prime, ‘sub-prime’ and ‘suitable’ herring spawning habitats. ‘Prime’ herring spawning habitat was found 22.2% of the sample points, which were mainly clustered towards the south of the array area and the majority of the array area was deemed as ‘unsuitable’ habitat (41.9%; GEOxyz, 2022a). EUSeaMap (2021) data, as presented in Volume 2, Figures 10.10 to 10.11 shows significant areas of fine sand and muddy sand sediments across the array area. Site specific PSA data (GEOxyz, 2022b) shows the ECC is largely dominated by ‘unsuitable’ herring spawning habitats (Volume 2, Figures 10.12 to 10.13). There are areas of ‘sub-prime’ and ‘suitable’ habitats located in the mid-section of the ECC.

38. Whilst these data indicate the potential for herring spawning habitats within the array area and the nearshore and mid-section of the offshore ECC, IHLS data (ICES, 2009-2021) (Volume 2, Figures 10.14 to 10.17) indicate that areas of high intensity spawning activity are located to the north of the Project. For the purposes of the assessment, it is assumed that the Coull et al. (1998) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2009-2021) provide an indication of the areas of seabed in active use for spawning.

Sandeel

39. Areas of potential sandeel spawning habitat have been identified using site-specific PSA data (GEOxyz 2022a, b) and broadscale habitat mapping (EUSeaMap, 2021). These data have been classified in accordance with the Latto *et al. (*2013) classifications to further refine the understanding of areas of potential sandeel spawning habitat within the Project site. Areas of potential sandeel spawning habitat are shown in Volume 2, Figures 10.18 to 10.21.

40. Site specific PSA data (GEOxyz 2022a) collected across the array area were primarily characterised by sandy gravel and gravelly sand, largely characterised as ‘prime, preferred’, ‘sub-prime, preferred’ and ‘suitable, marginal’ sandeel habitat (37%, 16% and 36%, respectively). EUSeaMap (2021) data, as presented in Volume 2, Figures 10.18 to 10.19, shows significant areas of fine sand and muddy sand sediments across the array area. Site-specific PSA data (GEOxyz, 2022a,b) (Volume 2, Figures 10.20 to 10.21) collected along the ECC show areas of ‘prime, preferred’, ‘sub-prime, preferred’ and ‘suitable, marginal’ sandeel habitat in the offshore section and mid-section of the ECC, with the nearshore section of the ECC dominated by ‘unsuitable’ sandeel habitat. On a broader scale, as indicated by broadscale marine habitat mapping (EUSeaMap, 2021) there are areas of ‘prime/preferred’ habitat located to the south of the ECC, and to the north of the array area.

Species of Commercial Importance

41. Detailed information on species of commercial importance is provided in Chapter 14 (document reference 6.1.14), which identifies brown crab, European lobster and common whelk as key species for potters, king scallop *Pecten maximus* as the key species for scallop dredgers, brown shrimp, plaice and common sole as key species for beam trawlers, whiting and sandeel as key species for demersal trawlers, and herring and Atlantic mackerel as the key species for pelagic trawlers in the study area.

Diadromous Species

42. Diadromous fish are fish that spend part of their life cycle in freshwater and part in seawater; such species are termed catadromous (born in marine habitats then migrate to freshwater areas) and anadromous (born in freshwater then migrate to, and mature in, the ocean). A number of diadromous fish species have the potential to occur in the 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.

43. The Humber Estuary, to the north of the study area, is known to host several key diadromous species which are known to spawn in the freshwater environments of tributaries flowing into the estuary, including the River Derwent Special Area of Conservation (SAC). These include sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluviatilis* (both qualifying species of the Humber Estuary SAC and SSSI), Atlantic salmon *Salmo salar*, brown trout *Salmo trutta*, European eel *Anguilla anguilla*, twaite shad *Alosa fallax* and allis shad *Alosa alosa* (Perez-Dominguez, 2008; Allen, 2003; Proctor *et al,* 2000; Proctor and Musk, 2001).

Elasmobranchs

44. Nursery grounds for thornback ray, spurdog and tope shark overlap with the study area (Volume 2, Figure 10.5 to 10.9). Furthermore, various elasmobranch species were caught in offshore wind development surveys, these include thornback ray, tope shark, small-spotted catshark *Scyliorhinus canicula*, starry smooth-hound and spotted ray.

Species of Conservation Importance

45. Within the study area there are number of marine and estuarine species protected under national and international legislation that have the potential to be present within the Project study area. These are discussed in full in Appendix 10.1 (document reference 6.3.10.1).

46. Those species which are designated under the Habitats Directive (among other legislation) are:
    - Allis shad;
    - Atlantic salmon;
    - River lamprey;
    - Sea lamprey;
    - Twaite shad; and

- European eel (designated under The Eels (England and Wales) Regulations 2009 (hereafter the Eels Regulations), and Eel Recovery Plan (Council Regulation No 1100/2007).

47. Several species of conservation importance were identified in the site-specific eDNA analysis. These were:
    - Tope shark (UK BAP Priority species and IUCN 'Critically Endangered' species);
    - Starry smooth-hound (classed as 'Near threatened' on the IUCN Red List);
    - Spotted ray (afforded protection as an OSPAR Threatened or Declining Species);
    - Atlantic herring (UK BAP Priority species due to their 'National Scarcity');
    - Alosa spp. (UK BAP Priority species);
    - Atlantic salmon (UK BAP Priority species and afforded protection as an OSPAR Threatened or Declining Species);
    - Brown trout (Section 41 Priority species);
    - Sandeel (UK BAP Priority species); and
    - Atlantic mackerel (UK BAP Priority species).
48. The Humber Estuary SAC, the Humber Estuary Ramsar and the Humber Estuary SSSI all have both the sea lamprey and river lamprey listed as qualifying features. These species are known to migrate through the Humber estuary to freshwater spawning habitats.
49. The Southern North Sea SAC is designated for the Annex II species harbour porpoise *Phocoena phocoena*. The SAC has a Conservation Objective to maintain Favourable Conservation for the harbour porpoise, which includes the maintenance of the availability of prey habitats (which typically consists of non-spiny fish such as herring, whiting, Atlantic cod, sprat and squid).
50. The Flamborough and Filey SPA is designated for a number of seabirds including black-legged kittiwake *Rissa tridactyla*, northern gannet *Morus bassanus*, common guillemot *Uria aalge* and razorbill *Alca torda*, of which sandeels, sprats and young herring are key prey species.
51. The Greater Wash SPA is designated for Red-throated diver *Gavia stellata*, Common scoter *Melanitta nigra*, Little gull *Hydrocoloeus minutus*, Sandwich tern *Sterna sandvicensis*, Common tern *Sterna hirundo* and Little tern *Sternula albifrons*. Cod, herring and sticklebacks are key prey species for Red-throated diver. All other designated features feed on crustacea, juvenile or small fish and insects.
52. The only MCZ of relevance to fish and shellfish receptors within the study area is the Holderness Offshore MCZ which is designated for the ocean quahog, a bivalve mollusc found in sandy seabed throughout the North Sea.

Valued Ecological Receptors

53. The Project has taken a Valued Ecological Receptor (VER) approach, in line with the Chartered Institute of Ecology and Environmental Management (CIEEM) 2018 Guidance (CIEEM, 2018), which allows the assessment to focus on the ecological importance of the features. This is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM, 2016).
54. Based on the baseline characterisation summarised above, a number of VERs were identified within the fish and shellfish study area and include species which have:
    - Populations present within the fish and shellfish study area;
    - Spawning, nursery and migratory behaviour within the fish and shellfish study area; and
    - Commercial, conservation and ecological interest, including importance in supporting species of high trophic levels (e.g., prey species for bird and marine mammal species).
55. See Appendix 10.1 (document reference 6.3.10.1), for detailed justification for the identification of the VERs listed in Table 10.6.

Table 10.6: Summary of fish and shellfish VERs.

VER	Valuation	Justification
Demersal VERs		
Atlantic cod	International	Study area overlaps low intensity spawning and low intensity nursery grounds. Cod were also recorded in Offshore Windfarm (OWF) development surveys. Cod are listed as a Section 41 priority species, listed on the Oslo/Paris Convention (for the Protection of the Marine Environment of the North-East Atlantic) (OSPAR) List of Threatened and/or Declining Species and Habitats, and are listed as vulnerable on the Union for Conservation of Nature (IUCN) Red List.
Dab	Local	Recorded throughout the Project fish and shellfish study area in site-specific epibenthic trawls, regional trawls and offshore wind development surveys.
Plaice	Regional	Study area overlaps high intensity spawning grounds and low intensity nursery grounds. UK BAP species (commercial marine fish grouped action plan) and NERC

VER	Valuation	Justification
		species of principal importance. Recorded throughout the Project fish and shellfish study area in site-specific trawls, regional trawls and offshore wind development surveys. Of commercial importance to the region.
Lemon sole	Local	Study area overlaps spawning grounds and low intensity nursery grounds. Recorded in regional trawls and offshore wind development surveys.
Common sole	Regional	Study area overlaps low intensity spawning ground. Of commercial importance to the region. Recorded in site-specific epibenthic trawls, regional trawls and offshore wind development surveys. Common sole is listed as a UK BAP and Section 41 Species.
Whiting	Regional	Study area overlaps low intensity spawning and low intensity nursery grounds. Whiting is listed as a UK BAP and Section 41 Species. Of commercial importance to the region. Recorded in site-specific epibenthic trawls, regional trawls and offshore wind development surveys.
Angler fish	Local	Study area overlaps low intensity nursery grounds.
Lesser weaver	Local	Study area overlaps low intensity nursery grounds. Recorded in site-specific grab samples and water column eDNA samples, and offshore wind development surveys.
Blue whiting	Local	Study area overlaps low intensity nursery grounds.
Ling	Local	Study area overlaps low intensity nursery grounds. Recorded in site-specific epibenthic trawls.
European hake	Local	Study area overlaps low intensity nursery ground.
Pelagic VERs		

VER	Valuation	Justification
Atlantic mackerel	Regional	Study area overlaps spawning grounds and low intensity nursery grounds. Of commercial importance to the region. UK BAP Species, and Section 41 Priority Species. Prey species for birds and marine mammals and forming key components of the ecosystem. Recorded in site-specific water column eDNA samples, regional trawls and offshore wind development surveys.
Sprat	Regional	Study area overlaps a spawning ground. Recorded in site-specific water column eDNA samples and offshore wind development surveys. Of commercial importance to the region. Important prey species for bird and marine mammal species.
European anchovy	Regional	Recorded in site-specific water column eDNA samples. Of commercial importance to the region.
European bass	Regional	Recorded in site-specific water column eDNA samples and offshore wind development surveys. Additionally, of commercial importance to the region.
Migratory VERs		
Brown trout	Regional	Recorded in site-specific water column eDNA samples. Section 41 and UK BAP Priority species. Potential for this species to transit the site.
European eel	International	Designated under the Eel Regulations. Listed as UK BAP priority species, listed on the OSPAR List of Threatened and/or Declining Species and Habitats, and European eel is listed as critically endangered on the IUCN Red List.

VER	Valuation	Justification
		Potential for this species to transit the site.
Atlantic salmon	International	Recorded in site-specific water column eDNA samples and offshore wind development surveys. Annex III of the Bern convention, listed on the OSPAR List of Threatened and/or Declining Species and Habitats, listed on The Conservation of Habitats and Species Regulations (2017), and a UK BAP priority species. Potential for this species to transit the site.
Sea lamprey	International	Annex III of the Bern Convention, listed on the OSPAR List of Threatened and/or Declining Species and Habitats, listed on The Conservation of Habitats and Species Regulations (2017), Schedule 5 of the Wildlife and Countryside Act, UK BAP priority fish species. Potential for this species to transit the site.
River lamprey	National	Annex III of the Bern Convention, listed on The Conservation of Habitats and Species Regulations (2017), Schedule 5 of the Wildlife and Countryside Act, UK BAP priority fish species. Potential for this species to transit the site.
Twaite shad	Regional	Annex II of the Bern Conventions, listed on The Conservation of Habitats and Species Regulations (2017), Schedule 5 of the Wildlife and Countryside Act 1981 and UK BAP priority fish species. Potential for this species to transit the site.
Allis shad	International	Annex II of the Bern Conventions, listed on the OSPAR List of Threatened and/or Declining Species and Habitats, listed on The

VER	Valuation	Justification
		Conservation of Habitats and Species Regulations (2017), Schedule 5 of the Wildlife and Countryside Act 1981 and UK BAP priority fish species. Potential for this species to transit the site.
Benthopelagic VERs		
Herring	Regional	Spawning and low intensity nursery grounds occur across the study area. UK BAP species and nationally important marine feature. Prey species for birds and marine mammals. Important commercial fish species. Recorded in site-specific water column eDNA samples, regional trawls and offshore wind development surveys. Of commercial importance to the region.
Sandeel (lesser sandeel, great sandeel, smooth sandeel, Raitts sandeel)	Regional	Low intensity spawning and low intensity nursery grounds occur across the study area. Important prey species for fish, birds and marine mammals. UK BAP species and a nationally important marine feature. Recorded in site-specific grab samples, epibenthic trawls and water column eDNA samples, and offshore wind development surveys. Of commercial importance to the region.
Shellfish VERS		
Brown crab	Regional	Important commercial shellfish species in the Project study area. Recorded in site-specific grab samples and epibenthic trawls, and offshore wind development surveys.
European lobster	Regional	Important commercial shellfish species in the Project study area. Recorded in offshore wind development surveys.

VER	Valuation	Justification
Nephrops	Regional	Known spawning and nursery ground located within the study area.
Ocean quahog	International	This species is listed on the OSPAR List of Threatened and/or Declining Species and Habitats. It is also a Feature of Conservation Importance for which the Holderness Offshore Marein Conservation Zone (MCZ) is designated. As such these are considered of international importance.
Blue mussel	Regional	Important commercial shellfish species in the Project study area. Recorded in site-specific epibenthic trawls.
Common cockle	Regional	Important commercial shellfish species in the Project study area.
Common whelk	Regional	Important commercial shellfish species in the Project study area. Recorded in site-specific epibenthic trawls.
Brown shrimp	Regional	Important commercial shellfish species in the Project study area. Important prey species. Recorded in site-specific grab samples and epibenthic trawls, and offshore wind development surveys.
Queen scallop	Regional	Recorded in site-specific epibenthic trawls. Important commercial shellfish species in the Project study area.
King scallop	Regional	Recorded in site-specific epibenthic trawls. Important commercial shellfish species in the Project study area.
Elasmobranch VERS		
Thornback ray	International	Study area overlaps low intensity nursery grounds. Listed on the OSPAR List of Threatened and/or Declining Species and Habitats and listed as near threatened by the IUCN red list. Recorded in site-specific epibenthic trawls and

VER	Valuation	Justification
		offshore wind development surveys.
Blonde ray	Regional	Blonde ray *Raja brachyura* is included as it has been identified by Lincolnshire Wildlife Trust as a species of concern.
Spotted ray	International	Recorded in site-specific water column eDNA samples and offshore wind development surveys. Listed on the OSPAR List of Threatened and/or Declining Species and Habitats
Common smooth-hound	International	Listed as ‘Vulnerable’ on the IUCN red list. Recorded in offshore wind development surveys.
Starry smooth-hound	Regional	Classed as ‘Near Threatened’ on the IUCN Red List. Recorded in site-specific water column eDNA samples and offshore wind development surveys.
Small-spotted catshark	Regional	Section 41 priority species. Recorded in site-specific water column eDNA samples and offshore wind development surveys.
Spurdog	International	Study area overlaps low intensity nursery grounds. UK BAP species, listed as ‘Vulnerable’ on the IUCN Red List, listed on the OSPAR List of Threatened and/or Declining Species and Habitats and NERC Species of Principle Importance.
Tope shark	International	Study area overlaps low intensity nursery grounds. UK BAP species and listed as ‘Critically Endangered’ by the IUCN red list. Recorded in site-specific water column eDNA samples and offshore wind development surveys.

10.4.5 Future Baseline

56. The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 require that "an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge" is included within the ES (EIA Regulations 2017, Schedule 4, Paragraph 3). From the point of assessment, over the course of the development and operational lifetime of the Project (operational lifetime is anticipated to be 35 years), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that the Project is not constructed, using available information and scientific knowledge of fish and shellfish ecology.
57. Recent research has suggested that there have been substantial changes in the fish communities in the northeast Atlantic, specifically the North Sea, over several decades as a result of a number of factors including climate change and fishing activities (DECC, 2016). These communities consist of species that have complex interactions with one another and the natural environment. Fish and shellfish populations are subject to natural variations in population size and distributions, largely as a result of year-to-year variation in recruitment success and these population trends will be influenced by broad-scale climatic and hydrological variations, as well as anthropogenic effects such as climate change and overfishing.
58. Fish and shellfish play a pivotal role in the transfer of energy from some of the lowest to the highest trophic levels within the ecosystem and serve to recycle nutrients from higher levels through the consumption of detritus. Consequently, their populations will be determined by both top-down factors such as predation, and bottom-up factors such as ocean climate and plankton abundance. Fish and shellfish are important prey items for top marine predators including elasmobranchs, seabirds and cetaceans, and small planktivorous species such as sandeel and herring act as important links between zooplankton and top predators (Frederiksen *et al.,* 2006).
59. Climate change influences fish distribution and abundance, affecting growth rates, recruitment, behaviour, survival and response to changes of other trophic levels (Prakash and Srivastava, 2019). Climate change is contributing to the declining levels of primary production in the North Sea which in turn effects the dynamics of higher trophic levels and fish recruitment (Capuzzo *et al*, 2018). Projected warming scenarios indicated regime shifts between sandeels and their copepod prey, resulting in sandeel recruitment declines (Regnier *et al.,* 2019). Increased sea surface temperatures in the North Sea may lead to an increase in the relative abundance of species associated with more southerly areas. For example, data on spawning herring and sardine *Sardina* spp. landings at ports in the English Channel showed that higher spawning herring landings were correlated with colder winters, while warm winters were associated with large catches of sardine (Alheit and Hagen, 1997).

60. One potential effect of increased sea surface temperatures is that some fish species will extend their distribution into deeper, colder waters (Poloczanska *et al*, 2013). In these cases, however, habitat requirements are likely to become important, with some shallow water species having specific habitat requirements in shallow water areas which are not available in these deeper areas. For example, sandeel is less likely to be able to adapt to increasing temperatures as a result of its specific habitat requirements for coarse sandy sediment and declining recruitment in sandeel in parts of the UK has been correlated with increasing temperature (Heath *et al*, 2012). Climate change may also affect key life history stages of fish and shellfish species, including the timing of spawning migrations (DESNZ, 2016). However, climate change effects on marine fish populations are difficult to predict and the evidence is not easy to interpret and therefore it is difficult to make accurate estimations of the future baseline scenario for the entire lifetime of the Project (35 years).

61. In addition to climate change, overfishing subjects the populations of many fish species to considerable pressure, reducing the biomass of commercially valuable species, and non-target species. Overfishing can reduce the resilience of fish and shellfish populations to other pressures, including climate change and other anthropogenic impacts. For example, a study on cod in an area where trawl fishing has been banned since 1932 indicated that this population was significantly more resilient to environmental change (including climate change) than populations in neighbouring fished areas (Lindegren *et al*, 2010). Modelling by Beggs *et al,* (2013) indicated that cod may be more sensitive to climate variability during periods of low spawning stock biomass.

62. The variations and trends in commercial fisheries activity are an important aspect of the future baseline, specifically as existing baseline data do not capture any potential changes in commercial fisheries activity resulting from the withdrawal of the UK from the European Union (EU).

63. Following withdrawal, the UK and the EU have agreed to a Trade and Cooperation Agreement (TCA), applicable on a provisional basis from 1st May 2021. The TCA sets out fisheries rights and confirms that from 1 May 2021 and during a transition period until 30 June 2026, UK and EU vessels will continue to access respective Exclusive Economic Zones (EEZs, 12nm to 200 nm) to fish. In this period, EU vessels will also be able to fish in specified parts of UK waters between 6nm to 12nm. It is not currently clear whether any changes in fishing pressure will occur following the end of the transition period for fishing post-Brexit, however it is likely that general trends of fishing pressure will continue in response to existing demand, although as stocks move north as would the corresponding fishing pressure. Whilst warming waters would allow new species to colonise new areas, specific fisheries quotas would have to be developed to allow the fishing of these stocks. As such, it not possible to predict the consequences of this.

64. In conclusion, it is considered that current trends with regard to the northward shift of specific species (e.g. sandeel) and an increase in the abundance of typically warmer water species (e.g. sardines) will continue in a warming climate, which will may result in alterations to the existing baseline, however, considering the timescales of warming oceans and changes in distribution of species, it is likely that in the near to medium term, this would be changes in the relative abundances of species rather than wholescale changes in the community structure.

65. The Project fish and shellfish baseline characterisation described in the preceding sections (and presented in detail in Appendix 10.1 (document reference 6.3.10.1)) represents a 'snapshot' of the fish and shellfish assemblages of the North Sea, within a gradual and continuously changing environment. Any changes that may occur during the lifetime of the project (i.e., construction, operation and decommissioning) should be considered in the context of the natural variability and other existing anthropogenic effects, including climate change and overfishing.

10.4.6 Scope of the Assessment

Impacts Scoped in for Assessment

66. The following impacts have been scoped into this assessment:

- Construction:
  - Impact 1: Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity;
  - Impact 2: Increase in SSC and sediment deposition;
  - Impact 3: Temporary seabed habitat loss/disturbance;
  - Impact 4: Direct and indirect seabed disturbances leading to the release of sediment contaminants; and
  - Impact 5: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish species.
- Operation and maintenance:
  - Impact 6: Underwater noise as a result of operational turbines;
  - Impact 7: Long-term habitat loss due to the presence of turbine foundations, scour protection and cable protection;
  - Impact 8: Increased hard substrate and structural complexity, as a result of the introduction of turbine foundations, scour protection and cable protection;
  - Impact 9: Direct disturbance resulting from O&M activities; and
  - Impact 10: EMF effects arising from cables.
- Decommissioning:
  - Impact 11: Mortality, injury and behavioural changes resulting from underwater noise arising from decommissioning activity;
  - Impact 12: Increase in SSC and sediment deposition;

- Impact 13: Temporary seabed habitat loss/disturbance;
- Impact 14: Direct and indirect seabed disturbances leading to the release of sediment contaminants;
- Impact 15: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish species; and
- Impact 16: Loss of additional habitat arising from the removal of infrastructure that have been used by fish and shellfish communities during the operational phase of the project.

Impacts Scoped out of Assessment

67. In line with the Scoping Opinion (The Planning Inspectorate, 2022) and based on the receiving environment, expected parameters of the Project (Chapter 3 (document reference 6.1.3)), and expected scale of impact/potential for a pathway for effect on the environment, the following impacts have been scoped out of the assessment:

- Accidental pollution; and
- Impacts on fishing pressure due to displacement.

10.4.7 Realistic Worst-Case Scenario

68. The following section identifies the Maximum Design Scenario (MDS) in environmental terms, defined by the Project design envelope.

69. Should the Project be constructed to different parameters within the design scenario, then impacts would not be any greater than those set out in this ES using the MDS presented in Table 10.7.

Table 10.7: Maximum design scenario for fish and shellfish ecology for the Project alone.

Potential effect	Maximum design scenario assessed	Justification
Construction		
Impact 1: Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity.	<u>Array Area – sequential piling of jacket Foundations (temporal Maximum Design Scenario (MDS))</u> ▪ 100 Wind Turbine Generators (WTGs) on jacket foundations (5m pile diameter, four pin piles per foundation, one foundation per WTG). Sequential piling of six piles in a 24-hour period); ▪ Four small Offshore Substations (OSS) on jacket foundations (5m pile diameter, four piles per foundation and six foundations per OSS), sequential piling of six piles in a 24-hour period); ▪ One offshore accommodation platform (5m diameter jacket foundation, four piles per foundation and six foundations); ▪ Total of 520 piles within the array area; ▪ Maximum hammer energy 3,500kJ; ▪ Six hour piling duration per pin pile for WTGs (2,400 hours piling) ▪ Eight-hour piling duration per pin pile for OSS and accommodation platform) (960 hours pling); ▪ 3,360 hours piling; ▪ Maximum separation distance between piling events will be the maximum extent of the array area. <u>Array Area – sequential piling of monopile foundations (this scenario does not represent the spatial or temporal MDS for stationary or fleeing receptors)</u>	For the array area, the spatial MDS for stationary receptors results from the concurrent piling of up to six pin piles for jacket foundations for 100 WTGs, four OSS and one accommodation platform using 3,500kJ hammer energy. The spatial MDS for fleeing receptors from piling in the array area relates to the concurrent piling of two monopile foundations for 100 WTGs, four OSS and one accommodation platform using 6,600kJ hammer energy. This would result in the largest spatial noise impact at any given time when considering impacts to fleeing receptors in the array area. In the ECC, the spatial MDS for stationary receptors results from the sequential piling of pin piles for two Offshore Reactive Compensation Platforms (ORCPs) on jacket foundations, using 3,500kJ hammer energy. Within the ECC, the spatial MDS for fleeing receptors results from the sequential piling of monopiles for two ORCPs using 6,600kJ hammer energy.

Potential effect	Maximum design scenario assessed	Justification
	■ 100 WTGs on monopile foundations (13m pile diameter). Piling of one monopile in a 24-hour period, or sequential piling of two piles in a 24-hour period; ■ Four small OSS on monopile foundations (14m pile diameter); ■ One offshore accommodation platform (14m pile diameter); ■ Total installation of 105 monopiles; ■ Maximum hammer energy 6,600kJ; ■ Eight-hour piling duration; ■ 840 hours piling duration. ■ Maximum separation distance between piling events will be the maximum extent of the array area. <u>Array area, concurrent piling of monopile foundations (spatial MDS for fleeing receptors)</u> ■ Monopile foundations (14m pile diameter). Two monopiles installed concurrently at NE and SW extents of array area (6,600kJ hammer energy). Eight hour-piling duration. <u>Array area, concurrent piling of jacket foundations (spatial MDS for stationary receptors)</u> ■ Jacket foundations (5m pile diameter). Six piles installed concurrently at NE and SW extents of array area (3,500kJ hammer energy). Six hour piling duration. <u>ECC (spatial MDS for stationary receptors, temporal MDS)</u> ■ Two ORCPs on jacket foundations (5m pile diameter, four piles per foundation and six foundations) total of 24 pin piles per ORCP;	For the Artificial Nesting Structure (ANSs), the spatial MDS for stationary receptors results from the sequential piling of up to four pin piles for jacket foundations within a 24-hour period using 3,500kJ hammer energy. For the ANSs, when considering fleeing receptors, the spatial MDS results from the sequential piling of up to four pin piles for jacket foundations within a 24-hour period, using 3,500kJ hammer energy; or the single piling of one monopile within a 24-hour period using 6,600kJ hammer energy. Note, that the sequential piling of monopiles for the ANSs is not being considered as a piling scenario by the Project. Across the whole project, the temporal MDS results from the sequential piling of pin piles for jacket foundations, using 3,500kJ hammer energy. A total of 3,792 hours of piling within a seven-year construction window would result in the longest duration of piling.

Potential effect	Maximum design scenario assessed	Justification
	▪ Sequential piling of six piles in a 24-hour period); ▪ Maximum hammer energy 3,500kJ; ▪ 8 hours piling duration per pile. ▪ 384 hours total piling duration. ECC (spatial MDS for fleeing receptors) ▪ Two ORCPs on monopile foundations (14m piles). Piling of one monopile in a 24-hour period, or sequential piling of two piles in a 24-hour period; ▪ Maximum hammer energy 6,600kJ; ▪ 8 hours piling per pile ▪ 16 hours total piling duration . ANS (spatial MDS for stationary and fleeing receptors, temporal MDS) ▪ Two ANS on jacket foundations (5m pile diameter, four piles per foundation). Sequential piling of four piles in a 24-hour period); ▪ Maximum hammer energy 3,500kJ; ▪ 6 Hours piling per pile ▪ 48 hours piling total duration. ANS (spatial MDS for fleeing receptors)Two ANS on monopile foundations (8m pile diameter). Single piling of one monopile in a 24-hour period. ▪ Maximum hammer energy 6,600kJ; ▪ 8 hours piling per pile ▪ 16 hours piling total duration.	

Potential effect	Maximum design scenario assessed	Justification
	UXO Clearance: ▪ Max charge size: 800kg + donor	
Impact 2: Increase in SSC and sediment deposition.	Total subtidal sediment volume = 36,163,760m^3 Foundation seabed preparation = 3,971,360m^3 ▪ 100 small WTGs (Gravity Base Structure (GBS) foundations) = 3,630,000m^3 ▪ Four small OSS (GBS foundations) = 194,000m^3 ▪ One Accommodation platform (GBS foundations) = 48,500m^3 ▪ Two ORCPs = (GBS foundations) 97,000m^3 ▪ Two ANS = (monopile foundations) = 1,855 m^3 Foundation installation (drill spoil volumes) = 987,400m^3 ▪ 100 WTG foundations (monopile foundations) = 780,000m^3 ▪ Four small OSS (pin pile jacket foundations) = 109,600m^3 ▪ One Accommodation platform (pin pile jacket foundations) = 27,400m^3 ▪ Two ORCPs (pin pile jacket foundations) = 54,800m^3 ▪ Two ANS (pin pile jacket foundations) = 15,600m^3 **Sandwave clearance for cable installation = 16,135,000m^3** ▪ Sandwave clearance for 380km of array cables resulting in the suspension of 7,820,000m^3 of sediment ▪ Sandwave clearance for 125km of interlink cables resulting in the suspension of 2,564,000m^3 of sediment	The MDS for foundation installation results from the largest volume suspended from seabed preparation and presents the worst-case for WTG installation. For cable installation, the MDS results from the greatest volume from sandwave clearance and installation. This also assumes the largest number of cables and the greatest burial depth.

Potential effect	Maximum design scenario assessed	Justification
	▪ Sandwave clearance for 440km of export cables resulting in the suspension of 5,751,000m^3 of sediment <u>Cable trenching = 15,050,000m^3</u> ▪ Installation of 380km of inter-array cables using mass flow excavation, resulting in the suspension of 6,039,000m^3 of sediment. ▪ Installation of 125km of interlink cables using mass flow excavation, resulting in the suspension of 1,980,000m^3 of sediment. ▪ Installation of 440km of export cables using mass flow excavation, resulting in the suspension of 7,040,000m^3 of sediment. <u>Total nearshore sediment volume = 20,000m^3</u> ▪ Six offshore trenchless technique exit pits require excavation of 20,000m^3 which will be side cast onto the adjacent seabed. Backfilling of exit pits will recover a similar amount from the surrounding seabed, as required. <u>Trenchless drilling fluid release</u> ▪ Maximum volume and mass of drilling fluid released per HDD conduit: 773m^3 fluid (138,000kg bentonite); and ▪ Period of release: 12 hours with estimated release rate of 3,195g/s. <u>Biogenic reef creation</u> ▪ Creation of a biogenic reef within the biogenic reef areas	

Potential effect	Maximum design scenario assessed	Justification
Impact 3: Temporary seabed habitat loss/disturbance.	Temporary habitat disturbance of 22,732,643m²**.** Foundation seabed preparation = 1,082,300m² ▪ 100 small WTGs (jacket foundations with suction buckets) = 930,000m² ▪ Four small OSS (jacket foundations with suction buckets) = 78,400m² ▪ One accommodation platform (jacket foundations with suction buckets) = 19,600m² ▪ Two ORCPs (jacket foundations with suction buckets) = 39,200m² ▪ Two ANS (GBS foundations) = 15,100m² Jack-up vessels (JUV) and anchoring operations = 1,185,843m² ▪ 388 anchoring operations during WTG installation, with a maximum disturbance of 800m² per operation = 310,400m² ▪ 16 anchoring operations a maximum disturbance of 800m² per operation for installation of four OSS = 12,800m² ▪ 16 anchoring operations with a maximum disturbance of 800m² per operation for installation of two ORCPs = 12,800 m² ▪ 16 anchoring operations with a maximum disturbance of 800m² per operation for installation of one accommodation platform = 12,800m²	This scenario represents the maximum total seabed disturbance and therefore the maximum amount of temporary habitat loss.

Potential effect	Maximum design scenario assessed	Justification
	▪ 16 anchoring operations with a maximum disturbance of 800m² per operation for installation of two ANS = 12,800 m² ▪ JUV operations for installation of 100 small WTGs (1,613m² disturbance per operation) (511 operations) = 824,243m² <u>Cable seabed preparation = 20,574,500 m²</u> ▪ Total area of seabed disturbed by sandwave clearance for inter-array cables = 3,680,000m² ▪ Total area of seabed disturbed by boulder clearance for inter-array cables = 6,794,000m² ▪ Total area of seabed disturbed by sandwave clearance for interlink cables = 1,207,000m² ▪ Total area of seabed disturbed by boulder clearance for interlink cables = 2,227,500m² ▪ Total area of seabed disturbed by sandwave clearance in offshore ECC = 2,706,000m² ▪ Total area of seabed disturbed by boulder clearance in offshore ECC = 3,960,000m² <u>Cable burial</u> ▪ Impact will occur fully within combined footprint from sandwave and boulder clearance <u>Biogenic reef creation</u> ▪ Creation of a biogenic reef within the biogenic reef areas	

Potential effect	Maximum design scenario assessed	Justification
Impact 4: Direct and indirect seabed disturbances leading to the release of sediment contaminants.	The MDS for the maximum volumes of seabed sediment disturbance are presented in Impact 2.	This scenario represents the maximum total seabed disturbance and therefore the maximum amount of contaminated sediment that may be released into the water column during construction activities.
Impact 5: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish species.	The MDS for direct damage/disturbance is presented in Impact 3.	The subtidal direct damage temporary disturbance relates to seabed preparation for foundations and cables, jack up and anchoring operations, and cable installation. It should be noted that where boulder clearance overlaps with sandwave clearance, the boulder clearance footprint will be within the sandwave clearance footprint. The MDS for direct damage in the intertidal area from the HDD works is included.
Operation and Maintenance		
Impact 6: Underwater noise as a result of operational turbines.	Underwater noise during the operational phase from 100 WTGs and maintenance vessel operations over the lifetime of the project (i.e., up to 35 years). Twenty-four maintenance vessel operations per year, with 840 operations over the lifetime of the project.	The maximum number of operational WTGs and related O&M visits by vessels during the lifetime of the project is approximately 840 vessels over the full lifetime of the project (up to 35 years).
Impact 7: Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection.	Habitat loss of 4,444,900**m^2** ▪ Turbine total structure footprint including scour protection, based on 100 GBS (small WTG-type) foundations = 1,230,000m^2 ▪ Structure footprint of four small OSS (jacket foundations with suction buckets) = 78,400m^2	The MDS is defined by the maximum area of seabed lost as a result of the placement of structures, scour protection, cable protection and cable crossings. The MDS also considers that scour protection is required for all foundations. Habitat loss from drilling and drill arisings is of a smaller magnitude than presence of project infrastructure.

Potential effect	Maximum design scenario assessed	Justification
	■ One Accommodation platform (jacket foundations with suction buckets) = 19,600m^2 ■ Two ORCPs platform (jacket foundations with suction buckets) = 39,200m^2 ■ Two ANS (GBS foundations) = 24,6000m^2 ■ Total area of seabed covered by cable protection required for inter-array cable crossings (rock berm) = 240,000m^2 (30 crossings) ■ Total area of seabed covered by cable protection required for interlink cable crossings (rock berm) = 128,000m^2 (16 crossings) ■ Total area of seabed covered by cable protection required for export cable crossings (rock berm) = 304,000m^2 (38 crossings) ■ Total area of seabed covered by inter-array cable protection, assuming 23% of the cable requires protection = 1,031,000m^2 ■ Total area of seabed covered by interlink cable protection, assuming 19% of the cable requires protection = 279,000m^2 ■ Total area of seabed covered by export cable protection, assuming 21% of the cable requires protection = 1,092,000m^2 ■ Creation of a biogenic reef within the biogenic reef areas	
Impact 8: Increased hard substrate and structural complexity, as a result of the introduction of	Total surface area of introduced hard substrate in the water column = 46,125,664m^2	The maximum scenario for introduced hard substrate is as for the maximum scenario for loss of habitat.

Potential effect	Maximum design scenario assessed	Justification
turbine foundations, scour protection and cable protection, and the biogenic reef creation.	▪ Total area of introduced hard substrate at seabed level = 4,444,900m^2 ▪ Total surface area of subsea portions of WTG foundations (GBS foundations) in contact with the water column = 40,782,200m^2 ▪ Total surface area of subsea portions of four small OSS (GBS foundations) in contact with the water column = 48,000m^2 ▪ Total surface area of subsea portions of one accommodation platform (GBS foundations) in contact with the water column = 12,000m^2 ▪ Total surface area of subsea portions of two ORCP (GBS foundations) in contact with the water column = 24,000m^2 ▪ Total surface area of subsea portions of two ANS (GBS foundations) in contact with the water column = 814,564m^2 ▪ Creation of a biogenic reef within the biogenic reef areas	
Impact 9: Direct disturbance resulting from O&M activities.	**Total direct disturbance to seabed from repair/replacement activities = 6,367,098m^2** ▪ Total seabed area disturbed by WTG maintenance activities (component replacements, anode/ladder replacements, J-tube repairs) = 3,582,000m^2 ▪ Total seabed area disturbed by ANS maintenance activities= 78,858m^2	Defined by the maximum number of jack-up vessel operations and maintenance activities that could have an interaction with the seabed anticipated during operation.

Potential effect	Maximum design scenario assessed	Justification
	▪ Total seabed area disturbed by offshore platform maintenance activities (OSS, ORCP and accommodation platform) = 313,740m^2 ▪ Total seabed disturbance from array cable repairs or remedial burial = 945,000m^2 ▪ Total seabed disturbance from ECC repairs or remedial burial = 1,111,500m^2 ▪ Total seabed disturbance from interlink cable repairs or remedial burial = 336,000m^2	
Impact 10: Electromagnetic Field (EMF) arising from cables.	▪ Up to 380km of inter-array cables, operating up to 132kV ▪ Up to 125km of interlink cables, operating from 66kV – 275kV. ▪ Up to 440km of export cable, operating at up to 275kV ▪ Cable burial depth (Inter-array, interlink and export cable) = 0 – 3m	The maximum adverse scenario is associated with the use of 100 WTGs as this results in the greatest length of inter-array cables, interlink cables and export cables as this results in the longest total length of cable.
Decommissioning		
Impact 11: Mortality, injury and behavioural changes resulting from underwater noise arising from decommissioning activity.	Maximum levels of underwater noise during decommissioning would be from underwater cutting required to remove structures. This is much less than pile driving and therefore impacts would be less than as assessed during the construction phase/piled foundations would likely be cut approximately 1m below the seabed	This would result in the maximum potential disturbance associated with noise associated with decommissioning activities including foundation decommissioning.
Impact 12: Increase in SSC and sediment deposition.	MDS is identical (or less) to that of the construction phase. Total subtidal sediment volume = 36,163,760m^3	The maximum impacts from remedial cable burial and cable repairs of array, interlink and export cables result from the use of mass flow excavation. This assumes the largest number of cables, repair events, the greatest burial depth and greatest length/area of

Potential effect	Maximum design scenario assessed	Justification
		maintenance. This results in the maximum sediment volume disturbance.
Impact 13: Temporary seabed habitat loss/disturbance	MDS is identical (or less) to that of the construction phase. Temporary habitat disturbance of 22,771,043m^2.	MDS is assumed to be similar to the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables and rock protection is considered the MDS, however the necessity to remove cables and rock protection will be reviewed at the time of decommissioning.
Impact 14: Direct and indirect seabed disturbances leading to the release of sediment contaminants.	MDS is identical (or less) to that of the construction phase. Total subtidal sediment volume = 36,163,760m^3.	MDS is assumed to be as per the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables is considered the MDS, however the necessity to remove cables will be reviewed at the time of decommissioning.
Impact 15: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish and shellfish.	MDS is identical (or less) to that of the construction phase. Temporary habitat disturbance of 22,771,043m^2.	MDS is assumed to be similar to the construction phase, with all infrastructure removed in reverse-construction order. The removal of cables and rock protection is considered the MDS, however the necessity to remove cables and rock protection will be reviewed at the time of decommissioning.
Impact 16: Loss of additional habitat arising from the removal of infrastructure that have been used by fish and shellfish communities	MDS is identical (or less) to that of the operation phase. Total area of habitat loss = 4,444,900m^2.	MDS is assumed to be similar to the construction phase, with all infrastructure removed in reverse-construction order.

Potential effect	Maximum design scenario assessed	Justification
during the operational phase of the project.		

10.4.8 Embedded Mitigation

70. Mitigation measures that were identified and adopted as part of the evolution of the project design (embedded into the Project design) and that are relevant to fish and shellfish ecology are listed in Table 10.8. General mitigation measures, which would apply to all parts of the project, are set out first. Thereafter mitigation measures that would apply specifically to fish and shellfish ecology issues associated with the array, export cable corridor and landfall, are described separately.

Table 10.8: Embedded mitigation relating to fish and shellfish ecology.

Project phase	Mitigation measures embedded into the project design	How the mitigation measures will be secured
General		
Definition of Development Boundaries	The development boundary selection was made following a series of constraints analyses, with the array area, Artificial Nesting Structure (ANS), benthic compensation areas and offshore ECC route selected to ensure the impacts on sensitive environmental receptors are minimised.	Development Consent Order (DCO) Order Limits
Construction		
Cable Specification and Installation Plan	A Cable Specification and Installation Plan (CSIP) will be developed prior to construction, informed by a cable burial risk assessment, which specify the installation techniques, necessary minimum burial depths and any remedial protection required. Cable burial will be the preferred option for cable protection, and this will minimise any impacts associated with habitat loss and EMF. An outline CSIP has been submitted with the DCO application. The CSIP which will be submitted under the dML condition will accord with the outline CSIP.	DCO (via a condition within the deemed Marine Licences (dMLs)).
Piling Marine Mammal Mitigation Program (MMMP)	Implementation of a piling MMMP (to minimize the risk of auditory injury to negligible levels).	DCO (via a condition within the dML).
Pollution Prevention	A Project Environmental Management Plan (PEMP) will be produced and followed. This will include a Marine Pollution Contingency Plan (MPCP) which will safeguard the marine environment in the event of accidental pollution occurring as a result of Project operations. Plans will also highlight key organisations and contact details in the event of a spill (e.g. Environment Agency, Marine Management Organisation, Natural England and the Maritime and Coastguard Agency (MCA)).	DCO (via a condition within the dML).
Marine INNS control	Relevant best practice guidelines will be followed and implemented through the PEMP, which will be in line with the Outline PEMP (document 8.4). Any vessels used for the delivery of materials to site will adhere to industry legislation, codes of conduct and/or best practice to reduce the risk of introduction or spread of invasive non-native species.	DCO (via a condition within the dML).

Project phase	Mitigation measures embedded into the project design	How the mitigation measures will be secured
	In the event that GBS foundations are selected for use on the Project, a Biosecurity Plan will be developed to minimise marine INNC introduction/spread.	
Operation and Maintenance		
Scour Protection Management Plan and CSIP	A Scour Protection Management Plan (SPMP) and CSIP will be developed which will consider the need for scour protection.	DCO (via a condition within the dML).
EMF	Where possible, cables will be buried to reduce the impacts of EMF on sensitive receptors and minimise the requirement for additional cable protection.	Within the Outline CSIP.
Pollution prevention	Development of, and adherence to, an appropriate PEMP, which will include a MPCP.	DCO (via a condition within the dML).
Decommissioning		
Decommissioning Programme	Development of a Decommissioning Programme (DP).	DCO

10.5 Assessment Methodology

71. The criteria for determining the significance of effects is a two-stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts (see Volume 1, Chapter 5: EIA Methodology (document reference 6.1.5)).
72. Information about the project and the project activities for all stages of the project life cycle (construction, O&M and decommissioning) have been combined with information about the environmental baseline to identify the potential interactions between the project and the environment. These potential interactions are known as potential impacts, the potential impacts are then assessed to give a level of significance of effect upon the receiving environment/receptors.
73. The outcome of the assessment is to determine the significance of these effects against predetermined criteria.
74. The magnitude of potential impacts is defined by a series of factors including the spatial extent of any interaction, the likelihood, duration, frequency and reversibility of a potential impact. The magnitude of impact is defined in Table 10.9.

Table 10.9: Impact magnitude definitions.

Magnitude	Description/reason
High	Fundamental, permanent/irreversible changes, over the whole receptor, and/or fundamental alteration to key characteristics or features of the particular receptors character or distinctiveness.
Medium	Considerable, permanent/irreversible changes, over the majority of the receptor, and/or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Low	Discernible, temporary change, over a minority of the receptor, and/or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (for part of the Proposed Development duration) change, or barely discernible change for any length of time, over a small area of the receptor, and/or slight alteration to key characteristics or features of the particular receptors character or distinctiveness.

75. The sensitivities of fish and shellfish receptors are defined by both their potential vulnerability to an impact from the development, their recoverability, and the value or importance of the receptor. The following parameters are also taken into account:
    - Timing of the impact: whether impacts overlap with critical life stages or seasons (i.e., spawning and migration); and
    - Probability of the receptor-impact interaction occurring.

76. The determination of a receptor's vulnerability to an impact is based on the ability of a receptor to accommodate a temporary or permanent change. The assessment of the receptor's vulnerability also considers the mobility of the receptor. Receptors that can flee from an impact are considered less sensitive than those that are stationary and unable to flee. When applying this consideration to a fish and shellfish assessment, static receptors typically include shellfish of limited mobility, fish that will potentially be engaging in spawning behaviours, substrate dependant receptors, and eggs and larvae. On this basis, 'static' receptors are considered to be of increased vulnerability to an impact. In determining the overall sensitivity of a receptor to an impact, the vulnerability of a receptor to the impact is typically given the greatest weighting.

77. The recoverability of the receptor is defined as the extent to which a receptor will recover following an impact. The rate of recovery is also taken into consideration in this criterion. Regarding fish and shellfish receptors, the recoverability of a receptor typically relates to the ability of a receptor to return/recolonise an area after an impact, or for normal behaviours to resume.

78. The value and importance of a receptor is a measure of the importance of a receptor in terms of its relative ecological, social or economic value or status. Regarding fish and shellfish receptors, the value and importance of the receptors is primarily informed by the conservation status of the receptor, the receptor's role in the ecosystem, and the receptor's geographic frame of reference. Note that for stocks of species which support significant fisheries, commercial value is also taken into consideration.

79. The value and importance of the receptor is defined by the following criteria:

- High value and importance: Internationally or nationally important (i.e., Annex II species listed as features of SACs, or species listed on the OSPAR Threatened or Declining Species List);
- Medium value and importance: Regionally important or internationally rare (i.e., MCZ/recommended MCZ (rMCZ) features (species classified as features of conservation importance), or Species that are of commercial value to the fisheries which operate within the North Sea);
- Low value and importance: Locally important or nationally rare (i.e., species of commercial importance but do not form a key component of the fish assemblages within the fish and shellfish study area); and
- Negligible value and importance: Not considered to be particularly important or rare.

80. Regarding the weighting of the sensitivity criteria (vulnerability, recoverability and value and importance), greater weighting is typically assigned to the vulnerability of a receptor. Expert judgement is used as appropriate, in line with the CIEEM 2018 Guidance (CIEEM, 2018), when applying the sensitivity criteria to the sensitivity assessment of receptors. For example, if receptors are considered of high value/importance, or have rapid recovery rates, these criteria may be given greater weighting in the assessment.

81. The sensitivity/importance of the receptor is defined in Table 10.10.

Table 10.10: Sensitivity/importance of the environment.

Receptor sensitivity/importance	Description/reason
High	Internationally or nationally important receptors with high vulnerability and no ability for recovery.
Medium	Regionally important receptors with high vulnerability and no ability for recovery. Internationally or nationally important receptors with medium to high vulnerability and low to medium recoverability.
Low	Locally important receptors with medium to high vulnerability and low recoverability. Regionally important receptors with low vulnerability and medium recoverability. Nationally important receptors with low vulnerability and medium to high recoverability. 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.

82. Assessment of the significance of potential effects is described in Table 10.11. The combination of the magnitude of the impact with the sensitivity of the receptor determines the assessment of significance of effect.

83. For the purposes of this assessment, any effect that is of major or moderate significance is considered to be significant in EIA terms, whether this be adverse or beneficial. Any effect that has a significance of minor or negligible is not significant.

Table 10.11 Matrix to determine effect significance.

		Magnitude of impact			
		Negligible	*Low*	*Medium*	*High*
Sensitivity of receptor	*Negligible*	Negligible (Not significant)	Negligible (Not significant)	Minor (Not significant)	Minor (Not significant)
	Low	Negligible (Not significant)	Minor (Not significant)	Minor (Not significant)	Moderate (Significant)
	Medium	Minor (Not significant)	Minor (Not significant)	Moderate (Significant)	Major (Significant)
	High	Minor (Not significant)	Moderate (Significant)	Major (Significant)	Major (Significant)

10.5.1 Assumptions and Limitations

Fish and shellfish ecology

84. Mobile species, such as fish, exhibit varying spatial and temporal patterns. All surveys from across the Project study area were undertaken to provide a semi-seasonal description of the fish and shellfish assemblages within the fish and shellfish study area. It should be noted, however, that the data collected during these surveys represent snapshots of the fish and shellfish assemblage within the study area at the time of sampling and the fish and shellfish assemblages may vary considerably both seasonally and annually. However, should species be absent from such surveys the outcome is not then to exclude consideration of these species from the baseline characterisation. Rather, the baseline description draws upon (or defaults to) the wider literature, as this provides a more thorough, robust, and longer time series evidence base, which therefore ensures a more comprehensive and precautionary baseline, identifying all species that are likely to be present within the study area.

85. It should also be noted that the methods of surveying for fish and shellfish species vary in their efficiency at capturing different species. For example, the semi-pelagic otter would not collect information on pelagic fish species (such as herring and sprat *Sprattus sprattus*) as efficiently as a pelagic trawl, and the 2m scientific beam trawl would not be as efficient at collecting sandeel and shellfish species as other methods used commercially in the study area (e.g., sandeel or shrimp trawls and shellfish potting). This limits the data utility in capturing relative abundances of species within the area. To minimise this limitation caused by trawl methodology of the survey, sensitive receptors have been chosen based on their presence or absence in surveys, rather than whether that species contributes more significantly to the fish assemblage in the survey data.

Spawning and nursery grounds

86. The description of spawning and nursery grounds provided in this report is primarily based on the information presented in Coull *et al.,* (1998) and Ellis *et al,* (2010, 2012), data sources widely accepted across the offshore wind industry. The limitations of these sources of information should, however, be recognised. These publications provide an indication of the general location of spawning and nursery grounds. They do not define precise boundaries of spawning and nursery grounds. Similarly, the spawning times given in these publications represent the maximum duration of spawning on a species/stock basis. In some cases, the duration of spawning may be much more contracted, on a site-specific basis, than reported in Coull *et al*, (1998) and Ellis *et al,* (2010, 2012). Therefore, where available, additional research publications have also been reviewed to provide site-specific information.
87. It is important to note, that although the data used in the characterisation of the fish and shellfish baseline conditions span a long time period, with some sources published over a decade ago, the information presented represents a long-term dataset. Accordingly, this allows for a detailed overview of the characteristic fish and shellfish species in the study area. The diversity and abundance of many species, particularly demersal fish species, is linked to habitat types, which have remained relatively constant in the study area, indicating no major shift in the fish and shellfish communities over the time period of the data used in this report.
88. The EUSeaMap (2021) broadscale marine habitat data used as one of the data sets to identify preferred sandeel and herring spawning habitats is limited by the broadscale nature of the data, since it does not account for small scale, localised differences in seabed sediments, unlike the data obtained from site-specific grab sampling. In this case it is important to review all of the datasets presented, to develop a clear overview of preferred sandeel and herring habitat. Site-specific benthic surveys of the area can be used to confirm and validate broadscale marine habitat data.

89. It should also be noted that the use of PSA data and broadscale habitat mapping only provides a proxy for the presence of sandeel and herring spawning habitat in these locations (based on suitability of habitats, i.e., the potential for spawning rather than actual contemporary spawning activity); therefore, this has been reviewed alongside other datasets presented in this chapter in determining the location and relative importance of spawning habitats. A key dataset utilised to inform the location of actively spawning herring is the IHLS data, which is collected under the auspices of the International Council for the Exploration of the Sea (ICES). The surveys are designed to provide a quantitative estimate of herring larval abundance to be used as a relative index of the changes in herring spawning stock biomass (Boyle and New, 2018). The use of this data as proxy is necessary in the absence of time-series data of direct spawning behaviour observations, or the presence of eggs on the seafloor. Additionally, these data represent a single snapshot in time for each year, with annual surveys aligned year to year, as informed by expert judgement, rather than being triggered by environmental factors (such as sea temperature) which may affect the seasonality of spawning. Previous analyses (Boyle and New, 2018) have demonstrated the suitability of the IHLS data to be used to aid in informing the location and extent of active herring spawning grounds as an update to the historical spawning grounds as defined by Coull *et al,* (1998). This method has been broadly accepted for use in EIAs (including Hornsea Four) and is therefore considered the most suitable dataset through which to define areas of active spawning for herring.

eDNA

90. eDNA data have also been collected alongside the geophysical surveys to provide a snapshot of fish and shellfish species presence (from approximately the preceding 24-hours) at each sample location. As eDNA is a relatively new way of supplementing baseline characterisation in offshore wind projects, there is not a wealth of literature or protocols available to understand the implications of these data. Although eDNA shows great promise in identifying receptors and aiding EIA monitoring, there are potentially some challenges when applying such data within the context of a more generic EIA framework within marine environments. As a result of these challenges, the use of eDNA is recommended as a proxy for the presence of a receptor and not a direct measure of presence (Hinz *et al.,* 2022). For example, one of the challenges is defining a sampling unit and sampling strategy with respect to the survey area which can create further challenges in drawing comparisons between different areas, across spatial and temporal scales (Hinz *et al.,* 2022). In addition, statistical modelling presents itself as a challenge when using eDNA in marine EIA assessments due to the possibility of collecting both false positives and negatives in samples. As such, it is considered vital that the uncertainty in presence/absence estimates is provided during data processing (Hinz *et al.,* 2022). The transport of eDNA fragments in marine environments is also generally unknown and influencing factors such as shedding dynamics, biogeochemical and physical processes need to be well understood in order to link a fragment of eDNA with a potential receptor's presence (Hinz *et al.,* 2022).

10.6 Impact Assessment

10.6.1 Construction

91. This section presents the assessment of impacts arising from the construction phase of the Project.

Impact 1: Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity

92. The assessment below focuses on underwater noise from pile-driving (pin piles and monopiles) for the installation of foundations for offshore structures within the array area (i.e. Wind Turbine Generators (WTGs), OSSs, and accommodation platform), the ORCPs, the ANSs, cable installation, vessel disturbance and Unexploded Ordnance (UXO) clearance.
93. To inform the assessment of potential impacts associated with underwater noise as a result of the installation of foundations, predictive underwater noise modelling has been undertaken for the relevant piling MDS, full details of which are presented in Appendix 3.2 (document reference 6.3.3.2).
94. To inform the assessment of the potential impacts associated with underwater noise as a result of UXO clearance, a high-level consideration has been provided of the potential effects arising from UXO clearance below. It should be noted that whilst UXO clearance will be consented under a separate Marine Licence and will therefore not be consented as part of the Project consenting process, it is considered to be reasonably foreseeable as an activity and therefore has been included in this assessment.
95. General construction noise, arising from vessel movements, dredging and seabed preparation works will generate low levels of continuous sounds (i.e., from the vessels themselves and/or the sounds from dredging tools) throughout the construction phase. The Order Limits are subject to relatively high levels of shipping activity currently, and it is expected that the vessel activity would be no greater than the baseline during construction activities (due to construction exclusion zones reducing current shipping activity and the number of construction vessels expected to be much lower than that which currently transit the area). The underwater noise impacts from vessel noise are generally spatially limited to the immediate area around the vessel rather than having impacts over a wide area (e.g., Mitson, 1993).
96. The spatial and temporal MDS for underwater noise impacts from foundation installation (piling of monopiles or pin piles in the array area, ORCPs or ANSs) are defined according to a maximum scenario, i.e., the maximum design parameters that may be utilised during the construction of the proposed development. In this context it is important to note that the maximum hammer energies assumed in the MDS are likely to be highly precautionary and that in fact for many piling events, a lesser hammer energy will be required to complete the pile installation (they represent the upper limit of the equipment, rather than the likely energy that will be required to install any given foundation).
97. The spatial MDS equates to the greatest area of effect from subsea noise during piling. The following scenarios represent the spatial MDS:

- Array area:
  - Stationary receptors – concurrent installation of six pin piles for jacket WTG foundations at the NE and SW extents of the array area;
  - Fleeing receptors – concurrent installation of two monopile WTGs at the NE and SW locations in the array area;
- ORCPs area:
  - Stationary receptors – sequential installation of six pin piles for jacket foundations within the ORCP in a 24-hour period;
  - Fleeing receptors – piling of a single monopile foundation in a 24-hour period, or the sequential installation of two monopiles in a 24-hour period within the ORCPs;
- ANSs area:
  - Stationary receptors – sequential installation of four pin piles in a 24-hour period; and
  - Fleeing receptors – sequential installation of four pin piles in a 24-hour period, or the piling of one monopile in a 24-hour period.

98. The temporal MDS represents the longest duration of effects from subsea noise. The following scenarios represent the temporal MDS:
    - Array area:
      - The sequential installation of six pin piles for jacket WTG foundations in the array area within a 24-hour period;
    - ORCPs area:
      - The sequential installation of six pin piles for jacket foundations within the ORCPs in a 24-hour period;
    - ANSs area:
      - The sequential installation of four pin piles in a 24-hour period in the ANSs.

99. Table 10.12 below provides the MDS for each piling scenario for foundations within the array area, the ORCPs and the ANSs.

Table 10.12: MDS Piling Scenarios within the Array Area.

	Single piling scenarios		Sequential piling scenarios		Simultaneous piling scenarios	
	Monopiles	Jacket foundations	Monopiles	Jacket Foundations	Monopiles	Jacket Foundations
Installation approach	Piling of a single monopile in a 24-hour period	Piling of a single pin pile in a 24-hour period	Sequential of two monopile foundations in a 24-hour period	Sequential piling of up to six pin piles for jacket foundations in a 24-hour period	Simultaneous piling of two monopile foundations at both the SW and NE piling locations in the array area.	Simultaneous piling of up to six pin piles at both the SW and NE piling locations in the array area.
Hammer energy	6,600kJ	3,500kJ	6,600kJ	3,500kJ	6,600kJ	3,500kJ
Maximum number of piles	Wind Turbine Generators (WTGs) - 100 monopiles Offshore Substation (OSS) - four monopiles Accommodation platform – one monopile Total = 105 monopiles	WTGs – 400 pin piles OSS – 96 pin piles Accommodation platform – 24 pin piles Total = 520 pin piles	WTGS - 100 WTG monopiles OSS - four monopiles Accommodation platform – one monopile Total = 105 monopiles	WTGs – 400 pin piles OSS – 96 pin piles Accommodation platform – 24 pin piles Total = 520 pin piles	WTGS - 100 WTG monopiles OSS - four monopiles Accommodation platform – one monopile Total = 105 monopiles	WTGs – 400 pin piles OSS – 96 pin piles Accommodation platform – 24 pin piles Total = 520 pin piles
Maximum piling duration	840 hours	3,360 hours	840 hours	3,360 hours	420 hours	1,680hours

Table 10.13: MDS Piling Scenarios within the ORCPs.

	Single Installation of Monopile Foundations	Single Installation of Jacket Foundations	Sequential Installation of Monopile Foundations	Sequential Installation of Jacket Foundations
Installation approach	Piling of a single monopile in a 24-hour period	Piling of a single pin pile in a 24-hour period	Sequential of two monopile foundations in a 24-hour period	Sequential piling of four jacket foundations at N and S piling locations the ORCPs within a 24-hour period.
Hammer energy	6,600kJ	3,500kJ	6,600kJ	3,500kJ
Maximum number of piles	two monopiles	48 pin piles	two monopiles	48 pin piles
Maximum piling duration	16 (eight hours per pile)	384 hours (eight hours per pile).	16 (eight hours per pile)	384 hours (eight hours per pile).

Table 10.14: MDS Piling Scenarios within the ANSs.

	Single Installation of Monopile Foundations	Single Installation of Jacket Foundations	Sequential Installation of Jacket Foundations
Installation approach	Piling of a single monopile in a 24-hour period	Piling of a single pin pile in a 24-hour period	Sequential piling of four jacket foundations at NW and SE piling locations the ANS within a 24-hour period.
Hammer energy	6,600kJ	3,500kJ	3,500kJ
Maximum number of piles	two monopiles	Eight pin piles	eight pin piles
Maximum piling duration	16 (eight hours per pile)	48 hours (six hours per pile).	48 hours (six hours per pile).

100. With regards to the seabed clearance works associated with UXO, as part of the site preparation activities for the Project, UXO clearance may be required. Presence of UXO within the Order Limits can be managed in a number of ways: avoidance (through micrositing), non-destructive clearance through moving or removal of the UXO, or destructive clearance (i.e., in-situ detonation).

101. If required, destructive UXO clearance through detonation of the UXO can introduce a further underwater noise effect-receptor pathway that may result in an effect on noise sensitive receptors. Any UXO clearance would be completed within the Project array and offshore ECC, as part of the pre-construction site preparatory works. Until detailed pre-construction surveys are undertaken across the array and offshore ECC, the exact number of potential UXO which will need to be cleared is unknown.

102. Detonation of UXO would represent a short-term (i.e., seconds) increase in underwater noise (i.e. Sound Pressure Levels (SPL) and particle motion) and while noise levels will be elevated such that this may result in injury or behavioural effects on fish and shellfish species, UXO detonations are considered to have a lower likelihood of triggering a population level effect than that associated from piling operations, due to the significantly reduced temporal footprint that would arise from UXO operations.

103. It should be noted that the Applicant will be seeking consent for UXO clearance within a separate Marine Licence application post-consent.

Receptor sensitivity and injury criteria for assessment

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

- Underwater noise associated with foundation installation within the array area;
  - Single installation of monopile foundations;
  - Single installation of jacket foundations;
  - Sequential installation of monopile foundations;
  - Sequential installation of jacket foundations;
  - Simultaneous piling scenario for monopile foundations; and
  - Simultaneous piling scenario for jacket foundations.
- Underwater noise associated with ORCP foundation installation;
  - Single installation of monopile foundations;
  - Single installation of jacket foundations;
  - Sequential installation of monopile foundations; and
  - Sequential installation of jacket foundations.
- Underwater noise associated with ANS foundation installation;

- Single installation of monopile foundations;
- Single installation of jacket foundations; and
- Sequential installation of jacket foundations.

- Underwater noise associated with UXO clearance.

105. Underwater noise can potentially have a negative impact on fish and shellfish species ranging from behavioural effects to physical injury/mortality. In general, biological damage as a result of sound energy is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration (i.e., UXO clearance or a single strike of a piling hammer). However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. Fish and shellfish are also considered to be sensitive to the particle motion element of underwater noise; an impact considered more important than sound pressure for many species, particularly invertebrates. However, research into this impact on fish populations is scarce, representing a source of uncertainty in the assessment process. Despite the lack of thresholds for particle motion, the criteria detailed within Popper *et al,* (2014) remain the best available evidence to inform the assessment of underwater noise impacts to fish and shellfish (Popper and Hawkins, 2021).

106. For the purposes of the assessment, Appendix 3.2 (document reference 6.3.3.2) presents the results of modelling for a range of noise levels, representing the MDS for the installation of both monopiles and pin piles. The modelling results for cumulative sound exposure level (SEL_{cum}) provide outputs for both fleeing receptors (with the receptors fleeing from the source at a consistent rate of $1.5ms^{-1}$), and stationary receptors to account for spawning activity for more static demersal spawners such as sandeel and herring, and for non-mobile receptors such as eggs and larvae.

Injury criteria

107. The fish VERs within the Project study area have been grouped into the Popper *et al.,* (2014) categories based on their hearing system, as outlined in Table 10.15 below. It is important to note that there are differences in impact thresholds for the different hearing groups (see Table 10.16).

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

Table 10.15: Hearing categories of fish receptors (Popper et al., 2014). (*denotes uncertainty or lack of current knowledge with regards to the potential role of the swim bladder in hearing)

Category	VERs relevant to the Project
Group 1 (least sensitive)	Sole, lemon sole, dab, plaice, sandeel spp., anglerfish, lesser weaver, mackerel, elasmobranchs (thornback ray, spotted ray, blonde ray, spurdog, tope shark, small-spotted catshark, starry smooth-hound, common smooth-hound), river lamprey and sea lamprey.
Group 2	Atlantic salmon, brown trout.
Group 3 (most sensitive)	Herring, sprat, cod, whiting, blue whiting, twaite shad, allis shad, ling*, European eel*, European anchovy*, European seabass and European hake.

Table 10.16: Impact threshold criteria from Popper *et al*. (2014).

Impact threshold noise level (dB re. 1µPa sound pressure level (SPL)/dB re. 1 µPa^{2}s sound exposure level (SEL))			
	Mortality and potential injury	Recoverable injury	TTS
Group 1	219dB SEL_{cum} 213dB SPL_{peak}	216dB SEL_{cum} 213dB SPL_{peak}	>>186dB SEL_{cum}
Group 2	210dB SEL_{cum} 207dB SPL_{peak}	203dB SEL_{cum} 207dB SPL_{peak}	>186dB SEL_{cum}
Group 3	207dB SEL_{cum} 207dB SPL_{peak}	203dB SEL_{cum} 207dB SPL_{peak}	186dB SEL_{cum}
Eggs and Larvae	210dB SEL_{cum} 207dB SPL_{peak}	N/A	N/A

109. The noise modelling for injury ranges for fleeing and stationary fish is presented in the Underwater Noise Assessment (Volume 2, Appendix 3.2)(document reference 6.3.11.2), and referred to as appropriate in the following assessments. Table 10.17, Table 10.18, Table 10.19 and Table 10.20, below summarise the results for each of the relevant criteria against each of the MDS under consideration.

Table 10.17: Noise modelling results for injury ranges for fleeing and stationary receptors from the sequential piling of foundations scenarios within the array area.

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa^2 Sound Exposure Level (SEL))	Monopile Foundation Impact Ranges (sequential piling of two monopiles in a 24-hour period)			Jacket Foundation Impact Ranges (sequential piling of up to six pin piles in a 24-hour period)		
		NW	NE	SW	NW	NE	SW
Mortality and Potentially Mortal Injury							
SPL_{peak}	213	90m	110m	70m	70m	100m	60m
SPL_{peak}	207	210m	280m	170m	170m	240m	140m
SEL_{cum} (static)	219	850m	1.2km	650m	980m	1,500m	750m
SEL_{cum} (fleeing)	219	<100m	<100m	<100m	<100m	<100m	<100m
SEL_{cum} (static)	210	2.6km	3.8km	2km	2.9km	4.5km	2.2km
SEL_{cum} (fleeing)	210	<100m	<100m	<100m	<100m	<100m	<100m
SEL_{cum} (static)	207	3.6km	5.5km	2.7km	4km	6.3km	3.1km
SEL_{cum} (fleeing)	207	<100m	<100m	<100m	<100m	<100m	<100m
Recoverable Injury							
SPL_{peak}	213	90m	110m	70m	70m	100m	60m
SPL_{peak}	207	210m	280m	170m	170m	240m	140m
SEL_{cum} (static)	216	1.3km	1.8km	950m	1.5km	2.1km	1.1km
SEL_{cum} (fleeing)	216	<100m	<100m	<100m	<100m	<100m	<100m
SEL_{cum} (static)	203	5.2km	8.1km	4.1km	5.7km	9,000m	4.5km
SEL_{cum} (fleeing)	203	<100m	<100m	<100m	<100m	<100m	<100m
TTS							
SEL_{cum} (static)	186	16km	23km	14km	17km	25km	14km
SEL_{cum} (fleeing)	186	5.2km	10km	3.6km	3.8km	8.3km	2.4km

Table 10.18: Noise modelling results for in-combination impact areas for fleeing and stationary receptors from the simultaneous piling of foundations within the array area.

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa^2 Sound Exposure Level (SEL))	Monopile Foundation Impact In-combination Area (simultaneous piling of two monopiles at the NE and SW locations in the array area)	Jacket Foundation Impact In-combination Area (simultaneous piling of up to six pin piles at the NE and SW piling locations in the array area)
Mortality and Potentially Mortal Injury			
SEL_{cum} (static)	219	6.4km^2	9km^2
SEL_{cum} (fleeing)	219	-[1]	-
SEL_{cum} (static)	210	53km^2	70km^2
SEL_{cum} (fleeing)	210	-	-
SEL_{cum} (static)	207	100km^2	130km^2
SEL_{cum} (fleeing)	207	-	-
Recoverable Injury			
SEL_{cum} (static)	216	14km^2	18km^2
SEL_{cum} (fleeing)	216	-	-
SEL_{cum} (static)	203	210km^2	260km^2
SEL_{cum} (fleeing)	203	-	-
TTS			
SEL_{cum} (static)	186	1,800km^2	2,000km^2
SEL_{cum} (fleeing)	186	740km^2	620km^2

[1] Fields denoted with a dash "-" show where there is no in combination effect when piling occurs at the two locations simultaneously.

Table 10.19: Noise modelling results for injury ranges for fleeing and stationary receptors from the single and sequential piling of ORCP foundations.

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa^2 Sound Exposure Level (SEL))	Monopile Foundations		Jacket Foundations (sequential piling of six pin piles in a 24-hour period)	
		N	S	N	S
Mortality and Potentially Mortal Injury					
SPL_{peak}	213	80m	80m	70m	70m
SPL_{peak}	207	190m	200m	160m	170m
SEL_{cum} (static)	219	730m	780m	830m	900m
SEL_{cum} (fleeing)	219	<100m	<100m	<100m	<100m
SEL_{cum} (static)	210	2km	2.3km	2.2km	2.6km
SEL_{cum} (fleeing)	210	<100m	<100m	<100m	<100m
SEL_{cum} (static)	207	2.7km	3.1km	3km	3.5km
SEL_{cum} (fleeing)	207	<100m	<100m	<100m	<100m
Recoverable Injury					
SPL_{peak}	213	80m	80m	70m	70m
SPL_{peak}	207	190m	200m	160m	170m
SEL_{cum} (static)	216	1km	1.1km	1.2km	1.3km
SEL_{cum} (fleeing)	216	<100m	<100m	<100m	<100m
SEL_{cum} (static)	203	3.8km	4.7km	4.2km	5.2km
SEL_{cum} (fleeing)	203	<100m	<100m	<100m	<100m
TTS					

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa^2 Sound Exposure Level (SEL))	Monopile Foundations		Jacket Foundations (sequential piling of six pin piles in a 24-hour period)	
		N	S	N	S
SEL_{cum} (static)	186	13km	15km	15km	16km
SEL_{cum} (fleeing)	186	2.7km	4.4km	1.8km	3.1km

Table 10.20: Noise modelling results for injury ranges for fleeing and stationary receptors from the single and sequential piling of ANS foundations.

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa^2 Sound Exposure Level (SEL))	Monopile Foundations (piling of one monopile in a 24-hour period)		Jacket Foundations (sequential piling of four pin piles in a 24-hour period)	
		NW	SE	NW	SE
Mortality and Potentially Mortal Injury					
SPL_{peak}	213	90m	90m	100	90m
SPL_{peak}	207	240m	220m	260m	220m
SEL_{cum} (static)	219	550m	450m	1.2km	1km
SEL_{cum} (fleeing)	219	<100m	<100m	<100m	<100m
SEL_{cum} (static)	210	1.9km	1.6km	3.9km	3.3km
SEL_{cum} (fleeing)	210	<100m	<100m	<100m	<100m
SEL_{cum} (static)	207	2.8km	2.4km	5.5km	4.6km
SEL_{cum} (fleeing)	207	<100m	<100m	<100m	<100m
Recoverable Injury					
SPL_{peak}	213	90m	90m	100	90m
SPL_{peak}	207	240m	220m	260m	220m
SEL_{cum} (static)	216	830m	700m	1.9km	1.6km
SEL_{cum} (fleeing)	216	<100m	<100m	<100m	<100m
SEL_{cum} (static)	203	4.5km	3.8km	8.1km	7km
SEL_{cum} (fleeing)	203	<100m	<100m	<100m	<100m
TTS					

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa^2 Sound Exposure Level (SEL))	Monopile Foundations (piling of one monopile in a 24-hour period)		Jacket Foundations (sequential piling of four pin piles in a 24-hour period)	
		NW	SE	NW	SE
SEL_{cum} (static)	186	20km	16km	28km	21km
SEL_{cum} (fleeing)	186	11km	7.2km	11km	7.1km

Mortality and potential mortal injury of Group 1 VERs

110. The following paragraphs provide the assessment of potential impacts on each VER within their associated hearing group for the spatial MDSs and temporal MDS for underwater noise associated with foundation installation. Initial consideration is given to the sensitivity of each VER within the hearing group to underwater noise, before characterising the scale and magnitude of effect before providing the overall conclusion.

111. Potential for mortality or mortal injury is likely to only occur in extreme proximity to the pile, although the risk of this occurring will be reduced by use of soft start techniques at the start of the piling sequence. This means that fish in close proximity to piling operations will move outside of the impact range, before noise levels reach a level likely to cause irreversible injury.

Sensitivity

112. Group 1 VERs (mortality onset at >213dB SPL_{peak} or >219dB SEL_{cum}) lack a swim bladder and are therefore considered less sensitive to underwater noise (than other species). Sandeel lack a swim bladder and are therefore considered less sensitive to underwater noise. Sandeel spawning grounds are located within the Project study area and suitable spawning habitats are widely distributed across the North Sea; therefore, noise impacts are anticipated to be small in the context of the wider environment.

113. Sandeel are considered stationary receptors, due to their burrowing nature, substrate dependence, and demersal spawning behaviours, and therefore may have limited capacity to flee the area compared to other Group 1 receptors. Sandeel are thought to be affected by vibration through the seabed, particularly when buried in the seabed during hibernation. Sandeel are however, anticipated to recover from noise impacts shortly after noise disturbance, with normal behaviours resuming (Hassel *et al.,* 2004). Taking this into account, sandeel are deemed to be of low vulnerability, medium recoverability and are of regional importance (Section 41 priority species). The sensitivity of the receptor to underwater noise impacts is therefore considered to be low.

114. Lemon sole, mackerel, plaice and sole all have spawning grounds within the Project study area and across the southern North Sea (Coull *et al.,* 1998, (Volume 2, Figures 10.2 to 10.4)). These VERs are pelagic spawners and are therefore not limited to specific sedimentary areas for spawning, and consequently are considered likely to move away from injurious effects. Based on their mobile nature, these VERs are expected to recover quickly, return to normal behaviours, recolonizing areas shortly after disturbance. Therefore, the sensitivity of these VERs to noise impacts is considered to be low.

115. All other Group 1 receptors are of mobile nature and unconstrained and are therefore able to flee from noise disturbance. Based on their low vulnerability to noise impacts, and their mobile nature, these receptors are expected to recover quickly, returning to normal behaviours, and recolonising areas shortly after disturbance. Taking this into account, the receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance (thornback ray, spotted ray and spurdog are afforded protection under the OSPAR list of threatened or declining species, and tope shark and common smooth hound are listed as vulnerable and critically endangered on the IUCN Red List respectively). The sensitivity of these receptors to underwater noise impacts is therefore considered to be low.

Magnitude of impact

116. When considering the potential for the mortality and potential mortal injury of stationary Group 1 receptors (e.g., sandeel) from piling in the array area, the greatest impact ranges result from the sequential piling of up to six pin piles in a 24-hour period for jacket foundations (hammer energy 3,500kJ, 5m pin pile diameter). An impact range for mortality and potential mortal injury of up to 1.5km is predicted from this piling within the array area (Volume 2, Figure 10.25)). When considering the spatial MDS for the mortality and potential injury of fleeing Group 1 receptors, the greatest range of impact occurs within the immediate vicinity of the works (<100m) from the sequential piling of either monopiles or pin piles for jacket foundations.

117. In the event that pin piles for jacket foundations are installed simultaneously at both the NE and SW piling locations in the array area, a larger impact range is predicted, with a maximum area of 9km^2 (Volume 2, Figure 10.29). This piling scenario would therefore represent the spatial MDS for stationary Group 1 receptors. The potential for mortality and potential mortal injury of stationary Group 1 receptors from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 6.4km^2 (Volume 2, Figure 10.30). There is no in-combination effect from the simultaneous piling of monopiles or jacket foundations on fleeing Group 1 receptors.

118. Regarding the spatial MDS for fleeing receptors within the ORCPs, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 1 receptors occurs within the immediate vicinity of the works (<100m) from the sequential piling of either monopiles or pin piles for jacket foundations.

119. Regarding the spatial MDS for stationary receptors from piling within the ANS, the maximum predicted range of impact for mortality and potential mortal injury of stationary Group 1 receptors occurs from the sequential installation of pin piles for jacket foundations (four pin piles installed within a 24-hour period). A maximum impact range of up to 1,200m is predicted from this piling within the ANS (Volume 2, 10.25).

120. Regarding the spatial MDS for fleeing receptors within the ANS, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 1 receptors occurs within the immediate vicinity of the works (<100m) from the both the piling of a single monopile in a 24-hour period, or the sequential piling pin piles for jacket foundations.

121. With regards the temporal MDS, the maximum duration of piling results from the sequential piling of pin piles for jacket foundations in the array area (520 pin piles), in the ORCPs (eight pin piles) and the ANSs (eight pin piles) resulting in a total piling time of 3,792 hours, within a 12-month piling campaign. This duration encapsulates the annual spawning periods for lemon sole (November to January), and common sole (March to May). The piling duration encapsulates the duration of the sandeel annual spawning period (November to February), the mackerel spawning period (May to August) and the plaice spawning period (December to March). However, for all receptors this assumes that all piling will occur within the spawning periods and that the noise contours overlap the entire spawning grounds, and therefore the actual temporal impact on the receptors will be significantly less.

122. Spawning grounds for all Group 1 receptors within the Project study area are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale (based on the modelling results).

123. Given the broadscale nature of the Group 1 receptors spawning grounds, and the intermittent nature of the piling activities, the impact magnitude for mortality and potential mortal injury on all Group 1 receptors is considered to be low for both the spatial and temporal MDS.

Significance of effect

124. The impact is considered to be of low magnitude and the sensitivity of Group 1 receptors is considered to be low. The significance of the effect is therefore concluded to be **minor (adverse)** in EIA terms.

Mortality and potential mortal injury of Group 2 VERs

Sensitivity

125. Group 2 receptors (mortality onset at >207dB SPL_{peak} or >210dB SEL_{cum}) have a swim bladder and are therefore considered more sensitive to underwater noise than Group 1 species (i.e., the species have an internal air sac which can be affected by sound pressure), however, the swim bladder is not involved in hearing (e.g., not linked to the inner ear) and as such they are less sensitive than Group 3 receptors.

126. Group 2 species identified as of relevance to the Project are Atlantic salmon and brown trout. As Group 2 receptors, they are considered to be primarily sensitive to particle motion and so are likely to mainly sense underwater noise through movement of the water particles.

127. Atlantic salmon and brown trout have swim bladders and are therefore considered more sensitive to underwater noise than Group 1 species. Atlantic salmon and brown trout are both diadromous species and are therefore likely to be transient receptors within the site. They are therefore considered to be mobile receptors, and able to flee from noise impacts.

128. Based on their low vulnerability to noise impacts, and their mobile nature, these receptors are expected to recover quickly, returning to normal behaviours, and recolonising areas shortly after disturbance. Brown trout and Atlantic salmon are therefore considered to be of low vulnerability, high recoverability, and regional (brown trout) to international (Atlantic salmon are afforded protection under the OSPAR threatened or declining species list) importance. The sensitivity of these receptors to underwater noise impacts is therefore considered to be low.

Magnitude of impact

129. Both salmon and brown trout are considered fleeing receptors within this assessment, as they are both migratory species and are therefore likely to be transient receptors within the site. Therefore, the magnitude of impact on static Group 2 receptors is not considered.

130. When considering the spatial MDS of mortality and potential mortal injury of fleeing Group 2 receptors from piling within the array area, the ORCPs and the ANSs, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 2 receptors occurs within the immediate vicinity of the works (<100m) from the sequential piling of monopiles, or the sequential piling of pin piles for jacket foundations.

131. There is no in-combination effect from the simultaneous piling of monopiles or jacket foundations in the array area on fleeing Group 2 receptors.

132. Regarding the temporal MDS, Atlantic salmon and brown trout have the potential to be within range of injurious effects from piling noise, however these VERs are anticipated to be transient across the site, and therefore any temporal impacts on these receptors are anticipated to be minimal. In late spring to early summer, adult Atlantic salmon return to rivers to spawn, whilst juvenile salmon migrate out to sea to feed. Most brown trout will migrate into rivers in June and then migrate back out to sea in October. As there are no rivers associated with migrating brown trout or Atlantic salmon within the localised impact zone (<100m), there is no potential for the underwater noise to result in a barrier to migration. Taking into account that Atlantic salmon and brown trout will be transient across the site, any impacts will be temporary. Therefore, the magnitude of impact to Group 2 receptors from the temporal MDS is considered to be low.

Significance of effects

133. Overall, the magnitude of the impact on Group 2 species has been assessed as low, with the sensitivity of the Group 2 VERs assessed as low. The effect is therefore considered to be **minor (adverse)** for the Group 2 fish species which is not significant in EIA terms.

Mortality and potential mortal injury of group 3 VERs

Sensitivity

134. Group 3 receptors (mortality onset at >207dB SPLpeak or >207dB SELcum) have a swim bladder which is linked to the inner ear and so is directly involved in hearing. These species are considered to be the most sensitive to underwater noise, with direct detection of sound pressure, rather than just particle motion.

135. Herring possess a swim bladder that is involved in hearing, and therefore are known to be sensitive to underwater noise. The study area overlaps an area indicated by Coull *et al,* (1998) as being part of the wider Banks herring spawning grounds (August-October). However, as stated in paragraph 38, the Coull et al. (1998) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2009-2021) provide an indication of the areas of seabed in active use for spawning.

136. The IHLS data indicates that in fact the main spawning (based on distribution and density of larvae) is located to the north of the project, off of Flamborough Head, and that the spawning intensity of the Banks spawning grounds that overlap with the study area are much less intense. The 2009/2010 to 2021/2022 HLS data presented in Volume 2, Figures 10.14 to 10.17 also reflect these trends. Suitable herring spawning substrates are located within the array area and along the offshore ECC and are also widely distributed across the southern North Sea. Herring are demersal spawners and are therefore considered stationary receptors in the assessment during the spawning season, increasing their theoretical exposure to underwater noise from the construction phase of the development. Taking this into account, herring are considered to be of high vulnerability, with low recoverability and of regional importance (Section 41 Priority species), therefore the sensitivity of spawning herring to noise impacts is considered to be medium.

137. Cod, sprat and whiting all have spawning grounds within the Project study area and across the southern North Sea (Coull *et al*, 1998). These VERs are pelagic spawners and are therefore not limited to specific sedimentary areas for spawning, and consequently are considered likely to move away from injurious effects. Based on their mobile nature, these VERs are expected to recover quickly, return to normal behaviours, recolonizing areas shortly after disturbance. Therefore, the sensitivity of these VERs to noise impacts is considered to be low.

138. All other Group 3 receptors (blue whiting, twaite shad, allis shad, ling, European eel, European hake, seabass) are key components of the fish assemblages within the Project study area, have nursery grounds overlapping the study area, or are of commercial or conservation importance. Based on their mobile nature, these receptors are expected to recover quickly, returning to normal behaviours, recolonizing areas shortly after disturbance, therefore, the sensitivity of these VERs to underwater noise is considered to be low.

Magnitude of impact

139. When considering the potential for mortality and potential mortal injury of stationary Group 3 receptors (e.g. spawning herring) from piling within the array area= the maximum predicted range of impact for mortality and potential mortal injury of stationary Group 3 receptors occurs from the sequential installation of pin piles for jacket foundations. A maximum impact range of up to 6.3km is predicted from piling within the array area (Volume 2, Figure 10.23) (sequential piling of six piles in a 24-hour period). Mortality and potential mortal injury of static Group 3 receptors is predicted to occur up to 3.5km from piling within the ORCPs (Volume 2, Figure 10.33) (sequential piling of six piles in a 24-hour period). Mortality and potential mortal injury of static Group 3 receptors is predicted to occur up to 5.5km from piling within the ANSs (sequential piling of four piles in a 24-hour period). This is considered precautionary, as it is assumed that an individual remains within this range of the piling activity for 24-hours which, even for a species engaged in spawning activity is deemed to be overly conservative.

140. In the event that pin piles for jacket foundations are installed simultaneously at both the NE and SW piling locations in the array area, a larger range of impact is predicted, with a maximum area of 130km^2 (Volume 2, Figure 10.27). This piling scenario would therefore represent the spatial MDS for stationary Group 3 receptors. The potential for mortality and potential mortal injury of stationary Group 3 receptors from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 100km^2 (Volume 2, Figure 10.28). There is no in-combination effect from the simultaneous piling of monopiles or jacket foundations on fleeing Group 3 receptors.

141. The noise contours for piling within the array area, the ORCPs, and ANSs in relation to the presence of historic herring spawning grounds and larvae abundances (Coull *et al*., 1998 and IHLS data (2009/2010 – 2022/2023)) in Volume 2, Figure 10.23 and Figure 10.33 indicate the potential for mortality and potential mortal injury of spawning herring. A partial overlap of the mortality and potential mortal injury noise contours with the historic Banks herring spawning grounds (Coul et al., 1998) can be observed although as shown by annual IHLS data (ICES, 2009/2010 – 2022/2023), the main spawning area utilised by the Banks herring stock is located to the north of the study area, off Flamborough Head. The total larval density from the combined 10-year dataset within the potential mortal injury noise contour ranges from 0 to 6,000 herring larvae per m^2. In comparison, the peak larval density in the main spawning area off Flamborough Head ranges from 74,250 to 93,250 larvae per m^2. Therefore, as evidenced by the IHLS data, the larval density and therefore spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning off of Flamborough Head (<10% of the peak density). In addition, as shown by PSA across the site (Volume 3, Appendix 7.1: Physical Processes Technical Baseline (document reference 6.3.7.1) and (Volume 3, Appendix 7.2: Physical Processes Modelling Report (document reference 6.3.7.2)) (BGS, 2015) suitable herring spawning substrates are located across the site, and across the wider region. Therefore, underwater noise from piling within the array area, the ORCPs and the ANSs is unlikely to have a population level effect on the Banks herring stock.

142. Regarding the spatial MDS for fleeing Group 3 receptors from piling within the array area, the ORCPs the ANSs, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 3 receptors occurs within the immediate vicinity of the works (<100m) from the sequential piling of monopiles, or the sequential piling of pin piles for jacket foundations.

143. With regards the temporal MDS, the maximum duration of piling results from the sequential piling of jacket foundations in the array area (520 pin piles), and in the ORCPs area (48 pin piles)and in the ANSs (eight pin piles), resulting in a total piling time of 3,792 hours, within a 12-month piling campaign. In the context of the annual herring spawning period for the Banks herring spawning stock (August to October, Coull *et al.,* (1998)) over one year the piling duration encapsulates the spawning period, therefore spawning herring have the potential to be disturbed throughout the entirety of the spawning period. The piling duration encapsulates the cod spawning period (January to April), the sprat spawning period (May to August) and the whiting spawning period (February to June). also encapsulates the spawning periods for cod and sprat (January to April and May to August respectively), and the whiting spawning period (February to June). However, for all receptors this assumes that all piling will occur within the spawning periods and that the noise contours overlap the entire spawning grounds, and therefore the actual temporal impact on the receptors will be significantly less.

144. Considering the small overlap of the mortality and potential mortal injury noise contours of the Banks herring spawning grounds and of areas of low-density herring larvae present within the noise contour extents, the magnitude of impact of spawning herring from piling activities is considered to be low.

145. Spawning grounds for cod, sprat and whiting are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale (based on the modelling results). All other Group 3 receptors are present in abundance within the region, and therefore any impacts from underwater noise are expected to be of local scale. Given the broadscale distribution of these receptors and their spawning grounds, and the intermittent nature of the piling activities, the maximum magnitude of impact from mortality and potential mortal injury is expected to be low.

Significance of effect

146. Taking into account the sensitivity of the spawning herring to underwater noise, which is medium, and the magnitude of impact, which is considered to be low, the significance of effect is **minor (adverse),** which is not significant in EIA terms.

147. The maximum sensitivity of all other Group 3 receptors is low, and the magnitude of impact is low. Therefore, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

Mortality and potential mortal injury of eggs and larvae

148. Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the vicinity of the Project (Volume 3, Appendix 10.1(document reference 6.3.10.1)). Eggs and larvae are considered organisms of concern by Popper *et al,* (2014), due to their vulnerability, reduced mobility and small size. Taking this into consideration and given the broadscale nature of the spawning grounds, the sensitivity of eggs and larvae to mortality and potential mortal injury from underwater noise is considered to be medium.

149. Thresholds of effects for eggs and larvae have been defined separately within the Popper *et al,* (2014) guidance, with damage expected to occur at 210dB SEL_{cum} or >207dB SPL_{peak}.

150. With regards to the potential for the mortality or potential mortal injury of eggs and larvae from piling in the array area, the ORCPs and the ANSs, the maximum predicted range of impact for mortality and potential mortal injury of eggs and larvae occurs from the sequential installation of pin piles for jacket foundations. A maximum impact range of up to 4.5km is predicted from piling within the array area (sequential piling of six piles in a 24-hour period). Mortality and potential mortal injury of eggs and larvae is predicted to occur up to 2.6km from piling within the ORCPs (sequential piling of six piles in a 24-hour period). Mortality and potential mortal injury of eggs and larvae is predicted to occur up to 3.9km from piling within the ANS areas (sequential piling of four piles in a 24-hour period). In the event that pin piles for jacket foundations are installed simultaneously at both the NE and SW piling locations in the array area, a larger range of impact is predicted, with a maximum area of up to $70km^2$ anticipated. This piling scenario would therefore represent the spatial MDS for eggs and larvae. The potential for mortality and potential mortal injury of eggs and larvae from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to foundations at the NE and SW piling locations in the array area equates to a maximum area of up to $53km^2$.

151. Considering the small overlap of the mortality and potential mortal injury noise contours of the historic Banks herring spawning ground (Coull et al., 1998), the magnitude of impact on herring eggs and larvae from piling activities is considered to be low.

152. Considering the broad distribution of all other receptors spawning grounds across the southern North Sea, the magnitude of impact on eggs and larvae from piling activities is considered to be low.

153. Taking into account the sensitivity of eggs and larvae to underwater noise, which is medium, and the magnitude of impact associated with which is considered to be low for all receptors, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

Mortality and potential mortal injury of shellfish

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

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

156. Considering the broad distribution of these receptors across the study area, the available literature suggesting a low risk of mortality or significant injury, and the relatively short-term nature of the impact, it is considered unlikely that there will be any more than a highly localised effect, with rapid recovery of the remaining stock avoiding a population level effect. Taking into account the sensitivity of the receptor to underwater noise, which is low and the magnitude of impact associated with which is considered to be low, this results in a maximum of **minor (adverse)** significance of effect, which is not significant in EIA terms.

Recoverable injury of Group 1 VERs

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

Sensitivity of VERs

158. As noted previously in paragraph 112 *et seq*., all Group 1 receptors (recoverable injury onset at >216dB SEL_{cum} or >213dB SPL_{peak}) have low sensitivity to underwater noise impacts from piling activities.

159. Regarding the potential for recoverable injury of stationary Group 1 receptors (i.e. sandeel) for piling in the array area, and the ORCPs and ANSs, the maximum predicted range of impact for recoverable injury of stationary Group 1 receptors (e.g., sandeel) occurs from the sequential installation of pin piles for jacket foundations (hammer energy, 3,500kJ, 5m pile diameter). An impact range for recoverable injury of up to 2.1km is predicted from piling within the array area (sequential piling of six pin piles in a 24-hour period). Impact ranges from recoverable injury are anticipated to occur up to 1.3km from the ORCPs (sequential piling of six pin piles in a 24-hour period), and up to 1.0km from the ANSs (sequential piling of four pin piles in a 24-hour period). In the event that pin piles for jacket foundations are installed simultaneously at both the NE and SW piling locations in the array area, a larger range of impact is predicted, with a maximum area of 18km^2 (Volume 2, Figure 10.27). This piling scenario would therefore represent the spatial MDS for stationary Group 1 receptors. The potential for recoverable injury of stationary Group 1 receptors from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 14km^2 (Volume 2, Figure 10.28). There is no in-combination effect from the simultaneous piling of monopiles or jacket foundations on fleeing Group 1 receptors.

160. Sandeel are known to be present around a substantial proportion of the UK coast and have suitable habitats and spawning grounds that are correspondingly broad (as shown in Volume 2, Figure 10.25). Considering this broad distribution of suitable spawning habitats across the southern North Sea, and the localised range of any injurious impacts, there are not considered to be any population level effects on the species.

161. Regarding the spatial MDS for fleeing Group 1 receptors from piling within the array area, the ORCP area and the ANSs, the maximum predicted range of impact for recoverable injury of fleeing Group 1 receptors occurs within the immediate vicinity of the works (<100m) from the sequential piling of monopiles, or the sequential piling of pin piles for jacket foundations.

162. Spawning grounds for all other Group 1 receptors within the Project study area are widely distributed across the southern North Sea and therefore in the context of the wider environment, the spatial impacts from underwater noise are considered to be of local scale (based on the modelling results).

163. The potential temporal impacts from piling activities within the array area, the ORCPs and the ANSs on Group 1 receptors are detailed in paragraph 121

164. Given the broadscale nature of the Group 1 receptors spawning grounds, and the intermittent nature of the piling activities, the impact magnitude for recoverable injury of all Group 1 receptors is considered to be low for both the spatial and temporal MDS.

Significance of effect

165. Taking into account the maximum sensitivity of the receptors to underwater noise, which is low, and the low magnitude of impact, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

Recoverable injury of Group 2 VERs

Sensitivity of VERs

166. As detailed in paragraph 125 *et seq.*, Group 2 receptors (recoverable injury onset at >207dB SPL_{peak} or >203dB SEL_{cum}) are considered to be of low sensitivity to underwater noise.

Magnitude of impact

167. Regarding the spatial MDS for fleeing receptors from piling within the array area, the ORCPs and the ANSs, the maximum predicted range of impact for recoverable injury of fleeing Group 2 receptors occurs within the immediate vicinity of the works (<100m) from the sequential piling of monopiles, or the sequential piling of pin piles for jacket foundations.

168. There is no in-combination effect from the simultaneous piling of monopiles or jacket foundations on fleeing Group 2 receptors.

169. Regarding the temporal MDS, Atlantic salmon and brown trout have the potential to be within range of injurious effects from piling noise, however these VERs are anticipated to be transient across the site, and therefore any temporal impacts on these receptors are anticipated to be minimal. In late spring to early summer, adult Atlantic salmon return to rivers to spawn, whilst juvenile salmon migrate out to sea to feed. Most brown trout will migrate into rivers in June and then migrate back out to sea in October. As there are no rivers associated with migrating brown trout or Atlantic salmon within the localised impact zone, there is no potential for the underwater noise to result in a barrier to migration. Taking into account the transient nature of these species across the site, the magnitude of impact to Group 2 receptors from the temporal MDS is considered to be low.

Significance of effects

170. Overall, the magnitude of the impact on Group 2 species has been assessed as low, with the sensitivity of the Group 2 VERs assessed as low. The effect is therefore considered to be of **minor (adverse)** significance for the Group 2 fish species, which is not significant in EIA terms.

Recoverable injury of Group 3 VERs

Sensitivity of VERs

171. As noted above in paragraph 135 *et seq.*, herring (Group 3 receptor, recoverable injury onset at >203dB SEL_{cum} or >207dB SPL_{peak}) are considered to be of medium sensitivity to underwater noise. All other Group 3 receptors are of low sensitivity to underwater noise impacts from piling activities.

Magnitude of impact

Regarding the potential for recoverable injury of stationary Group 3 receptors (e.g., spawning herring) from piling within the array area, the ORCPs and the ANSs, the maximum predicted range of impact for recoverable injury of stationary Group 3 receptors occurs from the sequential installation of pin piles for jacket foundations (hammer energy 3,500kJ, 5m pin pile diameter). A maximum impact range of up to 9km is predicted from piling within the array area (Volume 2, Figure 10.23) (sequential piling of six pin piles for jacket foundations in a 24-hour period). The maximum range of impact from recoverable injury of stationary Group 3 receptors is predicted to occur up to 5.2km from piling within the ORCPs area (sequential piling of up to six pin piles for jacket foundations in a 24-hour period), and up to 8.1km from piling within the ANSs (sequential piling of up to four pin piles for jacket foundations in a 24-hour period) (Volume 2, Figure 10.33). In the event that pin piles for jacket foundations are installed simultaneously at both the NE and SW piling locations in the array area, a larger range of impact is predicted, with a maximum area of 260km^2 (Volume 2, Figures 10.27). This piling scenario would therefore represent the spatial MDS for stationary Group 3 receptors. The potential for mortality and potential mortal injury of stationary Group 3 receptors from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 260km^2 (Volume 2, Figures 10.27). There is no in-combination effect from the simultaneous piling of monopiles or jacket foundations on fleeing Group 3 receptors. This is largely precautionary however, with the assumption that an individual remains within this range of the piling activity for 24-hours which, even for a species engaged in spawning activity is deemed to be overly conservative.

172. The noise contours from piling in the array area and ORCPs as shown in relation to historic herring spawning grounds, and larvae abundances (Coull *et al*, 1998 and IHLS data (ICES, 2009 - 2021)) in Volume 2, Figure 10.23 and Figure 10.33 indicate the potential for recoverable injury of spawning herring. A partial overlap of the recoverable injury noise contour with the historic Banks herring spawning ground (Coull et al., 1998) can be observed, although, as shown by annual IHLS data (ICES, 2009/2010-2022/2023) the main spawning of Banks herring stock consistently occurs north of the Project, off Flamborough Head. The larval density within the recoverable injury noise contour ranges from 0 to 6,000 herring larvae per m^2. In comparison, the peak larval density in the main spawning area off of Flamborough Head ranges from 74,250 to 93,250 larvae per m^2. Therefore, as evidenced by the IHLS data, the larval density and therefore spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning off of Flamborough Head. This is further supported by PSA datasets (as shown in Volume 2, Figure 10.11 and Figure 10.12), which show the availability of suitable herring spawning substrates across the Project, and the southern North Sea. Therefore, underwater noise from piling within the array area, the ORCPs and the ANSs is unlikely to have a population level effect on the Banks herring stock.

173. Regarding the spatial MDS for fleeing receptors from piling within the array area, the ORCPs area and the ANSs, the maximum predicted range of impact for recoverable injury of fleeing Group 3 receptors occurs within the immediate vicinity of the works (<100m) from the sequential piling of monopiles, or the sequential piling of pin piles for jacket foundations.

174. The potential temporal impacts from piling activities within the array area, the ORCPs and the ANSs are detailed in paragraph 143.

175. Considering the overlap of the recoverable injury noise contours with the historic Banks herring spawning grounds (Coull et al., 1998) and of areas of low-density herring larvae, and the broadscale distribution of available spawning substrates for herring across the southern North Sea, underwater noise from piling is not anticipated to cause a population level effect, and therefore the magnitude of impact is considered to be low.

176. Spawning grounds for cod, sprat and whiting are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale (based on the modelling results for fleeing receptors). All other Group 3 receptors are present in abundance within the region, and therefore any impacts from underwater noise are expected to be of local scale (based on the modelling results for fleeing receptors). Given the broadscale distribution of these receptors and their spawning grounds, and the intermittent nature of the piling activities, the maximum magnitude of impact from recoverable injury is expected to be low.

Significance of effect

177. Considering herring as a medium sensitivity receptor to an impact of low magnitude, the significance of effect is of **minor (adverse)** significance, which is not significant in EIA terms.

178. Taking into account the maximum sensitivity of all other Group 3 receptors to underwater noise, which is low, and the low magnitude of impact, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

Recoverable injury of eggs and larvae

179. Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the vicinity of the Project (Appendix 10.1 (document reference 6.3.10.1)). Eggs and larvae are considered organisms of concern by Popper *et al.,* (2014), due to their broadscale distribution, vulnerability, reduced mobility and small size, and are considered sensitive to particle motion generated by pile driving. As a result of this, eggs and larvae are considered to be of medium sensitivity to impacts from underwater noise. Taking into consideration the Popper *et al.,* (2014) criteria, the extent of noise disturbance potentially causing recoverable injury eggs and larvae would result in a moderate degree of disturbance at a near field distance from the source, and a low degree of disturbance in the near and far field.

180. Considering the broadscale distribution of the receptor spawning grounds across the southern North Sea, the magnitude of impact on eggs and larvae from piling activities is considered to be low.

181. Taking into consideration the medium sensitivity of eggs and larvae to underwater noise, and the low magnitude of impact, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

Recoverable injury of shellfish

182. Shellfish VERs within the study area are deemed to be of local to international importance (ocean quahog are of international importance due to being a OSPAR threatened and/or declining species), medium vulnerability, and high recoverability. The sensitivity of these receptors is therefore considered to be low.

183. Taking into consideration the low sensitivity of shellfish receptors to underwater noise, and the low magnitude of impact, the significance of effect is a maximum of **minor (adverse)**, which is not significant in EIA terms.

Temporary threshold shift (TTS)/Hearing damage

184. Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS has been demonstrated in some fishes, resulting from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves. However, sensory hair cells are constantly added to fishes and are replaced when damaged and therefore the extent of TTS is of variable duration and magnitude. Normal hearing ability returns following cessation of the noise causing TTS, though this period is variable. When experiencing TTS, fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment.

TTS of Group 1 receptors

Sensitivity of VERs

185. As noted previously in paragraph 112 *et seq*., all Group 1 receptors (TTS onset at >186dB SEL_{cum}) have low sensitivity to underwater noise impacts from piling activities.

Magnitude of impact

186. Regarding the potential for TTS of stationary Group 1 receptors (e.g. sandeel) from piling within the array area, the ORCPs, and the ANSs the maximum predicted range of impact occurs from the sequential installation of pin piles for jacket foundations (hammer energy 3,500kJ, 5m pin pile diameter). Impact ranges are predicted to occur up to 25km from the array area (sequential piling of up to six pin piles in a 24-hour period), up to 16 km from the ORCPs (sequential piling of up to six pin piles in a 24-hour period) and up to 28 km from piling in the ANSs (sequential piling of up to four pin piles in a 24-hour period). In the event that pin piles for jacket foundations are installed simultaneously at both the NE and SW piling locations in the array area, a larger range of impact is predicted, with a maximum area of 2,000km^2 (Volume 2, Figure 10.29). This piling scenario would therefore represent the spatial MDS for stationary Group 1 receptors. The potential for TTS of stationary Group 1 receptors from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 1,800km^2 (Volume 2, Figure 10.30). The potential for TTS of fleeing Group 1 receptors from the simultaneous installation of monopile foundations equates to a maximum area of up to 740km^2. The potential for TTS of fleeing Group 1 receptors from the simultaneous installation of jacket foundations equates to a maximum area of up to 620km^2. This, however, assumes that an individual remains within this range of the piling activity for 24-hours which, even for a species engaged in spawning activity is deemed to be overly conservative.

187. Sandeel are known to be present around a substantial proportion of the UK coast and have suitable habitats and spawning grounds that are correspondingly broad. Considering the broad distribution of suitable spawning habitats across the southern North Sea (Volume 2, Figures 10.18 to 10.21) and the localised range of any injurious impacts, there are not considered to be any population level effects on the species.

188. Regarding the spatial MDS for fleeing receptors, the maximum predicted range of impact of TTS on fleeing Group 1 receptors occurs from the piling of monopiles (hammer energy 6,600kJ). A maximum impact range of up to 10km is predicted from the sequential piling of monopiles within the array area (piling of up to two monopiles in a 24-hour period). A maximum impact range of TTS on fleeing Group 1 receptors is predicted to occur up to 4.4km from the ORCPs from the sequential piling of up to two monopile foundations in a 24-hour period. Lastly, the maximum TTS impact ranges from piling within the ANSs are anticipated to occur up to 11km from the source, from the piling of one monopile in a 24-hour period, or the sequential piling of up to four pin piles in a 24-hour period.

189. The potential for TTS of stationary Group 1 receptors (e.g., sandeel) from the simultaneous installation of two monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 1,800km^2 (Volume 2, Figure 10.30). The potential for TTS of stationary Group 1 receptors from the simultaneous installation of up to six pin piles for jacket foundations at both the NE and SW piling locations in the array area equates to a maximum area of up to 2,000km^2 (Volume 2, Figure 10.29). The potential for TTS of fleeing Group 1 receptors from the simultaneous installation of monopile foundations equates to a maximum area of up to 740km^2. The potential for TTS of fleeing Group 1 receptors from the simultaneous installation of jacket foundations equates to a maximum area of up to 620km^2.

190. Spawning grounds for all other Group 1 receptors within the Project study area are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale (based on the modelling results).

191. The potential temporal impacts from piling activities within the array area and the ORCPs on Group 1 receptors are detailed in paragraph 121.

192. Given the broadscale nature of the Group 1 receptors spawning grounds, and the intermittent nature of the piling activities, the impact magnitude for TTS on all Group 1 receptors is considered to be low for both the spatial and temporal MDS.

Significance of effect

193. Taking into account the low sensitivity of the Group 1 receptors to underwater noise and the low magnitude of impact, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

TTS of Group 2 receptors

Sensitivity

194. As detailed in paragraph 125 *et seq.*, Group 2 receptors (TTS onset at >186dB SEL_{cum}) are considered to be of low sensitivity to underwater noise.

Magnitude of impact

195. Regarding the spatial MDS, the Popper *et al.* (2014) criteria for TTS of Group 2 receptors are the same as that of risk of TTS to fleeing Group 1 receptors (as detailed in paragraph 188) and therefore the impact ranges presented for Group 2 receptors replicate those for Group 1 receptors.

196. Regarding the temporal MDS, Atlantic salmon and brown trout have the potential to be within range of injurious effects from piling noise, however these VERs are anticipated to be transient across the site, and therefore any temporal impacts on these receptors are anticipated to be minimal. In late spring to early summer, adult Atlantic salmon return to rivers to spawn, whilst juvenile salmon migrate out to sea to feed. Most brown trout will migrate into rivers in June and then migrate back out to sea in October. As there are no rivers associated with migrating brown trout or Atlantic salmon within the impact zone, there is no potential for the underwater noise to result in a barrier to migration. Taking into account the limited impact range anticipated on fleeing Group 2 receptors, and the transient nature of Atlantic salmon and brown trout across the site, the magnitude of impact to Group 2 receptors from the spatial and temporal MDS is considered to be low.

Significance of effect

197. Overall, the magnitude of the impact on Group 2 species has been assessed as low, with the sensitivity of the Group 2 VERs assessed as low. The significance of the effect is therefore considered to be **minor (adverse)** for the Group 2 fish species, which is not significant in EIA terms.

TTS of Group 3 receptors

Sensitivity

198. As detailed in paragraph 134 *et seq*., Group 3 receptors (TTS onset at 186dB SEL_{cum}) are considered to be of low to medium (herring) sensitivity to underwater noise.

Magnitude of impact

199. Regarding the spatial MDS for stationary Group 3 receptors, the Popper *et al.* (2014) criteria for TTS of Group 3 receptors are the same as that of risk of TTS to Group 1 receptors (as detailed in paragraph 186) and therefore the impact ranges presented for Group 3 receptors replicate those for Group 1 receptors.

200. The noise contours shown in relation to historic herring spawning grounds (Coull et al., 1998) and IHLS data (ICES, 2009/2010 – 2022/2023)) in Volume 2, Figure 10.23 indicates the potential for TTS of spawning herring. A partial overlap of the TTS noise contour with the historic Banks herring spawning ground (Coull et al., 1998) can be observed in Volume 2, Figure 10.23, although, as shown by annual IHLS data (ICES, 2009/2010-2022/2023) the main spawning of Banks herring stock consistently occurs to the north of the Project, off Flamborough Head. The larval density within the TTS noise contours (from both piling within the array area and the ORCPs) ranges from 0 to 6,000 herring larvae per m^2. In comparison, the peak larval density in the main spawning area off Flamborough Head ranges from 74,250 to 93,250 larvae per m^2. Therefore, as evidenced by the IHLS data, the larval density and therefore spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning off of Flamborough Head. This is further supported by PSA datasets (Volume 2, Figures 10.12 and 10.13) which show the availability of suitable herring spawning substrates across the Project, and the southern North Sea. which show the availability of suitable herring spawning substrates across the Project, and the southern North Sea.

201. Regarding the spatial MDS for fleeing Group 3 receptors, the Popper *et al.* (2014) criteria for TTS of Group 3 receptors are the same as that of risk of TTS to fleeing Group 1 receptors (as detailed in paragraph 188) and therefore the impact ranges presented for Group 3 receptors replicate those for Group 1 receptors.

202. The potential for TTS of stationary Group 3 receptors (e.g., herring) from the simultaneous installation of 2 monopile foundations at the NE and SW piling locations in the array area equates to a maximum area of up to 1,800km^2 (Volume 2, Figure 10.28). The potential for TTS of stationary Group 3 receptors from the simultaneous installation of jacket foundations at both the NE and SW piling locations in the array area equates to a maximum area of up to 2000km^2 (Volume 2, Figures10.27). The potential for TTS of fleeing Group 3 receptors from the simultaneous installation of monopile foundations equates to a maximum area of up to 740km^2. The potential for TTS of fleeing Group 3 receptors from the simultaneous installation of jacket foundations equates to a maximum area of up to 620km^2.

203. The potential temporal impacts from piling activities within the array area, the ORCPs and the ANSs are detailed in paragraph 143.

204. Considering the overlap of the TTS noise contours with the historic Banks herring spawning grounds (Coull et al., 1998) and of areas of low-density herring larvae, and the broadscale distribution of available spawning substrates for herring across the southern North Sea, underwater noise from piling is not anticipated to cause a population level effect, and therefore the magnitude of impact on spawning herring is considered to be low.

205. Spawning grounds for cod, whiting and sprat are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale (based on the modelling results). All other Group 3 receptors are present in abundance within the region, and therefore any impacts from underwater noise are expected to be of local scale. Given the broadscale distribution of these receptors and their spawning grounds, and the intermittent nature of the piling activities, the maximum magnitude of impact from TTS on spawning cod, whiting and sprat is expected to be low.

Significance of effect

206. The impact of TTS on spawning herring is considered to be of low magnitude, and the maximum sensitivity of the receptor is considered to be medium. The significance of the residual effect is therefore concluded to be **minor (adverse)**, which is not significant in EIA terms.

207. Taking into account the low maximum sensitivity of all other Group 3 receptors to underwater noise and the low magnitude of impact, the significance of effect is **minor (adverse)**, which is not significant in EIA terms.

TTS of eggs and larvae

208. The Popper *et al,* (2014) criteria for TTS are the same as that of risk of recoverable injury (in paragraph 179), and therefore the impact assessment for eggs and larvae replicates that undertaken for recoverable injury. Eggs and larvae were assessed as having medium sensitivity to underwater noise impacts, with a moderate degree of disturbance at a near field distance from the source predicted on the receptors. The magnitude of effect was considered to be low.

209. The impact of TTS on eggs and larvae is considered to be of low magnitude, and the sensitivity of the receptors is considered to be medium. The significance of the effect is therefore concluded to be **minor (adverse),** which is not significant in EIA terms.

TTS of shellfish

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

211. It is understood that particle motion attenuates rapidly, therefore any impacts on shellfish are likely to be localised. Taking this into account, and the broad distribution of these species along the UK coasts, and across the southern North Sea, the magnitude of magnitude of effect on shellfish receptors is assessed as low.

212. The impact of TTS on shellfish is considered to be of low magnitude, and the maximum sensitivity of the receptor is considered to be low. The significance of the residual effect is therefore concluded to be **minor (adverse)**, which is not significant in EIA terms.

Behavioural Impacts

213. Different fish and shellfish have varying sensitivities to piling noise, depending on how these species perceive sound in the environment. Behavioural effects in response to construction related underwater noise include a wide variety of responses including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column (e.g., Hawkins *et al*, 2014a). Depending on the strength of the response and the duration of the impact, there is the potential for some of these responses to lead to significant effects at an individual level (e.g., reduced fitness, increased susceptibility to predation) or at a population level (e.g., avoidance or delayed migration to key spawning grounds), although these may also result in short-term, intermittent changes in behaviour that have no wider effect, particularly once acclimatisation to the noise source is taken into account.

214. Regarding Group 1 fish and shellfish, these receptors lack a swim bladder, and so are largely considered to be less sensitive to sound pressure, with these species instead detecting sound in the environment through particle motion. The sensitivity of the receptors to 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) and the potential for piling activity to generate the type of sound fields that may contain substantial acoustic particle velocity components has also been noted in the literature (Hawkins, 2009). As such, sensitivity to particle motion in the Group 1 fish receptors and shellfish is more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Hawkins *et al*, 2014a; Mueller-Blenkle *et al*, 2010).

215. It has also been reported that slow, rolling interface waves that move out from a source like a pile driver can produce particle motion amplitudes travelling considerable distances (Hawkins and Popper, 2016), with implications for demersal and sediment dwelling fish (such as sandeel) and shellfish in close proximity to piling operations. Specifically, demersal dwelling receptors such as sandeel (Group 1 receptors) may be particularly affected by vibration through the seabed during winter hibernation when sandeel remain buried in sandy sediments.

216. Particle motion generated from piling is expected to attenuate more rapidly than the acoustic pressure component in the water, with a low risk of behavioural effects in the far-field (i.e., kilometres from the source).

217. Mueller-Blenkle *et al*. (2010) measured behavioural responses of Dover 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 influence 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 144 to 156dB re 1µPa SPL_{peak} for Dover sole. However, this threshold should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this, especially considering the varied responses observed across subjects.

218. Research into the impact of underwater noise on shellfish receptors is scarce, and no attempt has been made to set exposure criteria (Hawkins *et al*, 2014b). Studies on marine invertebrates have shown sensitivity of shellfish receptors 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 that provide the sensitivity, although these animals also have other sensor systems which could be capable of detecting vibration.

219. Group 2 and 3 fish receptors possess a swim bladder and therefore are more sensitive to the sound pressure components of underwater noise, therefore the risks of behavioural effects are considered 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 Group 3 gadoids. Mueller-Blenkle *et al*, (2010) measured behavioural responses of cod to sounds representative of those produced during marine piling and observed behavioural responses at 140 to 161dB re 1µPa SPL_{peak} for cod. However, variable responses were observed across subjects and consequently this threshold should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this. A study by Pearson *et al.* (1992) on the effects of seismic airgun noise on caged rockfish (*Sebastes* spp.) observed a startle or C-turn response at peak pressure levels beginning around 200dB re 1µPa, 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, in open water to seismic airgun noise and assessed behaviour, physiological and pathological changes. The study made the following observations:

- a general fish behavioural 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 to 161dB re 1µPa; approximately equivalent to SPL_{peak} levels of around 168 to 173dB re 1µPa);
  - 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 will only likely occur at short range from the source.

220. The authors did, however, note 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.

221. Picciulin *et al*, (2022) undertook a study based on free-living brown meagre (*Sciaena umbra*) fish and observed no influence on breeding site selection of brown meagre fish when exposed to vessel noise. Similar observations were made by Bruintjes *et al*, (2014), who observed no influence on the early-life survival and growth of the cichlid fish (*Neolsmprologus pulcher*) when exposed to moderate noise increases (motorboat noise). Although it should be noted that this study was conducted on captive fish.

222. Hawkins *et al*. (2014a) undertook a study on schools of sprat and mackerel, observing behavioural responses to pile driving. A range of responses were observed at sound pressure levels of 163.2 $SPL_{peak-to-peak}$ and estimated single strike SEL of 135dB re 1µPa^2s for sprat and 163.3dB re 1µPa peak-to-peak and estimated single strike SEL 142.0dB re 1µPa^2s for mackerel. Although responses were found to vary (to the same stimulus type and intensity), differing between the two species, schooling fish and individuals, and during night and day. However, it should be acknowledged that this threshold is based on a study undertaken within a quiet loch on fish not involved in any particular activity (i.e. not spawning), and it is therefore not considered appropriate to apply the outcomes of this study to a much noisier area such as the southern North Sea (which is subject to high levels of anthropogenic activity and consequently noise) as the fish within this area will be acclimated to the noise and would be expected to have a correspondingly lower sensitivity to noise levels. Site-specific ambient noise monitoring, undertaken in July 2022 (Appendix XX (document reference)) concluded that background sound levels in the area are typical for shallow coastal waters, which is representative of the North Sea (Putland *et al.,* 2021).

223. Acoustic trauma has been observed in selected cephalopod species, as evidenced by André *et al*. (2011) who observed acoustic trauma in European squid, following exposure to low frequency sound. This was also observed by Samson *et al*. (2016) with a range of behavioural responses to underwater noise in cephalopods recorded, including inking, colour changes and startle responses. However, Fewtrell and McCauley (2012) suggest that such alterations are only temporary from experimental studies.

224. Seahorse hearing is considered similar to that of herring (Group 3) and are therefore likely to be sensitive to underwater noise. A study on wild spiny/long snouted seahorse, found 87% of seahorse reacted to a noise stimulus (expressed by increased Opercular Movements Per Minute (OMPM)) during the induced sequence of transient (up to 127.6dB) and constant (137.1dB) sound exposure (Palma *et al*, 2019). In addition, Palma *et al*, (2019) also found <38% of those seahorses abandoned their holdfast and moved away, a behaviour the authors are interpreting as an attempt to avoid the negative sound stimuli. A study by Anderson *et al*. (2011) examined the behavioural response of the lined seahorse (*Hippocampus erectus*) when exposed to 123dB to 137dB rms re 1µPa in a tank for a month. Seahorse exposed to loud noises showed a behavioural response such as irritation and distress, and a physiological response, including lower weight, worse body condition, higher plasma cortisol and other blood measures indicative of stress, and more parasites in their kidneys. In addition to the primary and secondary stress indices in the blood and plasma, seahorses exhibited tertiary indices (e.g., growth, behaviour, and mortality) (Anderson *et al*, 2011). However, the study found that some of the variability in these measures (such as time spent mobile) subsided after the first week, presumably due to habituation. It is important to note that Radford *et al*, (2016) recorded shipping sound levels of 124dB rms re 1µPa, seismic survey noise levels at 131dB rms, and pile driving at 141dB rms; in this context and based on the Anderson *et al*. (2011) paper, seahorses can be expected to habituate to the noise levels that may be experienced during piling operations.

225. The European seabass has increasingly been used in the study of anthropogenic noise effects on fish. The hearing sensitivity of seabass is most acute at low frequencies (100–1000 Hz); coincident with many anthropogenic noises in water (Götz *et al.*, 2009). Spiga *et al*. (2017) investigated the effects of recordings of piling and drilling noise on the anti-predator behaviour of captive juvenile European seabass in response to a visual stimulus (a predatory mimic). None of the behavioural measures related to exploration, swimming activity or anxiety were affected by playback noise onset (Spiga *et al.*, 2017). Exploration behaviour is an important feature in fish as it leads to finding food, mates and escapes routes; therefore, it has been suggested that although piling noise triggers reflex behaviours, as no behavioural measures related to exploration were affected, the responses observed by Spiga *et al.*, (2017) would appear not to be detrimental to the fish (Spiga *et al.*, 2017

226. Research by Radford *et al*. (2016) using seabass was designed to examine the changes in ventilation rate (Opercular Beat Rate (OBR)) caused by noise to captive fish, which would indicate a stress response. When pile driving noise was played at 147dB SEL_{ss}, 30dB above the ambient noise played prior to the stimulus (117dB SPL_{rms}), a clear increase in OBR was detected. Additional research by Kastelein *et al.* (2017), also on seabass, identified that initial responses in adult fish (sudden short-lived changes in swimming speed) occurred in response to impulsive pile driving at 141dB SEL_{ss}, but concluded that no sustained responses (changes in school cohesion, swimming depth, and speed) occurred at levels up to 166dB SEL_{ss}. Kastelein *et al*. (2017) concluded that the analysis showed that there is no evidence, even at the highest sound level, for any consistent sustained response to sound exposure by the study animals. A study undertaken by Neo *et al*., (2018) on captive seabass, observed more significant behavioural responses of European bass to piling during the night than during the day, and also noted habituation over repeated sound exposure.

227. 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). Nonetheless, the quantitative criteria identified in the literature have been summarised in Table 10.21 below, for ease of the reader. Furthermore, to incorporate a spatial element to this review, and enable further interpretation, potential behavioural impact ranges have been presented as 5dB increments from the piling locations within the array area, ANS, and the ORCP, in Volume 2, Figure 10.36 and 10.37.

Table 10.21 Summary of behavioural noise response thresholds identified in literature

Literature	Receptor	Behavioural response threshold identified
Mueller-Blenkle *et al*. (2010)	Dover sole	144 to 156dB re 1µPa SPL_{peak}
Mueller-Blenkle *et al*. (2010)	Cod	140 to 161dB re 1µPa SPL_{peak}
Pearson *et al*. (1992)	Rock fish	200dB re 1µPa (mean-peak level)
McCauley *et al*. (2000)	N/A	156 to 161dB re 1µPa rms, 168 to 173dB re 1µPa SPL_{peak}
Hawkins *et al*. (2014a)	Sprat	163.2dB re 1µPa SPL_{peak}, 135dB re 1µPa SEL_{ss}
Hawkins *et al*. (2014b)	Mackerel	163.3dB re 1µPa SPL_{peak}, 142dB re 1µPa SEL_{ss}
Anderson *et al*. (2011)	Seahorse	123dB to 137dB re 1µPa rms
Radford *et al*. (2016)	Seabass	147dB re 1µPa SEL_{ss}
Kastelein *et al*. (2017)	Seabass	141dB re 1µPa SEL_{ss}

228. As evidenced by the studies above, fish and shellfish behavioural responses to underwater noise are highly dependent on factors such as the type of fish/shellfish, sex, age and condition, as well as other stressors to which the fish/shellfish have been exposed. For example, it is expected that smaller fish might show behavioural responses at lower levels of noise. 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 may increase the desire for the fish to remain in the area despite the elevated noise level (Peña *et al*., 2013). This is supported by Neo *et al*. (2014) who concluded that a single criterion value for behaviour does not take into consideration the substantial species differences in behaviour, nor does it take into consideration response changes with animal age, season, or motivational state. This is evidenced by Skaret *et al*. (2005) who observed no avoidance behaviours in herring, in response to vessel noise when engaged in spawning behaviours.

229. The thresholds identified in the literature detailed above and summarised in Table 10.21, are largely based on captive animals (as reviewed by Popper and Hawkins, 2019). Whilst studies on captive animals are suitable for gaining physiological information such as hearing sensitivity, they may not be suitable for understanding how a wild animal will respond behaviourally to a stimulus (Oldfield, 2011). Notably, a need for further research on behavioural responses to external stimuli was highlighted by Popper *et al*., (2014) with an emphasis on the requirement for studies on wild fish receptors.

230. Due to the range of behavioural responses elicited from fish and shellfish receptors, and the influence from environmental variables and ecological stressors, Popper *et al*. (2014) recommend the application of a qualitative assessment. The qualitative behavioural criteria derived from Popper *et al*. (2014) for fish are provided in Table 10.22 below. These categorise the risks of effects in relative terms as 'high, moderate or low' at three distances from the source: near (10s of metres), intermediate (100s of metres), and far (1,000s of metres), respectively. This qualitative approach as recommended by Popper *et al*. (2014) has been applied to the assessment of behavioural impacts of fish and shellfish below.

Table 10.22 Qualitative behavioural criteria (Popper *et al.,* 2014)

Type of animal	Impairment	
	Auditory masking	Behaviour
Fish: no swim bladder (Group 1)	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (Group 2)	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing (Group 3)	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate

Type of animal	Impairment	
	Auditory masking	Behaviour
Eggs and larvae	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
Risk of effect category (high, moderate low) is given at three distances from the source in relative terms: near field (N: 10s of metres), intermediate field (I: 100s of metres), and far field (F: 1,000s of metres); (Popper *et al*., 2014).		

Behavioural impacts of Group 1 receptors

Sensitivity of Group 1 VERs

231. As noted previously in paragraph 112 *et seq*., all Group 1 receptors are considered to be of low sensitivity to underwater noise.

Magnitude of impact

232. Considering the Popper *et al* (2014) criteria, any risk of behavioural effects or auditory masking in Group 1 species (particularly the less mobile species) from piling in the array area, ORCPs and ANSs are expected to be low in the intermediate field. Near field behavioural impacts are considered likely to be fully contained within TTS effects and so are not considered further. Taking this into consideration, the magnitude of impact on Group 1 species is considered to be low.

Significance of effect

233. Overall, the magnitude of the impact on Group 1 species has been assessed as low, with the sensitivity of Group 1 receptors assessed as low. The effect is therefore considered to be of **minor (adverse)** significance for all Group 1 fish species which is not significant in EIA terms.

Behavioural impacts of Group 2 receptors

Sensitivity of Group 2 VERs

234. As noted previously in paragraph 125 *et seq*., Group 2 receptors are considered to be of low sensitivity to underwater noise.

Magnitude of impact

235. Considering the Popper *et al* (2014) criteria, any risk of behavioural effects or auditory masking in Group 2 species from piling is expected to be low in the intermediate field. Near field behavioural impacts are considered likely to be fully contained within TTS effects and so are not considered further. Atlantic salmon and brown trout are considered unlikely to be within range of any behavioural impacts from piling noise as these VERs are anticipated to be transient across the site. Any temporal impacts on these receptors are therefore anticipated to be minimal. Therefore, the magnitude of the impact to Group 2 receptors from the temporal MDS is considered to be low.

Significance of effect

236. Overall, the magnitude of the impact on Group 2 species has been assessed as low, with the sensitivity of receptors assessed as low. The significance of the effect is therefore considered to be of **minor (adverse)** for all Group 2 fish species, which is not significant in EIA terms.

Behavioural impacts of Group 3 receptors

Sensitivity of Group 3 VERs

237. As noted in paragraph 134 *et seq*., spawning herring are considered to be of medium sensitivity to underwater noise. All other Group 3 receptors are considered to be of low sensitivity.

Magnitude of impact

238. Spawning grounds for a number of Group 3 species overlap with the Project site or are within the wider area. Whilst the Popper *et al* (2014) criteria suggest a high risk of behavioural disturbance in the intermediate field and a moderate risk in the far field, the risk assessment is likely to predicated on the individuals not being involved in activities with a strong biological driver (i.e., spawning or feeding). Specifically, Skaret *et al.* (2005) identified that herring (a Group 3 species), had a significantly reduced reaction to external stimulus when involved in spawning activity than when swimming. As such, it is likely that any behavioural impacts to fish would be significantly reduced when spawning, with consequently limited impact on spawning potential for the relevant species. Whilst there is a paucity of evidence on migratory behaviour of European eel, it is possible that migration would be an equally strong biological driver, with similar damping of behavioural reactions.

239. Taking this into consideration, the magnitude of impact on Group 3 species is considered to be low.

Significance of effect

240. The impact of behavioural effects on spawning herring are considered to be of low magnitude, and the maximum sensitivity of the receptor is considered to be medium. The significance of the effect is therefore concluded to be **minor (adverse)**, which is significant in EIA terms.

241. The impact of behavioural effects on all other Group 3 receptors are considered to be of low magnitude, and the maximum sensitivity of the receptors is considered to be low. The significance of the effect is therefore concluded to be **minor (adverse),** which is not significant in EIA terms.

Eggs and larvae

242. Given the considered stationary nature of eggs and larvae the potential for behavioural impacts is considered limited. As such, it is considered that the assessment of behavioural impacts to eggs and larvae is sufficiently captured within consideration of TTS for this group.

Shellfish VERs

Sensitivity of Shellfish VERs

243. There are no criteria for shellfish sensitivity to noise, and therefore, a qualitative assessment has been undertaken based on published literature. Shellfish are considered a potential sensitive receptor to particle motion from piling, due to typically having low motility, and therefore are considered unlikely to be able to vacate the area at the onset of 'soft-start piling'; Roberts (2015) suggested that vibroacoustic stimuli may elicit and affect anti-predator responses, such as startle response in crabs and valve closure in mussels. Such responses would effectively be distractions from routine activities such as feeding. Behavioural changes in mussels have also been observed in response to simulated pile-driving, with increased filtration rates observed in blue mussels (Spiga *et al.*, 2016). In addition to this, Samson *et al.* (2016) recorded a range of behavioural responses to underwater noise in cephalopods, including inking, colour changes and startle responses. Taking this into consideration, shellfish were considered to be of low sensitivity to underwater noise impacts.

Magnitude of impact

244. It is understood that particle motion attenuates rapidly, and therefore impacts on shellfish from particle motion are likely to occur local to the source. Taking this into account, and the broad distribution of these species within the southern North Sea and along UK coasts, the magnitude of impact on shellfish is considered to be low.

Significance of effect

245. Overall, the magnitude of the impact on shellfish has been assessed as low, with the sensitivity assessed as low. The significance of the effect is therefore considered to be **minor (adverse)**, which is not significant in EIA terms.

Barrier effects from noise and vibration on migrating herring

246. Herring spend their first few years in coastal nurseries, before moving offshore to deeper waters, where they join the adult populations (MacKenzie, 1985). These populations undertake feeding and spawning migrations, to the western areas of the North Sea, with migrations following a clockwise circuit (Cushing, 2001). The North Sea migration patterns, despite environmental variation, are considered to remain relatively constant over periods of several years (Corten, 2001). The Banks (Dogger) herring stock migrate in a clockwise circuit, from the northeast to the Banks spawning ground, and then continuing in a northerly direction (Cushing, 2001).

247. The migration circuit has been mapped alongside the herring larval hotspots, and noise contours from piling in the array area, the ORCPs and ANSs in Volume 2, Figure 10.38. The Project lies to the south of the migration pathway, and the noise contours fall outside of the migration pathway. Therefore, there will be no barrier impacts on herring migration from piling activities at the Project.

Noise and Vibration arising from UXO clearance

248. Prior to the start of construction UXO investigation works will be required which may require clearance of UXO through in-situ detonation, resulting in emission of underwater noise. The Applicant is not applying for consent for UXO clearance works as part of this DCO application (as at this stage it is not clear if it will be required, or indeed if required to what extent and location, and a separate Marine Licence will be sought for such works once these factors have been established). However, it is acknowledged that such UXO clearance could occur and therefore, it is appropriate to consider the potential impacts of this additional source of underwater noise on fish and shellfish species.

249. UXO clearance activities are one of the loudest anthropogenic noise sources that occur underwater, with typically much higher source levels than those from piling. UXO clearance is expected to result in mortality, mortal injury, recoverable injury, TTS and disturbance to fish and shellfish species, depending on the proximity of the individuals to the UXO location and the size of the UXO. Small scale mortality of fish as a result of UXO detonation are frequently recorded (Dahl *et al.,* 2020), with dead fish recorded floating at the surface following the detonation by Marine Mammal Observers in accordance with the Joint Nature Conservation Committee (JNCC) (2010) guidelines for minimising the risk of injury to marine mammals from using explosives (JNCC, 2010). The recordings for dead fish are typically made within the immediate vicinity of the detonation (Dahl *et al.,* 2020) and as such this is expected to be a small-scale impact.

250. An estimation of the potential impact ranges for mortality and potential mortal injury of fish from UXO clearance activities has been made, based purely on the charge weight of the UXO. Noting that this estimation does not take into account the design, composition, age, position, orientation, and sediment coverage of the UXO, which leads to a high degree of uncertainty. Due to these uncertainties, a worst case and therefore precautionary estimation is used for the calculations, assuming the UXO is not buried, degraded or subject to any other significant attenuation. The calculations are detailed in Appendix 3.2 (document reference 6.3.3.2). The maximum equivalent charge weight for the potential UXO devices that could be present within the Project site boundary is estimated as 800 kg, and an additional donor weight of 0.5 kg was included in the calculations to initiate detonation. The maximum impact range for mortality and potential mortal injury from the highest charge weight using the unweighted SPL_{peak} explosion noise criteria from Popper *et al.* (2014) is estimated to be 930m from the detonation, representing a localised impact. However, injury and disturbance effects will impact a progressively larger area, with TTS and disturbance effects potentially reaching 10’s of kilometres from the UXO location (Popper *et al.,* 2014).

251. Due to the potential impacts from underwater noise from UXO clearance, bubble curtains have become a standard requirement for high-order UXO clearance works to reduce the sound level received by marine animals from the detonation. While the primary driver for the deployment of bubble curtains is legislation protecting marine mammals, where bubble curtains are used, they will also result in a reduction of the impacts to fish and shellfish receptors as well. Recently, a new technique to the commercial sector for UXO clearance has been promoted, and used successfully for OWF projects: deflagration or "low order" detonation. This method, while currently in its infancy within the commercial offshore wind sector, is an alternative to standard techniques, and has been put forward as the primary clearance method for recent UXO licence applications (e.g. Sofia Offshore Windfarm UXO Marine Licence Application – MLA/2020/00489; Dogger Bank Offshore Windfarm UXO Marine Licence Application – MLA/2020/00581; evidence to date (e.g., Cheong *et al.,* 2020) suggests a much quieter, standard source level (regardless of UXO charge size, with the sound level emitted only relating to the donor charge size) which is anticipated to result in reduced impacts on the marine environment.

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

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

Impact 2: Increase in SSC and sediment deposition

254. Temporarily, localised increases in SSC and associated sediment deposition and smothering are expected from foundation and cable installation works (including trenchless technique installation) and seabed preparation works (including sandwave clearance). This assessment should be read in conjunction with Volume 1, Chapter 7: Marine Physical Processes (document reference 6.1.7), Volume 3, Appendix 7.1: Physical Processes Technical Baseline (document reference 6.3.7.1) and Volume 3, Appendix 7.2: Physical Processes Modelling Report (document reference 6.3.7.2) which provides the detailed offshore physical environment assessment (including project specific modelling of sediment plumes).

Magnitude of impact

255. Background surface SSCs within the Project array area are known to vary seasonally, with higher concentrations occurring during spring tides and storm conditions, with the greatest concentrations encountered close to the bed. Within the array area, surface SSCs are generally low, with concentrations of up to 5mg/l were recorded between the period 1998 to 2015 (Cefas, 2016). Within the nearshore zone of the offshore ECC, SSCs are much higher, being directly under the influence of terrestrial sources from the Humber Estuary and Holderness Cliffs, such that concentrations reach around 60mg/l, between the period 1998 to 2015 (Cefas, 2016). These concentrations also coincide with the winter months when a greater frequency of storm events and fluvial inputs (including storm runoff) can be expected to occur. During the summer months, for example July, maximum values are of the order of 12mg/l (Cefas, 2016). Site specific turbidity data from a metocean buoy currently deployed in the array area show similar concentrations, with surface values of approximately 5mg/l, rising to up to 12mg/l in the mid-water, and up to 18mg/l lower in the water column during the summer months.

256. Table 10.7 presents the MDS associated with increases in SSC and deposition. Seabed preparation for foundations, sandwave clearance for cable installation, cable trenching, drilling for foundations and spoil disposal are all predicted to result in sediment plumes and localised increases in SSC. Site-specific modelling of sediment plumes and deposition (Appendix 7.1 (document reference 6.3.7.1)) from seabed preparation and installation activities along the Project offshore ECC, and within the offshore array area has been undertaken to quantify the potential footprint of the plumes, their longevity and the concentration of SSC as well as the subsequent deposition of plume material on the seabed.

257. The release events that have been simulated within the numerical model, as described in Appendix 7.2 (document reference 6.3.7.1), have been specifically designed to capture the full range of realistic worst-case outcomes as the maximum:

- Sediment plume concentrations;
- Sediment plume extent;
- Vertical deposition depth (bed level change); and
- Horizontal extent of deposition (spatial extent (area) of bed level change).

258. A full assessment of the above, including the methodological approach used to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out in Part 6, Volume 2, Appendix 7.2: Physical Processes Modelling Report (document reference 6.3.7.2). To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative location (environmental) and project (MDS) specific information, including a range of water depths, heights of sediment ejection/initial resuspension, and sediment types.

259. Those Project activities within the array and offshore ECC which will result in the greatest disturbance of seabed sediments are:

- Pre-lay cable trenching using a Mass Flow Excavation (MFE) tool at the seabed;

- Seabed preparation (sandwave levelling) including spoil disposal via a Trailer Suction Hopper Dredger (TSHD); and
- Foundation installation using drilling techniques.; and
- Drilling fluid release during Horizontal Directional Drilling (HDD) operations (See paragraphs 260 to 265 and Table 10.7 for further details).

260. The maximum distance and as such the overall spatial extent that any resultant plume might be reasonably experienced can be estimated as the spring tidal excursion distance. Any location beyond the tidal excursion distance is unlikely to experience any measurable change in SSC from a sediment plume. Given the nature of the sediment disturbance (temporary), any impacts are also anticipated to be short-lived, with any deposited material re-worked. Specifically, the numerical modelling for seabed disturbance resulting from MFE, seabed levelling and sandwave clearance indicated that:

- MFE, seabed levelling and sandwave clearance activities may produce sediment plumes with SSC up to thousands of mg/l, however these concentrations will be spatially restricted and short-lived. Elevated SSC may be advected by tidal currents up to 20km away, although these concentrations will be low. In the majority of cases, elevated SSC will be indistinguishable from background levels after 20 hours from the start of activities. For sandwave clearance activities, elevated SSC may remain past 20 hours from the start of activities, although this is expected to continue to disperse and become indistinguishable from background levels within several tidal cycles, and can therefore be considered temporary and localised; and
- Associated deposition from sediment plumes is generally in the order of tens to low hundreds of mm within several hundreds of metres from the point of disturbance, reducing to low tens of mm beyond this. Sediment deposition is generally not measurable beyond 3km to 5km away from the associated activities and is therefore generally small-scale and restricted to the near-field. This deposition is likely to become integrated into the local sediment transport regime and will be redistributed by tidal currents.

261. Further information on sediment plume distances and modelling are provided in Chapter 7 (document reference 6.1.7) and Appendix 7.2 (document reference 6.3.7.2)

262. Note the sediment plume and deposition modelling takes into consideration a single sediment dispersion event, from the deposition of one hopper load of sediment. As informed by the modelling, a single deposition event will result in the rapid dissipation of the sediment plume and localised deposition impacts. However, due consideration should also be given to the volume of sediment dispersion and deposition during the entire construction phase (as detailed in Table 10.7). It is likely that the sediments being dispersed and deposited locally will be combined during dispersion events and therefore increased deposition and SSC are expected compared to the single event modelling, discussed above.

263. The subsea export cable ducts will be installed underneath the beach using trenchless installation techniques, with HDD techniques identified as the MDS (Table 10.7). The drilling activity utilises a viscous drilling fluid which consists of a mixture of water and bentonite, a non-toxic, naturally occurring clay mineral. The release of drilling fluid and drill cuttings from HDD operations will result in a plume of elevated SSC. The drilling fluid has an overall density and viscosity similar to seawater and so is expected to behave in a similar manner.

264. The results of bentonite release modelling demonstrate that:

- Elevated SSC will be of localised extent and temporary duration, with maximum concentrations of 7.5mg/l occurring within several hundreds of metres of the punch-out in the intertidal. SSC is advected along the coast along the tidal axis to distances of up to 2km, although concentrations at this distance are limited to below 2.5mg/l. All measurable SSC will have dispersed after 15 hours. Considering generally higher background SSC conditions along the coast, these changes are likely to be indiscernible from background conditions; and
- Sediment deposition of up to 10mm is predicted within several hundreds of metres of the punch-out, reducing rapidly to below 5mm. The maximum extent of deposition is predicted to be approximately 500m from release, with only thicknesses below 2mm identified at these distances. This deposition is small-scale and highly localised and is likely to be rapidly redistributed by wave action.

265. Bentonite release during HDD operations will produce low levels of SSC and is likely to be indiscernible from background conditions. This will correspond to low sediment deposition of tens of mm within several hundred metres of the activity and a maximum deposition extent of 500m. The effect of these activities is therefore considered to be restricted to the near-field, temporary, and indiscernible from background conditions.

266. Furthermore, the creation and recreation of biogenic reef, if required, could involve the deployment of cultch (a growing medium for mussels or oyster, e.g. empty shells) which could result in a small degree of sediment suspended into the marine environment. These would be of a very small scale which is predicted to be indetectable from background levels in the surrounding environment.

267. Taking the above into consideration, the impact of increased SSC and smothering from sediment deposition associated with construction activities is noticeable but temporary, with the majority of effects limited to the near field. The magnitude of impact has therefore been assessed as low.

Sensitivity of the receptor

268. Impacts from increased SSC and sediment deposition are of greatest concern for herring eggs as smothering of the eggs may disrupt the development of the larvae, through either the sediment grains retarding growth or a reduction in oxygen availability around the eggs. The Order Limits have a slight overlap with the historic Banks herring spawning ground (Coull et al., 1998). However, any impacts on this species are expected to be relatively small in the context of the spawning habitat available across the southern North Sea; the maximum sediment plume dispersal extends across 6.1% of the historic Banks herring spawning grounds (Coull *et al.,* 1998). In addition, the maximum extent of sediment dispersal in a spring tide only interacts with areas of low density herring larvae (Volume 2, Figures 10.14 to 10.17) overlapping with herring larval abundances ranging from 0 to 6,000 larvae per m^2. Compared to peak larval abundances located off of Flamborough Head, ranging from 74,250 to 93,250 larvae per m^2. This indicates that there will be no significant impacts on spawning herring, and eggs and larvae from increased SSC and sediment deposition. Furthermore, adult herring are mobile and as such would be expected to avoid unfavourable areas. Taking into consideration the vulnerability of herring eggs and larvae to this impact, and the slight overlap with the Banks herring spawning ground, herring are considered to be of medium sensitivity to increases in SSC and sediment deposition from construction activity of the Project.

269. Sandeel are highly substrate specific (Wright *et al*., 2000); after an initial larval dispersal period, sandeel display a degree of site fidelity (Jensen *et al*., 2011) so their settled distribution reflects the distribution of preferred habitat. Sandeel rarely occur in sediments where the silt content (particle size <0.63µm) is greater than 4%, and they are absent in substrates with a silt content greater than 10% (Holland *et al*., 2005; Wright *et al*., 2000). It has been found that they tend to occupy the top 4cm of the seabed and regulate their burial depth based on oxygen availability (Behrens *et al*. 2007). Potential sandeel spawning grounds and prime and sub-prime habitats (Volume 2, Figure 10.13) are located within the ECC and the array area. However, any impacts on this species are expected to be relatively small in the context of the spawning habitat available across the southern North Sea (the maximum sediment plume dispersal extends across 7.4% of the sandeel spawning ground (Coull *et al*., 2010)). Furthermore, the secondary effects of increased concentrations of SSC in the water column and smothering (from deposition of particles as a result of comparable activities such as dredging and screening of cargo), have been shown to be inconsequential to sandeel species (MarineSpace Ltd., 2010). Sandeel eggs are also considered tolerant to increases in SSC and smothering from sediment deposition, due to the nature of resuspension and deposition within their natural high energy environment. Sandeel deposit eggs on the seabed in the vicinity of their burrows between December and January. Grains of sand may become attached to the adhesive egg membranes. Tidal currents can cover sandeel eggs with sand to a depth of a few centimetres, however experiments have shown that the eggs are capable of developing normally and hatch as soon as currents uncover them again (Winslade, 1971). Buried eggs experiencing reduced current flow, and therefore lower oxygen tension, can have delayed hatching periods, which is considered a necessary adaptation to survival in a dynamic environment (Pérez-Domínguez and Vogel, 2010; Hassel *et al*. 2004). Taking this into account, sandeel are deemed to be of medium vulnerability, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is medium.

270. Cod, plaice, lemon sole, sole, whiting, Atlantic mackerel and sprat all have spawning grounds overlapping the Project study area. These receptors are pelagic spawners and do not exhibit substrate dependency. Therefore, sediment deposition within these spawning grounds will not result in any potential loss of available spawning habitats. These receptors are mobile, widely spread across the southern North Sea, and will experience exposure to naturally high variability to SSC within their natural range. The receptors are therefore considered to be broadly insensitive to sediment deposition. The sensitivity of these receptors to increases in SSC and sediment deposition from construction activity at the Project is considered to be low.

271. Common cockle is broadly distributed across the southern North Sea and found across a range of habitats. They are of commercial value to fisheries within the region. Cockle is adapted to life in a sedimentary environment and quite capable of burrowing. The MarLIN sensitivity review has assessed common cockle as having a low sensitivity to smothering and not sensitive to an increase in suspended sediment (Tyler-Walters, 2007). Therefore, taking into account their burrowing nature and their broad distribution, common cockle is therefore considered to be able to adapt to localised and short-term SSC plumes and smothering. Common cockle is considered to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is low.

272. Common whelk is broadly distributed across the southern North Sea and are found across a range of habitats. They are of commercial value to fisheries within the region. Whelk typically burrows into mud to overwinter and emerge to feed when conditions improve. Therefore, taking into account their burrowing nature and their broad distribution, common whelk is therefore considered to be able to adapt to localised and short-term SSC plumes and smothering. Common whelk is considered to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is low.

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

274. King scallop are of commercial value to fisheries within the region and are broadly distributed across the southern North Sea. King scallop can undertake limited swimming, although this is considered to be at a high energy cost and generally associated with predator avoidance, therefore this species is not expected to be able to travel large distances to avoid disturbance. The MarLIN sensitivity review has assessed king scallop as having a low sensitivity to smothering and an increase in suspended sediment (Marshall and Wilson, 2008). King scallop is therefore considered to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is low.

275. Brown crab is of commercial value to fisheries within the region and are broadly distributed across the southern North Sea. Brown crab is considered to have a high tolerance to SSC and are reported to be insensitive to short-term increases in turbidity; however, they may avoid areas of increased SSC as they rely on visual acuity during predation (Neal and Wilson, 2008). Berried female edible crab exhibit a largely sedentary lifestyle during the overwintering period whilst brooding eggs. During this time, they are considered a stationary receptor, burying themselves into soft mud and sand, and are therefore unlikely to move away from disturbances. Berried females are considered more vulnerable to smothering from sediment deposition, due to their sedentary nature at this time, and as the eggs carried require regular aeration. The MarLIN sensitivity review has assessed brown crab as having a very low sensitivity to smothering and low sensitivity to an increase in suspended sediment (Neal and Wilson, 2008). Taking all considerations into account, brown crab is considered to be of high vulnerability during the overwintering period, high recoverability (Neal and Wilson, 2008) and of regional importance, and therefore the sensitivity of the receptor is medium.

276. *Nephrops* has a known spawning ground that lies approximately 17.5km from the Project array area, and outside of the maximum sediment plume dispersal extent. The MarLIN sensitivity review has assessed *Nephrop*s as not being sensitive to smothering or an increase in suspended sediment (Sabatini and Hill, 2008). Therefore, no impacts are anticipated on spawning *Nephrops* from increased SSC and deposition during the construction phase, and this receptor is not considered further in the assessment of this impact.

277. Ocean quahog, a bivalve species is a Feature of Conservation Importance for which the Holderness Offshore MCZ is designated. The Holderness Offshore MCZ is located 14.4km from the Project array area, and outside of the maximum sediment plume dispersal extent. Therefore, no impacts are anticipated on this feature within the MCZ. Ocean quahog are also afforded protected status under the OSPAR Commission. Ocean quahog lives buried vertically in the top few centimetres of the sediment (soft sands and muddy sands) with is inhalant and exhalent siphons at the surface (Taylor, 1976; Morton, 2011 as cited in Tyler-Walters and Sabatini, 2017). Studies have recorded responses of ocean quahog to smothering and siltation rate changes, observing the bivalve being able to reach the surface, and recording no mortality, or effects on its growth or population structure (Powilliet *et al.,* 2006; 2009 as cited in Tyler-Walters and Sabatini, 2017). The MarLIN sensitivity review has assessed ocean quahog as not being sensitive to smothering or an increase in suspended sediment (Tyler-Walters and Sabatini, 2017). Taking this into consideration, ocean quahog is considered to be of low vulnerability, high recoverability and of international importance (ocean quahog are an OSPAR threatened and/or declining species), and therefore the sensitivity of the receptor is low.

278. All other shellfish VERs and their respective spawning grounds are distributed widely throughout the southern North Sea, and experience exposure to naturally high variability in SSC within their natural range. As a result of this, all other VERs are considered to be of low sensitivity.

279. All other identified VERs are mobile, and widespread throughout the southern North Sea and will experience exposure to naturally high variability to SSC within their natural range, with no substrate dependence for spawning. Therefore, the sensitivity of all other fish species is considered to be low.

Significance of effect

280. Overall, the magnitude of the impact of an increase in SSC and sediment deposition on all fish and shellfish species has been assessed as low. The maximum sensitivity of the receptors was assessed as medium. The significance of the effect is therefore considered to be a maximum of **minor (adverse)**, which is not significant in EIA terms.

Impact 3: Temporary seabed habitat loss/disturbance

281. Temporary habitat loss and disturbance in the Project fish and shellfish study area will be a likely occurrence from foundation seabed preparation, the use of jack-ups and anchored vessels and cable seabed preparation and installation works during the construction phase of the development. These construction activities have the potential to impact on fish and shellfish ecology by the removal of essential habitats for survival (e.g., spawning, nursery and feeding habitats).

Magnitude of impact

282. The maximum area of temporary habitat loss due to the presence of foundations, scour protection and cable protection is presented in Table 10.7and equates to 4.8% of the total seabed areas within the Order Limits. Comparable habitats are present and widespread within the wider area.

283. The impact is predicted to be of local spatial extent (i.e., within the Order Limits), of short-term duration and reversible. It is predicted that the impact will affect fish and shellfish receptors directly. Taking this into account, the magnitude of impact is considered to be low.

Sensitivity of the receptor

284. Sandeel are demersal spawners and are reliant upon the presence of suitable substrates for spawning (i.e., sandy sediments); as well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history. Sandeel habitats are widely distributed across the southern North Sea. The overlap of the Project with sandeel spawning grounds is small compared to the overall extent of spawning grounds across the southern North Sea (overlap of the Project of approximately 1.56% of the sandeel spawning ground (Coull *et al*., 1998). Taking into account their substrate dependency, their ecological value as prey species, and their broad spatial distribution across the southern North Sea, sandeel are consequently deemed to be of high vulnerability to long-term changes in substrate, with limited ability for recovery, and of regional importance within the southern North Sea, and therefore are considered to be of medium sensitivity.

285. Herring are also demersal spawners, reliant upon the presence of suitable substrates for spawning (i.e., gravelly sediments). Herring spawning habitats are widely distributed across the southern North Sea. In addition, the overlap of the Project with historic herring spawning grounds (Coull et al., 1998) is small compared to the overall extent of the Banks herring spawning ground across the southern North Sea (overlap of the Project of approximately 0.5% of the Banks herring spawning grounds (Coull *et al.,* 1998). Herring is deemed to be of medium vulnerability to temporary habitat loss, and of regional importance within the southern North Sea, and therefore are considered to be of medium sensitivity.

286. These receptors are pelagic spawners and therefore do not display substrate dependency, and therefore are not considered vulnerable to temporary habitat loss and as such the sensitivity of these species is considered to be negligible.

287. Whelk, cockle, king scallop, queen scallop, brown crab, European lobster, are broadly distributed across the southern North Sea and are found across a range of habitats. These species are also of commercial importance to the region.

288. Common whelk typically burrows into mud to overwinter and emerge to feed when conditions improve. Common cockle is adapted to life in a sedimentary environment and quite capable of burrowing. Brown crab bedrock including under boulders, mixed coarse grounds, and offshore in muddy sand, and berried females overwinter in pits dug in the sediment or under rocks. Common cockle, common whelk and brown crab are therefore considered potentially sensitive to temporary habitat loss during the overwintering period. King scallop typically prefer clean firm sand, fine or sandy gravel substrates, and European lobster typically inhabit rocky substrata, typically living in holes and excavated tunnels. However common whelk, common cockle, king scallop, brown crab, and European lobster, are substrate dependent rather than being philopatric and can therefore fully utilise adjacent areas which will be unaffected. Furthermore, the MarLIN sensitivity review has assessed common cockle, king scallop and brown crab as having a low sensitivity to abrasion and physical displacement (Tyler-Walters, 2007; Marshall, and Wilson, 2008; Neal and Wilson, 2008). Therefore, the sensitivity of these receptors is considered to be low.

289. *Nephrops* have a known spawning ground that lies approximately 17.5km from the Project array area, and therefore no impacts are anticipated on spawning *Nephrops* from temporary habitat loss during the construction phase. The MarLIN sensitivity review has assessed *Nephrops* as having a low sensitivity to abrasion and physical displacement (Tyler-Walters and Sabatini, 2017). Therefore, this receptor is not considered further in the assessment of this impact.

290. Ocean quahog is a Feature of Conservation Importance for which the Holderness Offshore MCZ is designated. The Holderness Offshore MCZ is located 14.4km from the Project array area, and therefore no impacts are anticipated on ocean quahog within the MCZ during the construction phase. Ocean quahogs are also afforded protected status under the OSPAR Commission. Ocean quahog lives buried vertically in the top few centimetres of the sediment (soft sands and muddy sands) with is inhalant and exhalent siphons at the surface (Taylor, 1976; Morton, 2011 as cited in Tyler-Walters and Sabatini, 2017), and is therefore considered potentially sensitive to temporary habitat loss due to their burrowing nature. The MarLIN sensitivity review has assessed ocean quahog as having a high sensitivity to abrasion/disturbance of the seabed (Tyler-Walters and Sabatini, 2017). However, ocean quahog are substrate dependent rather than being philopatric and can therefore fully utilise adjacent areas which will be unaffected. Therefore, the sensitivity of these receptors is considered to be low.

291. All other shellfish VERs are distributed widely throughout the southern North Sea and are not of high value to fisheries in the region. As a result of this, all other VERs are considered to be of low sensitivity to impacts from temporary habitat loss.

292. These species do not display substrate dependency, and therefore are not considered vulnerable to temporary habitat loss and as such the sensitivity of these species is considered to be negligible.

Significance of effect

293. Temporary habitat loss during the construction phase will represent a short-term and localised effect. The magnitude of the impact was determined to be low. The maximum sensitivity of the receptors was assessed as medium. The significance of the effect is therefore considered to be a maximum of **minor (adverse)**, which is not significant in EIA terms.

Impact 4: Direct and indirect seabed disturbances leading to the release of the sediment contaminants

294. As discussed under Impact 2, construction activities will re-suspend sediments. While in suspension, there is the potential for sediment-bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on fish and shellfish receptors.

Magnitude of impact

295. A review of subtidal sediment contamination within the Project site was undertaken in Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology. When considering the contaminant levels present within the array and offshore ECC, it becomes important to note that this area has a large number of oil and gas facilities within it. Further detail is provided in Volume 2, Chapter 18: Marine Infrastructure and Other Users. Contaminant surveys in the array and the offshore ECC reported three metal concentrations that exceeded Cefas Level 1; Arsenic, Nickel and Chromium. Within the array area, one station recorded Polycyclic Aromatic Hydrocarbons (PAHs) that exceeded the Threshold Effect Limit (TEL) threshold; the TEL thresholds were exceeded for Acenaphthene and Phenanthrene. Within the offshore ECC, two stations recorded contaminants exceeding the TEL threshold; TEL thresholds were exceeded for Dibenz(a,h)anthracene, Naphthalene and Phenanthrene. No PAH concentrations recorded across the array or ECC exceeded the Probable Effect Limit (PEL) threshold.

296. Following disturbance as a result of construction activities, the majority of re-suspended sediments are expected to be deposited in the immediate vicinity of the works. The release of contaminants such as metals, hydrocarbons and organic pollutants from the small proportion of fine sediments is likely to be rapidly dispersed with the tide and/or currents and therefore increased bioavailability resulting in adverse eco-toxicological effects are not expected. The contaminants levels found are all comparable to the wider regional background and not considered to be recorded at a level that could result in a significant effect-receptor pathway if made bioavailable. The impacts as a result of the release of sediment-bound contaminants are therefore considered to be of negligible magnitude.

Sensitivity of the receptor

297. Construction activities leading to the resuspension of sediments will have varying levels of effect dependent on the species present and pollutants involved. As sediment-bound contaminants would be expected to be dispersed quickly in the subtidal environment, the level of effect is predicted to be small.

298. Due to their increased mobility, adult fish are less likely to be affected by marine pollution and are therefore not considered to be vulnerable to the release of sediment bound contaminants, and as such the sensitivity of the VERs is considered to be low.

299. Fish eggs and larvae are, however, likely to be particularly sensitive, with potentially toxic effects of pollutants on fish eggs and larvae (Westerhagen, 1988). Effects of resuspension of sediment-bound contaminants (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). It is on this basis, that eggs and larvae are considered to be of medium sensitivity to the impact.

300. Filter-feeding shellfish are considered to be more sensitive to marine pollution due to the recognised bioaccumulation which occurs within this group. Shellfish also display limited mobility and are therefore not anticipated to flee from the impact. These VERs are therefore considered to be of medium sensitivity to the impact.

Significance of effects

301. The resuspension of contaminants as a result of sediment disturbance is predicted to occur on a small scale, with contaminants predicted to be rapidly dispersed by the tide. Overall, the magnitude of the impact is deemed to be negligible, and the maximum sensitivity of receptors is medium. The significance of the effect is therefore considered to be a maximum of **minor (adverse)**, which is not significant in EIA terms.

Impact 5: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish species

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

Magnitude of Impact

303. The maximum area of direct damage and disturbance of subtidal habitat due to construction activities are described in Table 10.7.This equates to approximately 4.8% of the total seabed areas within the offshore Order Limits. This impact has the potential to result in direct damage and disturbance to fish and shellfish receptors and their habitats within this footprint. The impact is predicted to be of local spatial extent (only affects the areas directly within the construction footprint), or short-term duration, intermittent and reversible. It is predicted that the impact will affect fish and shellfish receptors directly, through direct damage (crushing) and disturbance.

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

305. Due to the predicted local spatial extent, short-term duration and intermittent and reversible nature of the impact, the magnitude of the impact will be low.

Sensitivity of the receptor

306. On account of the demersal spawning nature of herring and sandeel they are considered to be vulnerable to the effects of direct damage and disturbance during the construction phase of development. Both receptors are considered most vulnerable during spawning when they are less mobile, with their eggs and larvae also considered to be unable to avoid this impact; therefore, in the case of this assessment, herring and sandeel are considered stationary receptors. In addition to this, the species are both considered to be reliant on the presence of suitable spawning substrates. Therefore, both herring and sandeel are considered to be more vulnerable to direct damage and disturbance compared to other fish receptors as a result of this reliance on a specific habitat type (which is present for both receptors within the Project site).

307. Herring spawning habitats are widely distributed across the southern North Sea. In addition, the overlap of the Project with historic herring spawning grounds is small compared to the overall extent of the Banks herring spawning ground across the southern North Sea (overlap of the Project of approximately 0.5% of the Banks herring spawning grounds (Coull *et al.,* 1998).. It should be noted however, that as stated in paragraph 38, the Coull et al. (1998) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2009-2021) provide an indication of the areas of seabed in active use for spawning. As evidenced by annual IHLS data (ICES, 2009/2010-2022/2023) the main spawning of Banks herring stock consistently occurs to the north of the Project, off Flamborough Head, and outside of the range of any localised impacts from direct damage and disturbance.

308. Sandeel habitats are widely distributed across the southern North Sea. In addition, the overlap of the Project with sandeel spawning grounds is small compared to the overall extent of spawning grounds across the southern North Sea (overlap of the Project of approximately 1.56% of sandeel spawning ground (Ellis, *et al.,* 2012).

309. Taking into account the substrate dependency of herring and sandeel, and their ecological importance as key prey species, herring and sandeel are deemed to be of high vulnerability to direct damage and disturbance, with medium recoverability (due to the temporary nature of the impact) and are of regional importance in the southern North Sea and are therefore considered to be of medium sensitivity to direct damage and disturbance during the construction phase.

310. Due to the mobile nature of the other relevant fish species within the study area these species are considered to be not vulnerable to direct damage and as such the sensitivity of these species is considered to be negligible.

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

312. Common whelk is broadly distributed across the southern North Sea and are found across a range of habitats. Whelk typically burrow into mud to overwinter and emerge to feed when conditions improve. Common whelk is therefore considered to be of high vulnerability during the overwintering period, is considered to exhibit high recoverability and to be of regional importance, and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is medium.

313. Common cockle is broadly distributed across the southern North Sea and is found across a range of habitats. Common cockle is of commercial value to fisheries within the region. Cockle is adapted to life in a sedimentary environment and quite capable of burrowing. Common cockle is considered to be of high vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is medium.

314. King scallop is broadly distributed across the southern North Sea and are found across a range of habitats. They are of commercial value to fisheries within the region. The species exhibits limited swimming, with this behaviour generally limited to predator avoidance. King scallop is therefore considered unlikely to be able to actively avoid disturbance. King scallop is therefore considered to be of medium vulnerability, high recoverability (Marshall and Wilson, 2008) and of regional importance, and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is medium.

315. European lobster is considered a species of commercial importance within the region. The species is not known to exhibit a sedentary overwintering habit, being typically mobile and therefore the species is considered to have a greater ability to move away from disturbances by comparison to brown crab. European lobster is therefore considered to be of medium vulnerability, is considered to have a high recoverability and to be of regional importance and is therefore considered to be of low sensitivity to direct damage and disturbance from construction activities.

316. Ocean quahog is also afforded protected status under the OSPAR Commission. Ocean quahog lives buried vertically in the top few centimetres of the sediment (soft sands and muddy sands) with is inhalant and exhalent siphons at the surface (Taylor, 1976; Morton, 2011 as cited in Tyler-Walters and Sabatini, 2017). Ocean quahog is therefore adapted to life in a sedimentary environment and quite capable of burrowing. Ocean quahog is considered to be of high vulnerability, high recoverability and of international importance (ocean quahog are an OSPAR threatened and/or declining species), and therefore the sensitivity of the receptor to direct damage and disturbance from construction activities is medium.

317. All other shellfish VERs and their respective spawning grounds are distributed widely throughout the southern North Sea and are not of high value to fisheries in the region. As a result of this, all other VERs are considered to be of low sensitivity to impacts from direct damage and disturbance.

Significance of effects

318. Direct damage and disturbance during the construction phase will represent a short-term and localised effect. The magnitude of the impact was determined to be low. The maximum sensitivity of the receptors was assessed as medium. The significance of the effect is therefore considered to be a maximum of **minor (adverse)**, which is not significant in EIA terms.

10.6.2 Operations and Maintenance

Impact 6: Underwater noise as a result of operational turbines

319. 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

320. Underwater noise from an operational turbine mainly originates from the gearbox and the generator and has tonal characteristics (Madsen *et al.,* 2005; Tougaard *et al.,* 2009). The radiated levels are low and the spatial extent of the potential impact of the operational windfarm 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.

321. Marine animals may perceive the radiated tonal components where they 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).

322. 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. ICES has formulated recommendations for maximum radiated underwater noise from research vessels which are approximately 30dB above the hearing threshold of cod and herring (Mitson, 1995). The implication of this is that the presence of continuous noise that is not significantly above the hearing threshold of fish is not thought to cause any significant movement of fish away from the source. 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 sound pressure level of 160dB re 1µPa (RMS) (Sand *et al.*, 2001). This is higher than the noise levels reported in the open literature for operational windfarms measured at a number of ranges, all within a few hundred metres of the turbine (Nedwell *et al.*, 2007a; Edwards *et al.*, 2007; Betke *et al.*, 2004, see also Wahlberg and Westerberg, 2005 and Madsen *et al.*, 2006). The 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 10m from the turbine were comparable with hearing thresholds. Whilst limited, the available data provides an indicator that operational wind turbines are unlikely to result in disturbance of fish except within very close proximity of the turbine structure, as postulated by Wahlberg and Westerberg (2005). However, the available measurement data is mostly for smaller turbines (up to 1.5MW), and it would be expected that larger wind turbines would result in different acoustic characteristics, with foundation type also having an influence on the acoustic characteristics of the noise radiated from the structure.

323. Noise would also result from surface vessels servicing the windfarm. 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.

324. Considering the operational turbine noise of the windfarm and any associated service vessels, the ambient noise levels within the site would be expected to be lower than those present in the vicinity of nearby shipping lanes.

325. The impact is predicted to be of a highly localised spatial extent, 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

326. The sensitivities of fish and shellfish receptors were assessed as having a maximum sensitivity of medium (for Group 3 receptors).

Significance of effect

327. Subsea noise resulting from turbine operation 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 limited to the area immediately surrounding the turbine. The sensitivity of receptors is medium and the magnitude of the impact on fish and shellfish is negligible. Therefore, the significance of the effect of subsea noise on fish and shellfish will be **minor (adverse)**, which is not significant in EIA terms.

Impact 7: Long-term habitat loss due to the presence of turbine foundations, scour protection and cable protection.

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

Magnitude of impact

329. The long-term habitat loss due to the presence of foundations, scour protection and cable protection is expected to be up to approximately 5.6km^2, which represents approximately 0.8% of the total seabed areas within the Order Limits. Comparable habitats are present and widespread within the wider area.

330. Whilst the creation of a biogenic reef would be a change in habitat from a sediment habitat to a hard substrate habitat, similar to that from the deployment of scour or cable protection, the biogenic reef would provide a naturally occurring habitat that may have both negative and positive impacts depending on the receptor species. For sandeel, the creation of the reef would result in loss of habitat, although noting that the reef is proposed for off the sandbanks which represent the prime habitat and therefore any impact will likely be to less preferable habitat; any loss of habitat will be very small scale. Countering this, the reef would increase the habitat heterogeneity and availability of niche space, providing additional habitat for other fish species and particularly shellfish species, such as brown crab.

331. The impact is predicted to be of local spatial extent (i.e., within the Order Limits), of long-term duration, continuous and irreversible (within the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude of impact is therefore deemed to be low due to the highly localised nature of the impact.

Sensitivity of the receptor

332. Sandeel are demersal spawners and are reliant upon the presence of suitable substrates for spawning (i.e., sandy sediments); as well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history. Sandeel habitats are widely distributed across the southern North Sea. The overlap of the Project with sandeel spawning grounds is small compared to the overall extent of spawning grounds across the southern North Sea (overlap of Project of approximately 1.56% of sandeel spawning ground (Coull *et al.,* 1998). Taking into account their substrate dependency, their ecological value as prey species, and their broad spatial distribution across the southern North Sea, sandeel are consequently deemed to be of high vulnerability to long-term changes in substrate, with limited ability for recovery, and of regional importance within the southern North Sea, and therefore are considered to be of medium sensitivity.

333. Herring are also demersal spawners, reliant upon the presence of suitable substrates for spawning (i.e., gravelly sediments). Herring spawning habitats are widely distributed across the southern North Sea. In addition, the overlap of the Project with herring spawning grounds is small compared to the overall extent of the historic Banks herring spawning ground across the southern North Sea (overlap of the Project of approximately 0.5% of the Banks herring spawning grounds (Coull *et al.,* 1998). It should be noted however, that as stated in paragraph 38, the Coull et al. (1998) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2009-2021) provide an indication of the areas of seabed in active use for spawning. As evidenced by annual IHLS data (ICES, 2009/2010-2022/2023) the main spawning of Banks herring stock consistently occurs to the north of the Project, off Flamborough Head, and outside of the range of any localised impacts from ling term habitat loss.

334. Herring is deemed to be of medium vulnerability to long-term habitat loss, and of regional importance within the southern North Sea, and therefore are considered to be of medium sensitivity.

335. Cod, plaice, whiting, lemon sole, mackerel, common sole and sprat are pelagic spawners and do not display substrate dependency, and therefore are not considered vulnerable to temporary habitat loss and as such the sensitivity of these species is considered to be negligible.

336. Mobile VERs (without spawning grounds within the vicinity of the project) do not display substrate dependency, and therefore are not considered vulnerable to long-term habitat loss and as such the sensitivity of these species is considered to be negligible.

337. Common whelk, common cockle, king scallop, brown crab and European lobster are broadly distributed across the southern North Sea and are found across a range of habitats. These species are also of commercial importance to the region. Whelk typically burrow into mud to overwinter and emerge to feed when conditions improve. Cockle is adapted to life in a sedimentary environment and quite capable of burrowing. Brown crab bedrock including under boulders, mixed coarse grounds, and offshore in muddy sand, and berried females overwinter in pits dug in the sediment or under rocks. Common cockle, common whelk and brown crab are therefore considered potentially sensitive to long-term habitat loss during the overwintering period. King scallop typically prefer clean firm sand, fine or sandy gravel substrates. European lobster typically inhabit rocky substrata, living in holes and excavated tunnels. The MarLIN sensitivity review has assessed common cockle, king scallop and brown crab as having a moderate sensitivity to substratum loss (Tyler-Walters, 2007; Marshall and Wilson, 2008; Neal and Wilson, 2008). Ocean quahog are of international importance (ocean quahog are an OSPAR threatened and/or declining species). Ocean quahog lives buried vertically in the top few centimetres of the sediment (soft sands and muddy sands) with is inhalant and exhalent siphons at the surface (Taylor, 1976; Morton, 2011 as cited in Tyler-Walters and Sabatini, 2017). The MarLIN sensitivity review has assessed ocean quahog as having a high sensitivity to physical change (Tyler-Walters and Sabatini, 2017.) and is therefore considered potentially sensitive to long-term habitat loss due to their burrowing nature.

338. However, common whelk, common cockle, king scallop, brown crab, European lobster and ocean quahog are substrate dependent rather than being philopatric and can therefore fully utilise adjacent areas which will be unaffected. Therefore, the sensitivity of these receptors is considered to be low.

339. All other shellfish VERs are distributed widely throughout the southern North Sea and are not of high value to fisheries in the region. As a result of this, all other VERs are considered to be of low sensitivity to impacts from long-term habitat loss.

Significance of effect

340. Long-term habitat loss will represent a long-term and continuous impact throughout the lifetime of the project. However only a relatively small proportion of the fish and shellfish habitats are likely to be affected in the context of wider habitats in the area. Most receptors are predicted to have some tolerance to this impact. Overall, the magnitude of the impact has been assessed as low for all species. The sensitivity of sandeel and herring is assessed as medium, with all other species having lower sensitivities. The significance of the effect is therefore considered to be of **negligible** to **minor (adverse)**, which is not significant in EIA terms.

Impact 8: Increased hard substrate and structural complexity, as a result of the introduction of turbine foundations, scour protection and cable protection

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

Magnitude of impact

342. Up to 7.9km^2 of new hard substrate is likely to be created in the Project as a result of foundation installation, scour protection and cable protection, which represents less than 1.1% of the total seabed areas within the Order Limits. The potential impact is predicted to be of local spatial extent, and of long-term duration, continuous and irreversible (during the lifetime of the Project).

343. Whilst the creation and recreation of biogenic reef if required, would be a change in habitat from a sediment habitat to a hard substrate habitat, similar to that from the deployment of scour or cable protection, the biogenic reef could provide a naturally occurring habitat that may have both negative and positive impacts depending on the receptor species. For sandeel, the creation of the reef would result in loss of habitat, although noting that the reef is not proposed for the sandbanks, which represent the prime habitat. Therefore, any impact will likely be to less preferable habitat; any loss of habitat will be very small scale. Countering this, the reef would increase the habitat heterogeneity and availability of niche space, providing additional habitat for other fish species and particularly shellfish species, such as brown crab.

344. It is predicted that the impact has the potential to affect fish and shellfish receptors both directly and indirectly, and therefore the magnitude of effect is considered to be low due to the potentially limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.

Sensitivity of the receptor

345. Sandeel preferred habitats and spawning areas are typically dominated by coarse sediments and sandy habitats. The array area and offshore ECC are located in preferred sandeel habitat and spawning grounds (see Volume 2, Figure 10.18). Due to specific habitat requirements of sandeel, their broad spatial distributions across the southern North Sea and their ecological value as key prey species, they are considered to be of high vulnerability to permanent changes in the substrate, with no ability for recovery, and of regional importance. As a result of this, sandeel are of medium sensitivity to this impact.

346. Herring are also demersal spawners, reliant upon the presence of suitable substrates for spawning (i.e., gravelly sediments). Herring spawning habitats are widely distributed across the southern North Sea. The overlap of the Project with historic herring spawning grounds is small compared to the overall extent of the Banks herring spawning ground across the southern North Sea (overlap of the Project of approximately 0.5% of the Banks herring spawning grounds (Coull *et al.,* 1998). It should be noted however, that as stated in paragraph 38, the Coull et al. (1998) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2009-2021) provide an indication of the areas of seabed in active use for spawning. As evidenced by annual IHLS data (ICES, 2009/2010-2022/2023) the main spawning of Banks herring stock consistently occurs to the north of the Project, off Flamborough Head, and outside of the range of any localised impacts from increased hard substrate and structural complexity. Herring is deemed to be of medium vulnerability to temporary habitat loss, and of regional importance within the southern North Sea, and therefore are considered to be of medium sensitivity.

347. Pelagic spawners (cod, plaice, whiting, lemon sole, mackerel, sole, sprat) with spawning grounds overlapping the project are widespread across the southern North Sea and do no display substrate dependency (unlike herring and sandeel). These VERs are therefore considered to be of low vulnerability and medium recoverability and so are assessed as being of low sensitivity.

348. There is the potential for positive effects on crustacean species, such as brown crab and European lobster, due to expansion of their natural habitats (Linley *et al.,* 2007) and the creation of additional refuge areas. Novel habitats and new potential food sources may be created from foundations and scour protection installed in areas of sandy and coarse sediments, which could extend the habitat ranges of some shellfish species. However, the colonisation of new habitats by shellfish receptors could lead to the introduction of non-indigenous and invasive species (see Volume 1, Chapter 9: Benthic Subtidal and Intertidal Ecology (document reference 6.1.9) for detailed discussion), this may have indirect adverse effects on shellfish populations as a result of competition. However, the implementation of a Project Environmental Management Plan (PEMP), which will include a biosecurity plan, will ensure that the risk of potential introduction and spread INNS will be minimised. Taking the above into consideration, shellfish receptors are deemed to not be vulnerable to increased hard substrate and structural complexity and are considered to be of local to international (Ocean quahog are afforded protected under the OSPAR list of threatened or declining species list) importance to the area. Shellfish are therefore considered to be of low sensitivity to this impact.

349. Mobile VERs (without spawning grounds within the vicinity of the project) are widespread across the southern North Sea and do no display substrate dependency behaviours (unlike herring and sandeel). These VERs are therefore considered to be of low vulnerability and medium recoverability and so are assessed as being of low sensitivity.

Significance of effect

350. There is some uncertainty associated with the likely effects of introduction of hard substrates into the marine environment on fish and shellfish receptors. Fish populations are unlikely to show noticeable benefits as a result of this impact, though there is evidence that shellfish populations (particularly brown crab and European lobster) would benefit from the introduction of hard substrates (Roach and Cohen, 2022; Hooper and Austen, 2014; Krone *et al.*, 2013). Demersal spawners, herring and sandeel, are considered to have increased sensitivity to the introduction of hard substrate, due to their specific habitat requirements.

351. The magnitude of the impact on all receptors has been assessed as low. Herring and sandeel, having specific requirements for spawning habitats, are considered to be of medium sensitivity, with all other fish and shellfish species considered to be of low sensitivity. The significance of the effect is therefore considered to be **minor (adverse)** for all receptors, which is not significant in EIA terms.

Impact 9: Direct disturbance resulting from O&M activities

352. Direct disturbance is likely to occur during the operational phase of the project as a result of major repairs within the array (including jack-up operations, cable repairs/replacements, and repairs to OSSs and accommodation platforms), along the cable corridor (cable reburial, protection replacement and cable repairs/replacements).

Magnitude of impact

353. The maximum area of disturbance to subtidal habitat will arise from cable repair and/or replacement during the operation and maintenance phase of the development (including de-burial and reburial of export, interlink and array cables). The maximum area of direct damage is presented in Table 10.7, and equates to approximately 0.7% of the total seabed areas within the ES Boundary over the operational lifetime of the project. Given that the habitats are common and widespread throughout the region impacts from the individual O&M activities will represent a very small footprint compared to their overall extent.

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

355. Due to the predicted local spatial extent, short-term duration and intermittent and reversible nature of the impact, the magnitude of the impact will be low.

Sensitivity of the receptor

356. The maximum sensitivity of fish and shellfish receptors to direct damage and disturbance has been assessed as medium (see Impact 4, paragraphs 294 to 301).

Significance of effect

357. The impact of direct damage and disturbance on fish and shellfish receptors is considered to be of low magnitude, and the maximum sensitivity of the receptors is considered to be medium. The significance of the effect is therefore concluded to be **minor (adverse)**, which is not significant in EIA terms.

Impact 10: EMF effects arising from cables

358. EMFs are produced as a result of the electricity passing through the cables (inter-array and export cables). EMFs will result from operation of up to 380km of inter-array cable, up to 125km of interlink cables and 440km of export cable. Three different EMF types can be generated by offshore wind cables: electric fields (E fields); magnetic fields (B fields); and induced electric fields (iE fields). Industry standard offshore wind cables all contain shielding which prevents E fields from passing into the marine environment and as such, these are not considered any further.

359. Cable shielding does not however significantly alter or prevent the emission of B fields. It is the movement of the B fields within a medium (i.e., seawater) which generates iE fields. These iE fields can be produced by the movement of the alternating B field (in the case of alternating current (AC) transmission) through the seawater. transmission). It should be noted that offshore wind AC cables emit weak fields which are mostly undetectable by fish and shellfish communities (Tricas and Gill, 2011).

Magnitude of impact

360. Many fish and shellfish species are thought to be able to sense electric and magnetic fields, with some species having developed specialised organs to facilitate this. The most well-known example of these is the Ampullae of Lorenzini in elasmobranchs, with this group of animals using electroreceptors to find prey. iE fields may cause either attraction or repulsion, with varying strength fields having been demonstrated to cause both reactions (Gill and Taylor, 2001; Yano *et al.*, 2000; Kimber *et al.*, 2011; Kalmijn, 1982). The threshold for the change between attraction and avoidance of E fields in elasmobranchs is considered to be between 400-1,000µV/m (reviewed in CMACS, 2012) and these levels would only likely be found at or within 1–2m of the seabed for a cable buried at 1m. For deeper burial, the iE field at the seabed would be correspondingly lower.

361. In a review by Tricas and Gill (2011) it was noted that the sensitivity of elasmobranchs to E fields was highest at frequencies of 1-10Hz, with a broader response frequency range of 0.01-25Hz where fields intensities of 10x or greater were required to elicit a reaction. This suggests that weak fields such as those generated by offshore wind AC cables are likely to be mostly undetectable.

362. Some fish species are known to have magneto-receptors, with this thought to primarily be for the purposes of navigation (Walker *et al.,* 2007). However, most of the research to date on magneto-reception in fish has been undertaken in migratory species such as Salmonidae, Anguillidae and Scombridae, with information on other species being limited (reviewed in Tricas and Gill, 2011). There have been suggestions (Gill and Kimber, 2005) that the presence of magnetic fields generated by cables may interrupt navigation and consequently migration.

363. EMFs monitored around subsea electricity cables have been shown to attenuate exponentially vertically and horizontally away from the cables, with the magnetic field generated by the cables typically having reached zero within 10m of the cable (reviewed by Tricas and Gill, 2011). Burial of the cables and protection with cable protection where shallow buried or surface laid will not reduce the strength of the fields, however, it moves the cables further from the receptors, and as such the receptors will be subject to reduced field strengths.

364. The impact is predicted to be highly localised, long-term duration, continuous and irreversible (within the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore considered to be low.

Sensitivity of the receptor

365. Many marine invertebrates are thought to be magneto-sensitive, with this often being used for navigational purposes (migration etc.). However, evidence for potential impacts from anthropogenic B fields is limited and can be contradictory even within the same species. Studies on the green shore crab *Carcinus maenas* have been directly contradictory, with one study demonstrating reduced aggression in response to AC B fields matching those from an offshore windfarm (Everitt, 2008), however, another study showed no effects from static B fields (Bochert and Zettler, 2004). Brown shrimp were recorded as being attracted to B fields of the magnitude expected from offshore wind cabling (ICES, 2003). One recent study (Hutchinson *et al.*, 2020) has suggested potential changes to exploratory behaviour in American lobster *Homarus americanus* in response to DC B fields when in tanks placed near a subsea cable. Recent studies have also identified both behavioural (Scott *et al.*, 2018) and physiological (Scott *et al.*, 2021) reactions in brown crab from EMF. Scott *et al.* (2018) suggests that the natural roaming behaviour, where individuals will actively seek food and/or mates has been overridden by an attraction to the source of the EMF (strength 2,800µT to 40,000µT). However, the exposure to EMF does not affect the activity levels of the crabs but affects their ability to select a site to rest. Scott *et al.* (2021) investigated the effects of EMF (strengths 250µT, 500µT and 1,000µT) from submarine power cables on edible crab, showed limited physiological and behavioural effects on the crabs exposed to EMF of 250µT. EMFs of 500µT or above showed physiological stress in crabs, and changes to behavioural trends, specifically an attraction to EMF. It is to be noted however, that these studies investigated EMF strengths significantly higher than those that receptors will typically be exposed to as a result of offshore wind cables in the marine environment. Specifically, the lowest experimental EMF used in Scott *et al.* (2021) was a factor of 10 higher than that expected for the Project, with no impacts identified at this EMF strength. Effects were only noted in these studies using EMF strengths which were a factor of 20 – 1,000 higher than those expected from the Project cables. Therefore, it is considered that it is unlikely that there would be any impacts to crustaceans from EMF. Taking the above into consideration, marine invertebrates are deemed to be of low sensitivity to impacts from EMF.

366. Elasmobranchs (sharks, skates and rays), especially demersal species, are known to be the most electro-receptive of all fish. A study commissioned by the MMO (2014) found no evidence to suggest that EMF posed a significant risk to elasmobranchs at the site or population level. A recent study by Hutchison *et al.* (2020) observed an increase in exploratory/foraging behaviour in little skate *Leucoraja erinacea* in response to EMF. Taking this into consideration, elasmobranchs are deemed to be of low sensitivity to impacts from EMF.

367. Studies on European eel have shown some deviation from migratory routes in response to low (5μT) DC B fields, however, the effects were short-term and short scale and not thought to impact on overall migration (Westerberg, 2000; Ohman *et al.*, 2007). Interestingly, no effects were seen in European eel from AC fields of 9.6μT (Orpwood *et al.*, 2015), suggesting that there may be differences in effects between DC and AC cabling. A review of potential effects of EMF on migratory fish for Scottish Natural Heritage (Gill and Bartlett, 2010) identified that there was insufficient evidence to be able to confirm whether any impacts would arise from the field strengths generated by offshore windfarm cabling. Taking this into consideration, it is considered unlikely that EMF will impact any migratory behaviours, and therefore migratory species are deemed to be of low sensitivity to impacts from EMF.

368. A broad scale study of fish aggregations and directional movement around cable at Nysted offshore windfarm in Denmark, showed no evidence of any change in directionality or distribution of species as a result of the cable installation (Hvidt *et al.*, 2004). Taking this into consideration, all other fish VERs are deemed to be of low sensitivity to impacts from EMF.

Significance of effect

369. The power cables used for the project will produce both magnetic and induced electric fields in the surrounding water sediment and water column. The EMFs created will rapidly attenuate away from the cables and are unlikely to be at strengths which would result in any impacts to fish and shellfish. Overall, it is predicted that the sensitivity of fish and shellfish receptors to EMF from the project is considered to be low and the magnitude is deemed to be low. The significance of the effect is therefore considered to be **minor (adverse)**, which is not significant in EIA terms.

10.6.3 Decommissioning

Impact 11: Mortality, injury and behavioural changes resulting from underwater noise arising from decommissioning activity

370. Decommissioning of offshore infrastructure for the Project may result in temporarily elevated underwater noise levels which may have effects on fish and shellfish species, with subsequent effects on spawning and nursery habitats. These elevated noise levels may be due to increased vessel movements and removal of the turbine foundations with the resulting noise levels dependant on the method used for removal of the foundation. The decommissioning sequence will generally be the reverse of the construction sequence and involve similar types and numbers of vessels and equipment. The maximum levels of underwater noise during decommissioning would be from underwater cutting required to remove structures, with piled foundations cut approximately 1m below the seabed. The noise levels from this process are expected to be much less than pile driving and therefore impacts would be less than as assessed during the construction phase.

371. 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 vessels. The impact is predicted to be of highly local spatial extent, short-term duration, intermittent and reversible. Based on the information available at the time of writing, and due to the localised spatial extent, the expected magnitude is considered to be negligible for all receptors. The sensitivity of all receptors to underwater noise is a maximum of medium. Therefore, the significance of the effect is considered to be a maximum of **minor (adverse)**, which is not significant in EIA terms.

Impact 12: Temporary increase in SSC and sediment deposition

372. Increases in SSC and sediment deposition from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to increased SSC and sediment deposition are described in detail under Impact 2.

373. Overall, the magnitude of the impact has been assessed as minor adverse, with the maximum sensitivity of receptors assessed as medium. Therefore, the significance of effect from changes in SSC and associated sediment deposition occurring as a result of decommissioning activities is considered to be **minor (adverse)** for all receptors, which is not significant in EIA terms.

Impact 13: Temporary seabed habitat loss/disturbance

374. Temporary habitat loss and disturbance from the decommissioning works will be similar to that for construction and are of similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to temporary habitat loss and disturbance are described in detail under 3.

375. The magnitude of the impact was determined to be low, with the maximum sensitivity of the receptors being medium. Therefore, the significance of the effect of temporary seabed habitat loss/disturbance occurring as a result of decommissioning activities is a maximum of **minor (adverse)**, which is not significant in EIA terms.

Impact 14: Direct and indirect seabed disturbances leading to the release of sediment contaminants

376. Direct and indirect seabed disturbances leading to release of sediment contaminants from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to the impact are detailed under Impact 4.

377. To summarise, the resuspension of contaminants as a result of sediment disturbance is predicted to occur on a small scale, with contaminants predicted to be rapidly dispersed by the tide. Overall, the magnitude of the impact is deemed to be negligible, and the maximum sensitivity of receptors is considered to be medium. The significance of the effect is therefore considered to be a maximum of **minor (adverse)**, which is not significant in EIA terms.

Impact 15: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish species

378. Direct damage and disturbance from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact and the sensitivities of fish and shellfish to the impact are detailed under Impact 5.

379. The magnitude of the impact has been assessed as low for sandeel (due to the small area affected relative to the wider spawning habitat). The maximum sensitivity of receptors is considered to be medium, and the magnitude of impact has been assessed as negligible. The significance of the effect is therefore considered to be a maximum of **minor (adverse),** which is not significant in EIA terms.

Impact 16: Loss of additional habitat arising from the removal of infrastructure that have been used by fish and shellfish communities during the operational phase of the project

380. The loss of additional habitat from the removal of infrastructure during the decommissioning works will be similar to the habitat loss detailed in Impact 7 during the operational phase of the project, and will be of a similar magnitude. Nonetheless, it is important to note that the impacts of removal of foundations on any fish or shellfish that have created a habitat on those structures would be unique to the decommissioning phase. Additionally, to date no UK windfarm projects have been decommissioned and therefore the full extent of impacts associated with decommissioning remain unseen. However, it can be said with confidence that the magnitude of the impact and the sensitivities of fish and shellfish will be analogous to the impacts which are detailed under Impact 7 (Long term habitat loss due to foundations, scour protection and cable protection).

381. To summarise, the loss of additional habitat from the removal of infrastructure in the decommissioning phase will represent a spatially discrete impact, affecting a small proportion of the fish and shellfish habitats within the study area.

382. The impact of loss of additional habitat on fish and shellfish receptors is considered to be of low magnitude, and the maximum sensitivity of the receptor is considered to be medium. The significance of the effect is therefore concluded to be **minor (adverse)**, which is not significant in EIA terms.

10.7 Cumulative Effects Assessment

383. This cumulative impact assessment for fish and shellfish ecology has been undertaken in accordance with the methodology provided in Volume 3, Appendix 5.1: Offshore Cumulative Effects Assessment (document reference 6.3.5.1).

384. The projects and plans selected as relevant to the assessment of impacts to fish and shellfish ecology are based upon an initial screening exercise undertaken on a long list. Each project, plan or activity has been considered and scoped in or out on the basis of effect–receptor pathway, data confidence and the temporal and spatial scales involved. For the purposes of assessing the impact of the Project on fish and shellfish ecology in the region, the cumulative effect assessment technical note submitted through the EIA Evidence Plan and forming Appendix 5.1 (document reference 6.3.5.1) of this ES screened in a number of projects and plans as presented in Table 10.23.

385. For potential effects on fish and shellfish, planned projects were screened into the assessment based on a screening range that encapsulates the project fish and shellfish study area as defined by the secondary ZoI, which has been defined based on the expected maximum distance that sediment within the Project might be transported on a single mean spring tide, in the flood and/or ebb direction. An additional screening range of 100km has also been applied around the array area to encapsulate potential cumulative impacts from underwater noise. This screening area therefore encompasses the extent of impacts to fish and shellfish ecology associated with the project.

386. The operational projects included within Table 10.23 are included due to their completion/commissioning occurring subsequent to the data collection process for the Project, and as such are not included within the baseline characterisation. Note that this table only includes the projects screened into the assessment for fish and shellfish ecology.

Table 10.23 Projects considered within the fish and shellfish ecology cumulative assessment.

Development type	Project	Status	Data confidence assessment/phase	Tier	Reason for inclusion in CEA
Offshore Windfarm	Scroby Sands	Active/In Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Potential cumulative impact exists. Temporal overlap with the Project construction during Scroby Sands decommissioning.
	Norfolk Boreas	Consented	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Potential cumulative impact exists. Temporal overlap with construction.
	Sheringham Shoal Extension	Determination	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Potential cumulative impact exists. Temporal overlap with construction.
	Dudgeon Extension	Determination	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Potential cumulative impact exists. Temporal overlap with construction.
	Dudgeon	Active/In Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Part of the baseline but has ongoing impact and is therefore considered relevant to the CIA.
	Lincs	Active/In Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Part of the baseline but has ongoing impact and is therefore considered relevant to the CIA.
	Race Bank	Active/In Operation	High - Third party project details published in the public domain and	Tier 1	Part of the baseline but has ongoing impact and is

Development type	Project	Status	Data confidence assessment/phase	Tier	Reason for inclusion in CEA
			confirmed as being 'accurate' by The Crown Estate.		therefore considered relevant to the CIA.
	Inner Dowsing	Active/In Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Part of the baseline but has ongoing impact and is therefore considered relevant to the CIA.
	Triton Knoll	Active/In Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Part of the baseline but has ongoing impact and is therefore considered relevant to the CIA.
	Hornsea Project Three	Consented	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Potential cumulative impact exists. Temporal overlap with construction.
	Hornsea Project Four	Consented	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 1	Potential cumulative impact exists. Temporal overlap with construction.
	Dogger Bank South (East)	In Planning	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 2	Potential cumulative impact exists. Temporal overlap with construction.
	Dogger Banks South (West)	In Planning	High - Third party project details published in the public domain and confirmed as being 'accurate' by The Crown Estate.	Tier 2	Potential cumulative impact exists. Temporal overlap with construction.
	Dogger Bank D	In Planning			
	Lynn	Active/In Operation	High - Third party project details published in the public domain and	Tier 1	Part of the baseline but has ongoing impact and is

Development type	Project	Status	Data confidence assessment/phase	Tier	Reason for inclusion in CEA
			confirmed as being 'accurate' by The Crown Estate.		therefore considered relevant to the CIA.
Aggregate Production Area	Westminster Gravels Ltd (515/2)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Westminster Gravels Ltd (515/1)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Hanson Aggregates Marine Ltd (106/2)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Hanson Aggregates Marine Ltd (106/3)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Hanson Aggregates Marine Ltd (106/1)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Hanson Aggregates Marine Ltd (400)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Tarmac Marine Ltd (197)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.

Development type	Project	Status	Data confidence assessment/phase	Tier	Reason for inclusion in CEA
	Tarmac Marine Ltd (493)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1	Potential ongoing cumulative impact exists.
	Inner Dowsing Tarmac Marine Ltd (481/1)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	Tier 1	Potential ongoing cumulative impact exists.
	Inner Dowsing Tarmac Marine Ltd (481/2)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	Tier 1	Potential ongoing cumulative impact exists.
	Inner Dowsing Hanson Aggregates Marine Ltd (1805)	Operational (Exploration and Option Area, application for Extraction expected shortly)	Low – no information available	Tier 3	Potential ongoing cumulative impact exists.
	Aggregate Tender Area (2103)	Tender Area (2021/2022)	Low – no information available	Tier 3	Potential ongoing cumulative impact exists.
Pipelines	Gas Shearwater to Bacton Seal Line (Shell)	Operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	Tier 1	Potential ongoing cumulative impact exists.
Subsea Cable	Viking Link Interconnector	Complete/in operation	High - Third party project details published in the public domain and confirmed as being 'accurate' by the Crown Estate	Tier 1	Potential ongoing cumulative impact exists.

388. Certain impacts assessed for the Project alone are not considered in the cumulative assessment due to:

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

389. The impacts that have been considered in the CIA are as follows:

- Construction phase:
- Cumulative mortality, injury and behavioural changes resulting from underwater noise; and
- Cumulative increase in SSC and sediment deposition.

390. The cumulative MDS described in Table 10.24 have been selected as those having the potential to result in the greatest cumulative effect on an identified receptor group. The cumulative impacts presented and assessed in this section have been selected from the details provided in the project description for the Project, as well as the information available on other projects and plans in order to inform a cumulative MDS. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project design envelope to that assessed here, be taken forward in the final design scheme.

Table 10.24 Cumulative MDS.

Potential effect	Scenario	Justification
Cumulative mortality, injury and behavioural changes resulting from underwater noise	▪ Tier 1: ▪ Decommissioning of Scroby Sands Offshore Wind Farm (OWF) ▪ Construction of Norfolk Boreas OWF ▪ Construction of Hornsea Project Three OWF ▪ Construction of Hornsea Project Four OWF ▪ Construction of Sheringham Shoal Extension OWF ▪ Construction of Dudgeon Extension OWF ▪ Tier 2: ▪ Construction of Dogger Bank South (East) ▪ Construction of Dogger Bank South (West)	If these intermittent activities overlap temporally with either the construction or maintenance of the Project, there is potential for cumulative effects from underwater noise to occur which may impact fish and shellfish populations.

Potential effect	Scenario	Justification
	▪ Tier 3: No Tier 3 projects identified	
Cumulative increase in Suspended Sediment Concentration (SSC) and sediment deposition	▪ Tier 1: ▪ Operation and Maintenance (O&M) of OWF (Dudgeon, Lincs, Lynn, Race Bank, Inner Dowsing, Triton Knoll) ▪ Construction and O&M of Sheringham Shoal Extension ▪ Construction and O&M of Dudgeon Extension ▪ Operation of aggregate production areas including Westminster Gravels Ltd (515/1, 515/2), Hanson Aggregates Marine Ltd (106/1, 106/2, 106/3, 400), Tarmac Marine Ltd (197, 493), Inner Dowsing Tarmac Marine Ltd (481/1) and Inner Dowsing Tarmac Marine Ltd (481/2) ▪ Operation of Viking Link Interconnector cable ▪ Operation of Gas Shearwater to Bacton Seal Line ▪ Tier 2: No Tier 2 projects identified ▪ Tier 3: ▪ Aggregate Area 1805 (Inner Dowsing Hanson Aggregates Marine Ltd). ▪ Aggregate Tender Area 2103.	If these intermittent activities overlap temporally with either the construction or maintenance of the Project, there is potential for cumulative SSC and sediment deposition to occur within the modelled plume footprints.

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

Impact 17: Cumulative mortality, injury and behavioural changes resulting from underwater noise

392. There is potential for cumulative mortality, injury and behavioural changes from noise and vibration as a result of construction and decommissioning activities associated with the Project and other projects. For the purposes of this assessment, this additive impact has been assessed within 100km of the Project, which is considered a precautionary buffer upon which to screen in/out projects within the area.

393. The greatest risk of cumulative impacts of underwater noise on fish and shellfish has been identified as being that produced by impact piling during the construction phase of other offshore windfarm sites within 100km of the Project, including the decommissioning of Scroby Sands and construction of Norfolk Boreas, Hornsea Projects Three and Four, and Sheringham Shoal and Dudgeon Extensions.

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

10.8.12 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 the Project. For the Project, the temporal MDS for piling duration is for the sequential installation of jacket foundations in the array area, the ORCPs and the ANSs.

Table 10.25: Cumulative piling durations for the Project and other offshore wind farms within a representative 100 km buffer of the Project (where construction or decommissioning occurs concurrently).

Project	Maximum total active piling time	Source
Tier 1 Offshore Wind Farms (OWFs)		
The Project	3,792 hours (158 days)	Volume 1, Chapter 3: Project Description (document reference 6.1.3)
Scroby Sands	152 hours (6.3 days)	Total duration taken from Environmental Statement (ES) (PowerGen Renewables Offshore Ltd, 2001) for the piling of all infrastructure assuming four hours per pile (construction duration used as proxy for decommissioning)
Norfolk Boreas	1,167 hours (48.6 days)	Total duration taken from ES (Vattenfall, 2019) for the piling of all infrastructure assuming 1.5 hours per pile.
Hornsea Project Three	7,392 hours (308 days)	Total duration taken from ES (Ørsted, 2018) for the piling of all infrastructure assuming four hours per pile.
Hornsea Project Four	3,312 hours (138 days)	Total duration taken from ES (Ørsted, 2021) for the piling of all infrastructure assuming four hours per pile.
Sheringham Shoal Extension	300 hours (12.5 days)	Total duration taken from ES (Equinor, 2022) for the piling of all infrastructure assuming three hours per pile.

Project	Maximum total active piling time	Source
Dudgeon Extension	384 hours (15 days)	Total duration taken from ES (Equinor, 2022) for the piling of all infrastructure assuming three hours per pile.
Dogger Bank South (East)	3,792 hours (158 days)	Volume 1, Chapter 3: Project Description (document reference 6.1.3) (as proxy for Dogger Bank South (East))
Digger Bank South (West)	3,792 hours (158 days)	Volume 1, Chapter 3: Project Description (document reference 6.1.3) (as proxy for Dogger Bank South (West))
Total duration	24,083 hours (1,003.5 days)	

395. The following paragraphs describe the spatial extent of potential behavioural effects on fish and shellfish species. Each of the impact assessments consider the MDS for hammer energy and/or the largest pile diameter and therefore result in the greatest propagation ranges. It should be noted, however, that the specific assessments used in the individual projects below may have used behavioural response criteria which differ from the approach used for the current Project and from the other projects in the cumulative assessment.

396. The project specific assessments were undertaken using the best scientific evidence available at the time that the assessments were drafted. However, more recent papers on the effects of underwater noise on fish and shellfish species have highlighted the lack of clear evidence to support setting thresholds for impacts on fish and shellfish receptors (Hawkins and Popper, 2016; Popper *et al.,* 2014). These papers have highlighted some of the shortcomings of historic impact assessments, including the use of broad criteria for injury and behavioural effects based on limited studies. As such, it is not appropriate to make direct comparisons between the behavioural response ranges across projects. However, the following paragraphs do give an indication of the extents of behavioural responses from fish and shellfish to support this cumulative assessment.

397. The Scroby Sands OWF ES assessed the MDS for noise impacts from piling activities and concluded no detrimental effects on fish receptors from all phases of the project (PowerGen Renewables Offshore Ltd, 2001).

398. The Norfolk Boreas OWF ES (Vattenfall, 2019) assessed MDS for noise impacts from the installation of monopiles using the maximum hammer energy (5,000kJ). This assessment assumed a maximum of 90 WTGs on monopile foundations across the site and predicted behavioural effects up to 6.5km from the piling locations. The assessment predicted no significant effects on all fish and shellfish receptors.

399. The Hornsea Project Three OWF (Ørsted, 2018) assessed MDS for noise impacts from the installation of monopiles using the maximum hammer energy (5,000kJ). This assessment assumed a maximum of 319 monopiles across the site and predicted behavioural effects up to 10.8km from the piling locations. The assessment predicted no significant effects on all fish and shellfish receptors during the construction phase of the development.

400. The Hornsea Project Four OWF (Ørsted, 2021) assessed MDS for noise impacts from the installation of monopiles using the maximum hammer energy (5,000kJ). This assessment assumed a maximum of 180 monopile WTG foundations and predicted TTS up to 38km from the piling locations. A qualitative assessment using the Popper *et al.* (2014) behavioural criteria was undertaken to determine the potential for behavioural effects on fish and shellfish receptors from underwater noise. The assessment predicted no significant effects on all fish and shellfish receptors.

401. The Sheringham Shoal and Dudgeon OWF Extension projects (Equinor, 2022) assessed MDS for noise impacts from the installation of monopiles using the maximum hammer energy (5,500kJ). This assessment assumed a maximum of 30 and 23 monopiles for Sheringham Shoal and Dudgeon Extension, respectively, with predicted behavioural effects up to 34km and 39km from the piling locations. The assessment predicted no significant effects on all fish and shellfish receptors.

402. There is currently limited detail on the Dogger Bank South (East) and the Dogger Bank South (West) OWFs, therefore it is not possible to undertake detailed assessments of the significance of effect. However, given the intermittent nature of piling, it is unlikely that there will be a temporal overlap resulting in significant effects on fish and shellfish receptors.

403. The cumulative impact of underwater noise on fish and shellfish is predicted to be of regional spatial extent, medium term duration (i.e., cumulatively over approximately six years (2026-2031)), intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be **low.**

404. Sensitivities of fish and shellfish receptors to underwater noise are fully detailed in Section 10.6, Impact 1. Fish mortality and potential mortal 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 eggs and larvae would be expected is similarly small. . Effects on shellfish species are also predicted to be limited as these species are less sensitive to noise than fish species and would only be affected at ranges much less than those predicted for fish.

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

406. The proportions of fish spawning and nursery habitats predicted to be affected by underwater noise from piling operations are expected to be small, particularly in the context of available spawning and nursery habitats within the southern North Sea (particularly for pelagic spawning species). The maximum sensitivity of fish receptors to underwater noise is considered to be medium.

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

408. The impact of cumulative mortality, injury and behavioural changes arising from noise and vibration is considered to be of low magnitude and the maximum sensitivity of receptors affected is considered to be medium for fish and shellfish species. The significance of the residual effect is therefore concluded to be **minor (adverse)**, which is significant in EIA terms.

Impact 18: Cumulative temporary increases in SSC and sediment deposition

409. Due to uncertainty associated with the exact timing of other projects and activities, there is insufficient data on which to undertake a quantitative or semi-quantitative assessment. As such, the discussion presented here is qualitative. It is considered highly unlikely that each of the identified projects would be undertaking major maintenance works, in particular asset reburial or repairs, as these are infrequent occurrences during the lifetime of developments.

410. Sediment plumes from operational and maintenance activities are generally short-lived, with major maintenance works infrequent. Any impacts from operational offshore wind farm export cables, pipelines, and oil and gas activities are therefore likely to be short-lived and of localised extent, with limited opportunity to overlap with Project-related activities. The Viking Link Interlink subsea cable and the Gas Shearwater to Bacton Seal Line pipeline are both currently operational, therefore maintenance-related impacts are similarly considered to be primarily short-lived and localised. Accordingly, the potential for cumulative interaction with these sites is limited and therefore has not been assessed further.

411. Aggregate Area 515/2 ('Outer Dowsing') is located approximately 1.1km from the Project array area, and 0km from the offshore ECC, as shown in Volume 2, Figure 10.41. In addition, Area 481/1 ('Inner Dowsing') is located 1.3km south of the offshore ECC, and Areas 5.15/1, 106/3, and 400 are located between 2.5km and 3km north of the offshore ECC. In addition, the Exploration and Option Area 1805 ('Inner Dowsing') overlaps with the offshore ECC, as shown in Volume 2, Figure 10.41, and an application is expected shortly for a production licence. Area 2103, also overlapping the offshore ECC (see Volume 2, Figure 10.41) has been selected by The Crown Estate (TCE) within the 2021/22 marine aggregates tender round and is subject to the outcome of a plan-level HRA. Due to uncertainty associated with the timing, possible extent, or license outcome of Tender Area 2103, this area has not been assessed further.

412. On the basis of sediment plume modelling presented in Part 6, Volume 1, Chapter 7: Marine Physical Processes (document reference 6.1.7), it can reasonably be assumed that sediment plumes may be advected this distance from the Project infrastructure. This means that in theory, should Project construction related activities be occurring at the same time as aggregate extraction, there could be the potential for cumulative changes in SSC and bed levels. According to figures provided by British Marine Aggregate Producers Association (BMAPA) for the last five years, dredging intensity within these Areas located within the Humber Region primarily ranges from low (<15 minutes) to medium (15 minutes to 75 minutes), with only a small proportion dredged at a high intensity (>75 minutes).

413. As detailed by the numerical modelling within Part 6, Volume 1, Chapter 7: Marine Physical Processes (document reference 6.1.3) the levels of sediment dispersion are high, however almost all sediment plumes are indistinguishable from background levels after 20 hours. Given the short-lived nature of the sediment plumes, and the location of other infrastructure (Volume 2, Figure 10.41), there is not anticipated to be a notable overlap with concentrated sediment plumes created from other industry activities. Any overlap expected with aggregate dredging activities is likely to be temporary and restricted to the near field, with the magnitude of this change being assessed as low.

414. Full discussion of the sensitivity of fish and shellfish ecology receptors to increased SSC and sediment deposition is discussed under Impact 2, in Section 10.6, which conclude that the habitats that have the potential to be indirectly affected by increased SSC and deposition within the benthic subtidal and intertidal ecology study area have a worst-case medium sensitivity to the expected levels of SSC and deposition.

415. The impact of cumulative temporary increases in SSC and deposition is considered to be of low adverse magnitude, and the maximum sensitivity of receptors affected is considered to be medium for fish and shellfish species. The significance of the residual effect is therefore concluded to be minor adverse, which is not significant in EIA terms.

10.8 Inter-Relationships

10.8.1 Interactions

416. An assessment of whether the impacts identified and assessed in this chapter have the potential to interact with each other

417. Inter-related effects consider impacts from the construction, operation or decommissioning of the Project on the same receptor (or group).

418. Such inter-related effects include both:

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

419. A description of the process to identify and assess these effects is presented in Chapter 5 (document reference 6.1.5), with a summary of assessed inter-relationships provided in Table 10.26 below.

Table 10.26 Summary of assessed inter-relationships

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
Project-lifetime effects			
Construction, O&M and decommissioning	Disturbance from underwater noise	Impacts were assessed as being **Not Significant** in the construction, O&M and decommissioning phases.	The impacts of underwater noise during the construction and decommissioning phases are expected to be short-term and intermittent. Impacts from underwater noise during the operational phase will be long term but of a very localised extent. The interaction of these impacts across construction, O&M and decommissioning stages of the development is not predicted to result in an effect of any greater significance than those assessed in the individual project phases.
Construction and decommissioning	Increase in SSC and sediment deposition	Impacts were assessed as being **Not Significant** in the construction and decommissioning phases.	The impacts of increased SSC and sediment deposition during the construction and decommissioning phases are expected to be short-term and intermittent, and of localised extent with any effects being reversible. The interaction of these impacts across construction and decommissioning stages of the development is not predicted to result in an effect of any greater significance than those assessed in the individual project phases.
Construction, O&M and decommissioning	Habitat loss and disturbance, and increased SSC and deposition	Impacts were assessed as being **Not Significant** in the construction and decommissioning phases.	The impacts of habitat loss and disturbance and increased SSC and deposition during the construction, O&M and decommissioning phases are expected to be short-term and intermittent, and of localised extent. The interaction of these impacts across construction, O&M and decommissioning stages of the development is not predicted to result in an effect of any greater significance

Project phase(s)	Nature of inter-related effect	Assessment alone	Inter-related effects assessment
			than those assessed in the individual project phases.
Receptor led effects			
No spatial or temporal interaction between the effects assessed above is expected during the project lifetime.			

420. Overall, no inter-relationships have been identified where an accumulation of residual impacts on fish and shellfish receptors and the relationship between those impacts gives rise to a need for additional mitigation beyond the embedded mitigation already considered.

10.9 Transboundary Effects

421. Transboundary effects are defined as those effects upon the receiving environment of other European Economic Area (EEA) states, whether occurring from the Project alone, or cumulatively with other projects in the wider area. A screening of potential transboundary effects was undertaken at Scoping which identified that there was the potential for transboundary effects to occur on Annex II migratory fish species listed as features of European sites in other EEA States.

422. Potential transboundary effects that could arise include direct impacts as a result of underwater noise from piling operations during the installation of subsea infrastructure. Indirect impacts may occur from increased SSC and deposition from the placement/removal of foundations and cables in or on the seabed.

423. Underwater noise levels expected to elicit behavioural responses in certain migratory fish receptors, are predicted to extend up to 1,000s of metres several 10s of kilometres beyond the Project (for Group 3 migratory species, European eel, twaite shad and allis shad) and therefore have the potential to affect migratory fish species of the Netherlands, an EEA state (94km from the Project) during the construction period. These impacts were predicted to be short term and intermittent, with recovery of fish populations to affected areas following completion of all piling activities. Overall, the sensitivity of migratory fish receptors to this impact were assessed as low and the magnitude predicted to be low. The low magnitude, and maximum sensitivity of low results in a **minor significance** of effect, which is not significant in EIA terms.

424. Effects of increases in SSC are predicted to occur up to 15km from the Project and are therefore not predicted to extend into the waters of other EEA states. Effects on migratory fish species from all impacts, including habitat loss and disturbance and increases in SSC, were predicted to be not significant in EIA terms.

10.10 Conclusions

425. This chapter has assessed the potential effects on fish and shellfish ecology receptors arising from the Project. The range of potential impacts and associated effects considered has been informed by scoping responses, as well as reference to existing policy and guidance. The impacts considered include those brought about directly (e.g., by the presence of infrastructure at the seabed), as well as indirectly (e.g., the release of sediment contaminants from seabed disturbances). Potential impacts considered in this chapter, alongside any mitigation and residual effects are listed below in Table 10.27.The impacts on relevant receptors from all stages of the project were assessed, including impacts from habitat loss, underwater noise, increased SSC and deposition and release of sediment contaminants. All impacts throughout the construction, operation, and decommissioning phases, were found to have minor effects on fish or shellfish receptors within the study area (i.e., not significant in terms of the EIA Regulations). Cumulative impacts from underwater noise and increased SSC and deposition were assessed as minor significance, which is not significant in terms of the EIA Regulations.

Table 10.27 Summary of effects for fish and shellfish.

Description of impact		Effect	Additional mitigation measures	Residual significance of effect
Construction				
Impact 1: Mortality, injury, behavioural impacts and auditory masking from underwater noise and vibration	Mortality and potential mortal injury	**Group 1:** Minor significance of effect **Group 2:** Minor significance of effect **Group 3:** Minor significance of effect Shellfish receptors: Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
	Recoverable Injury	**Group 1:** Minor significance of effect **Group 2:** Minor significance of effect **Group 3:** Minor significance of effect Shellfish receptors: Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
	TTS	**Group 1:** Minor significance of effect **Group 2:** Minor significance of effect **Group 3:** Minor significance of effect Shellfish receptors: Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects

Description of impact		Effect	Additional mitigation measures	Residual significance of effect
	Behavioural effects	**Group 1:** Minor significance of effect **Group 2:** Minor significance of effect **Group 3:** Minor significance of effect Shellfish receptors: Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 2: Temporary increase in SSC and sediment deposition		Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 3: Temporary seabed habitat loss/disturbance		Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 4: Direct and indirect seabed disturbances leading to the release of sediment contaminants.		Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 5: Direct damage (e.g. crushing) and disturbance to demersal and pelagic fish and shellfish species arising from shellfish activities		Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Operation and Maintenance				
Impact 6: Underwater noise as a result of operational turbines.		Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 7: Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection.		Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects

Description of impact	Effect	Additional mitigation measures	Residual significance of effect
Impact 8: Increased hard substrate and structural complexity, as a result of the introduction of turbine foundations, scour protection and cable protection.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 9: Direct disturbance resulting from O&M activities.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 10: EMF arising from cables.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Decommissioning			
Impact 11: Mortality, injury and behavioural changes resulting from underwater noise arising from decommissioning activity.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 12: Increase in SSC and sediment deposition.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 13: Temporary seabed habitat loss/disturbance	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 14: Direct and indirect seabed disturbances leading to the release of sediment contaminants.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 15: Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish and shellfish.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 16: Loss of additional habitat arising from the removal of infrastructure that have been used by fish and shellfish communities during the operational phase of the project.	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects

Description of impact	Effect	Additional mitigation measures	Residual significance of effect
Cumulative effects			
Impact 17: Cumulative mortality, injury, behavioural changes and auditory masking arising from noise and vibration	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects
Impact 18: Temporary increase in suspended sediment and sediment deposition	Minor significance of effect	Not Applicable – no additional mitigation identified.	No significant adverse residual effects

10.11 References

Alheit, J and Hagen E. (1997), 'Long-term climate forcing of European herring and sardine populations'. Fisheries Oceanography 6: 130-139.

Allen, J., 2003. The Humber Estuary: A comprehensive review of its nature conservation interest. English Nature.

Beggs, S.E. Cardinale, M. Gowen, R.J. & Bartolino, V. (2013), 'Linking cod (*Gadus morhua*) and climate: investigating variability in Irish Sea cod recruitment'. Fisheries Oceanography 23: 54-64.

Behrens, J.W., Stahl, H.J., Steffensen, J.F. and Glud, R.N. (2007). Oxygen dynamics around buried lesser sandeels Ammodytes tobianus (Linnaeus 1785): mode of ventilation and oxygen requirements. Journal of Experimental Biology, 210(6): 1006-1014.

Bochert R., and M. L. Zettler. "Long-term exposure of several marine benthic animals to static magnetic fields." Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association 25, no. 7 (2004): 498-502.

Boyle, G. and New, P. (2018), 'ORJIP Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options'. Final report. The Carbon Trust, 247.

Brown & May Marine Ltd. (2008a), 'Dudgeon Offshore Wind Farm Spring Pre-construction Adult and Juvenile Fish Survey'.

Brown & May Marine Ltd. (2008b), 'Dudgeon Offshore Wind Farm Autumn Pre-construction Adult and Juvenile Fish Survey'.

Brown and May Marine Ltd (2009), 'Sheringham Shoal Offshore Wind Farm Herring Spawning Survey'. Final Report.

Brown & May Marine Ltd. (2010) 'Sheringham Shoal Wind Farm Pre-cable Installation Elasmobranch Survey'. Interim Report.

Brown and May Marine Ltd (2015) Sheringham Shoal Wind Farm Post-cable Installation Elasmobranch Survey. Interim Report.

Bunn, N.A., Fox, C.J. and Webb, T. (2000). A Literature Review of Studies on Fish Egg Mortality: Implications for the Estimation of Spawning Stock Biomass by the Annual Egg Production Method. Cefas Science Series Technical Report No 111: 37.

Capuzzo, E., Lynam, C.P., Barry, J., Stephens, D., Forster, R.M., Greenwood, N., McQuatters-Gollop, A., Silva, T., van Leeuwen, S.M. and Engelhard, H.G. (2018). A Decline in Primary Production in the North Sea over 25 Years, Associated with Reductions in Zooplankton Abundance and Fish Stock Recruitment. Global Change Biology 24, 1:352–64.

Chartered Institute of Ecology and Environment Management (CIEEM) (2016), 'Guidelines for Ecological Impact Assessment in the UK and Ireland'. Terrestrial, Freshwater and Coastal. Chartered Institute of Ecology and Environmental Management. Second Edition. January 2016.

Chartered Institute of Ecology and Environment Management (CIEEM) (2018), 'Guidelines for Ecological Impact Assessment in the UK and Ireland'. Terrestrial, Freshwater and Coastal. Chartered Institute of Ecology and Environmental Management, Winchester.

Cheong, S-H., Wang, L., Lepper, P. and Robinson, S. (2020). Characterisation of Acoustic Fields Generated by UXO Removal. Phase 2. NPL REPORT AC 19.

Coull, K.A. Johnstone, R. and Rogers, S.I. (1998), 'Fisheries Sensitivity Maps in British Waters,' Published and distributed by UKOOA Ltd. Aberdeen, 63.

Dahl, P. H., Jenkins, A. K., Casper, B., Kotecki, S. E., Bowman, V., Boerger, C., Dall'Osto, D. R., Babina, M. A., and Popper, A. N. (2020). "Physical effects of sound exposure from underwater explosions on Pacific sardines (Sardinops sagax)," J. Acoust. Soc. Am. 147(4): 2383–2395.

Dare, P.J. and Edwards, D.B., 1976. Experiments on the survival, growth and yield of relaid seed mussels (Mytilus edulis L.) in the Menai Straits, North Wales. ICES Journal of Marine Science, 37(1): 16-28.

Defra (2014). East Offshore Marine Plans. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312496/east-plan.pdf [Accessed March 2023].

Defra (2021). Southeast Marine Plan. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1004493/FINAL_South_East_Marine_Plan__1_.pdf [Accessed March 2023].

Department of Energy and Climate Change (DECC) (2011a). Overarching National Policy Statement for Energy (EN-1). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarching-nps-for-energy-en1.pdf [Accessed March 2023].

Department of Energy and Climate Change (DECC) (2011b). National Policy Statement for Renewable Energy Infrastructure (EN-3). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/37048/1940-nps-renewable-energy-en3.pdf [Accessed March 2023].

Department of Energy and Climate Change (DECC) (2016). UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3) Appendix 1a.4 Fish and Shellfish.

Department for Energy Security and Net Zero (DESNZ) (2023a). Draft Overarching National Policy Statement for Energy (EN-1). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147380/NPS_EN-1.pdf [Accessed April 2023].

Department for Energy Security and Net Zero (DESNZ) (2023b). Draft National Policy Statement for Renewable Energy Infrastructure (EN-3). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147382/NPS_EN-3.pdf [Accessed April 2023].

Edwards, B., Brooker, A., Workman, R., Parvin, S. J. and Nedwell, J. R. (2007) Subsea operational noise assessment at the Barrow Offshore Wind Farm site. Subacoustech Report No. 753R0109.

Ellis, J.R., Milligan, S.P., Readdy, L., South, A., Taylor, N. and Brown, M. (2010), 'MB5301 Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones'). Report No. 1: Final Report on development of derived data layers for 40 mobile species considered to be of conservation importance.

Ellis, J.R.. Milligan, S.P. Readdy, L. Taylor, N. and Brown, M.J. (2012) Spawning and nursery grounds of selected fish species in UK waters. Cefas Scientific Series Technical Report 147.

EMODnet. (2021), 'EMODnet broad scale seabred habitat map for Europe (EUSeaMap) (2021) EUNIS 2019 habitat type'. [online]. Available at: https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/ [Accessed March 2023].

Equinor (2022) Sheringham Shoal and Dudgeon OWF Extension Projects Environmental Statement. Chapter 9 - Fish and Shellfish Ecology. PINS Document Reference: 6.1.9. APFP Regulation: 5(2)(a)

EMU (2005) Lincs Offshore Wind Farm Benthic Baseline Survey Report.

EUSeaMap, (2021) Broadscale Marine Habitats Map.

Everitt, N. (2008). Behavioural responses of the shore crab, Carcinus maenas, to magnetic fields. MSc Thesis, University of Newcastle-upon-Tyne: 94pp.

Frederiksen, M. Edwards, M. Richardson, A.J. Halliday, N.C. and Wanless, S. (2006), 'From plankton to top predators: bottom-up control of a marine food web across four trophic levels'. Journal of Animal Ecology 75: 1259-1268.

GEOxyz (2022a), 'Benthic Ecology OWF Area Results Report (Vol. 1)'. UK4855H-824-RR-01.

GEOxyz (2022b), 'Benthic Ecology ECC Area Results Report (Vol. 2)'. UK4855H-824-RR-02.

GEOxyz (2022c), 'Benthic Ecology OWF & ECC Area eDNA Report (Vol. 7). UK4855H-824-RR-07.

Gill, A. B. & Taylor, H (2001). The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes. 488. 2001b. Countryside Council for Wales Contract Science Report.

Gill, A. B. and A. A. Kimber. (2005). The potential for cooperative management of elasmobranchs and offshore renewable energy Page 250 of 256 development in UK waters. Journal of the Marine Biological Association of the United Kingdom 85:1075-1081.

Gill, A.B., and Bartlett, M. (2010). Literature Review on the Potential Effects of Electromagnetic Fields and Subsea Noise from Marine Renewable Energy Developments on Atlantic Salmon, Sea Trout and European Eel. Scottish Natural Heritage, Commissioned Report No. 401. (Sutton and Boyd, 2009).

Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Løkkeborg, S., Misund, O.A., Østensen, Ø., Fonn, M. and Haugland, E.K., 2004. Influence of seismic shooting on the lesser sandeel (Ammodytes marinus). ICES Journal of Marine Science, 61(7): 1165-1173.

Hawkins, A., Roberts, L and Cheesman, S. (2014a). Responses of free-living coastal pelagic fish to impulsive sounds. Acoustical Society of America: 3101-3116.

Hawkins, A.D. and Popper, A.N. (2016), 'A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates'. ICES Journal of Marine Science, 74/3: 635–651.

Hawkins, A.D., Pembroke, A.E. and Popper A.N. (2014b), 'Information gaps in understanding the effects of noise on fishes and invertebrates'. Reviews in Fish Biology and Fisheries, 25: 39–64.

Hazelwood, R. and Macey, P. (2016). Modeling Water Motion near Seismic Waves Propagating across a Graded Seabed, as Generated by ManMade Impacts. Journal of Marine Science and Engineering. 4. 47. 10.3390/jmse4030047.

Heath, M.R. Neat F.C. Pinnegar J.K. Reid D.G. Sims D.W. and Wright P.J. (2012), 'Review of climate change impacts on marine fish and shellfish around the UK and Ireland'. Aquatic Conservation: Marine and Freshwater Ecosystems 22: 337-367.

Hemingway K.L., Cutts N.C. and Pérez-Dominguez R., 2008. Managed Realignment in the Humber estuary, UK. Institute of Estuarine and Coastal Studies (IECS), University of Hull, UK.

Hinz, S., Coston-Guarini, J., Marnane, M., Guarini, J.-M. (2022), 'Evaluating eDNA for Use within Marine Environmental Impact Assessments'. [online]. Available at: https://mdpi-res.com/d_attachment/jmse/jmse-10-00375/article_deploy/jmse-10-00375-v2.pdf [Accessed March 2023].

HM Government. (2011), 'UK Marine Policy Statement'. [online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69322/pb3654-marine-policy-statement-110316.pdf [Accessed March 2023].

Holland, G.J., Greenstreet, S.P., Gibb, I.M., Fraser, H.M. and Robertson, M.R., (2005). Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment. Marine ecology progress series, 303: 269-282.

Hooper, T., & Austen, M. (2014). The co-location of offshore wind farms and decapod fisheries in the UK: Constraints and opportunities. Marine Policy, 43, 295.

Humber Aggregate Dredging Association (2012), 'Marine Aggregate Regional Environmental Assessment of the Humber and Outer Wash Region Volume I: Chapters 1 - 6'. http://marine-aggregate-rea.info/sites/www.marine-aggregate-rea.info/files/private/volume-i-marea-final-hada-report-10-may-2012.pdf [Accessed March 2023].

Huntsberger C.J., Kilada R., Ambrose Jr W.G. and Wahle R.A., 2020. Age-at-size relationships of the American lobster (Homarus americanus) from three contrasting thermal regimes using gastric mill band counts as a direct aging technique. Canadian Journal of Fisheries and Aquatic Sciences, 77(10): 1733-1740.

Hutchison, Z.L., Gill, A.B., Sigray, P., He, H. and King, J.W. (2020). Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom dwelling marine species. Scientific Reports 10:4219.

Hvidt, C. B., Bech, M., & Klaustrup, M. (2004). Monitoring programme-status report 2003. Fish at the cable trace. Nysted offshore wind farm at Rødsand. Bioconsult.

ICES. (2018), 'Greater North Sea Ecoregion – Ecosystem overview'. ICES Ecosystem Overviews.

International Council for the Exploration of the Sea (ICES), (2020b). The International Herring Larvae Surveys.

International Council for the Exploration of the Sea (ICES). (2019), 'Offshore beam trawl surveys (1987-2011)'. [online] Available at: https://obis.org/dataset/c238cd9b-50c0-4185-9ed2-0bccb25e6386 [Accessed March 2023].

International Council for the Exploration of the Sea (ICES). (2020a), 'North Sea International Bottom Trawl Survey (1965-2011)'. [online] Available at: https://obis.org/dataset/ad65221f-0539-44aa-925e-4acf62ad0c6a [Accessed March 2023].

International Herring Larvae Survey (IHLS), 2009/2010 to 2022/2023. ICES. Available online at http://eggsandlarvae.ices.dk [Accessed March 2023].

Jensen, H., Rindorf, A., Wright, P. J., Mosegaard, H. (2011) Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery. ICES Journal of Marine Science 68: 43–51.

Joint Nature Conservation Committee (JNCC) (2010). Guidelines for minimising the risk of injury to marine mammals from using explosives. JNCC, Peterborough.

Joint Nature Conservation Committee (JNCC). (2007), 'UK BAP List of UK Priority Species'. [online]. Available at: https://hub.jncc.gov.uk/assets/98fb6dab-13ae-470d-884b-7816afce42d4#UKBAP-priority-fish.pdf [Accessed March 2023].

Jones, I.T., Stanley, J.A. and Mooney, T.A., 2020. Impulsive pile driving noise elicits alarm responses in squid (Doryteuthis pealeii). Marine pollution bulletin, 150: 110792.

Kalmijn, A. J. (1971). The Electric Sense of Sharks and Rays. Journal of Experimental Biology 55: 371–383.

Kimber, J. A., Sims, D. W., Bellamy, P. H. & Gill, A. B. (2011). The ability of a benthic elasmobranch to discriminate between biological and artificial electric fields. Marine Biology 158: 1–8.

Kosheleva, V. (1992). The impact of air guns used in marine seismic explorations on organisms living in the Barents Sea. Contr. Petro Piscis II `92 Conference F-5, Bergen, 6-8 April, 1992. 6 s.

Krone, R. Gutowa, L. Joschko, T.J. Schröder, A. (2013). Epifauna dynamics at an offshore foundation Implications of future wind power farming in the North Sea. Marine Environmental Research, 85: 1-12.

Latto, P. L. Reach, I.S. Alexander, D. Armstrong, S. Backstrom, J. Beagley E. Murphy, K. Piper, R. and Seiderer, L.J. (2013), 'Screening spatial interactions between marine aggregate application areas and sandeel habitat'. A Method Statement produced for BMAPA.

Lewandowski J., Luczkovich J., Cato D. and Dunlop R. (2016). Summary Report Panel 3: Gap Analysis from the Perspective of Animal Biology: Results of the Panel Discussion from the Third International Conference Page 252 of 256 on the Effects of Noise on Aquatic Life. In Popper A.N. and Hawkins A.D. The effects of noise on aquatic life. Springer Science+Business Media, New York, II:1277 – 1282.

Lindegren, M. Diekmann, R. and Möllmann, C. (2010), 'Regime shifts, resilience and recovery of a cod stock'. Marine Ecology Progress Series 402: 239-253

Linley, E.A.S. Wilding, T.A. Black, K. Hawkins, A.J.S. and Mangi S. (2007). Review of the Reef Effects of Offshore Wind Farm Structures and their Potential for Enhancement and Mitigation. Report from PML Applications Ltd and the Scottish Association for Marine Science to the Department for Business, Enterprise and Regulatory Reform (BERR), Contract No: RFCA/005/0029P.

Linnane, K., McGarry, T., Rowson, T. and Simpson N. (2011) 'Triton Knoll Offshore Wind Farm Limited, Demersal Fish Ecology Characterisation'.

Linnane A., McGarvey R., Feenstra J. and Hoare M., 2011. Northern Zone Rock Lobster (Jasus edwardsii) Fishery 2009/10. SARDI Research Report Series, 560: 000276-4.

Linnane, K. and Simpson, N. (2011), 'Triton Knoll Offshore Wind Farm Ltd, Herring Larvae Survey Report'.

Madsen, P. T. (2005) Marine Mammals and Noise: Problems with Root Mean Square Sound Pressure for Transients", J. Acoust. Soc. Am. 117: 3952-3956.

Mainwaring, K., Tillin, H. & Tyler-Walters, H. 2014. Assessing the sensitivity of blue mussel beds to pressures associated with human activities. Peterborough, Joint Nature Conservation Committee, JNCC Report No. 506.

Malme, C. I., Miles, P. R., Miller, G. W., Richardson, W. J., Reseneau, D. G., Thomson, D. H., Greene, C. R. (1989). Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska, BBN Report No. 6945 OCS Study MMS 89-0005. Reb. From BBN Labs Inc., Cambridge, MA, for U.S. Minerals Managements Service, Anchorage, AK. NTIS PB90-188673.

Marshall, C.E. & Wilson, E. (2008). *Pecten maximus* Great scallop. In TylerWalters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.

McCauley, R. D. Fewtrell, J. Duncan, A. J. Jenner, C. Jenner, M-N. Penrose, J. D. Prince, R. I. T. Adhitya, A. Murdoch, J. and McCabe, K. (2000). Marine Seismic Surveys – A Study of Environmental Implications. Appea Journal: 692-707.

Mitson, R. B., ed. 1995. Underwater Noise of Research Vessels: Review and Recommendations. ICES Cooperative Research Report, 209: 61.

Mitson, R.B. (1993). Underwater noise radiated by research vessels. ICES Marine Science Symposium 196: 147 – 152.

MMO (2012). Seascape Character Assessment. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312481/east_seascape.pdf [Accessed March, 2023].

MMO (2014). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation. pp 194. MMO Project No: 1031. ISBN: 978- 1-909451-24-4.

Mueller-Blenkle, C., McGregor, P.K., Gill, A.B., Andersson, M.H., Metcalfe, J., Bendall, V., Sigray, P., Wood, D.T. & Thomsen, F. (2010). Effects of Piledriving Noise on the Behaviour of Marine Fish. COWRIE Ref: Fish 06-08, Technical Report 31st March 2010.

National Policy Statement for Electricity Networks Infrastructure EN-5 (DESNZ, 2024). Available from: National Policy Statement for electricity networks infrastructure (EN-5) - GOV.UK (www.gov.uk). [Accessed January 2024].

National Policy Statement for Renewable Energy Infrastructure (NPS EN-3; DESNZ, 2024). Available from: Overarching National Policy Statement for energy (EN-1) - GOV.UK (www.gov.uk). [Accessed January 2024].

Neal, K.J. & Wilson, E. 2008. Cancer pagurus Edible crab. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: https://www.marlin.ac.uk/species/detail/1179 [Accessed March 2023]

Nedwell, J. R. Parvin, S. J. Edwards, B. Workman, R. Brooker, A. G. and Kynoch, J. E. (2007) Measurement and Interpretation of Underwater Noise During Construction and Operation of Wind farms in UK waters, Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0- 9554279-5-4

Ohman, M. C., Sigray, P. & Westerberg, H. (2007). Offshore windmills and the effects of electromagnetic fields on fish. Ambio 36: 630–633.

Orpwood, J. E., Fryer, R. J., Rycroft P. & J D Armstrong (2015). Effects of AC Magnetic Fields (MFs) on Swimming Activity in European Eels Anguilla, Scottish Marine and Freshwater Science Vol 6 No 8.

Ørsted (2021), Hornsea Four Offshore Wind Farm Environmental Statement. Annex 3.1: Fish and Shellfish Ecology Technical Report. PINS Document Reference: A5.3.1. APFP Regulation: 5(2)(a)

Ørsted. (2018), 'Fish and Shellfish Ecology Technical Report.' Hornsea Project Three Offshore Wind Farm Environmental Statement.

OSPAR. (2010), Quality Status Report 2010. OSPAR Commission, London, 176.

Outer Dowsing Offshore Wind (2022). Outer Dowsing Offshore Wind Scoping Report. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010130/EN010130-000037-EN010130-Scoping-Report.pdf [Accessed March, 2023].

Overarching National Policy Statement (NPS) for Energy (NPS EN-1; Department for Energy and Climate Change (DECC), 2024). Available from: Overarching National Policy Statement for Energy - EN-1 (publishing.service.gov.uk). [Accessed January 2024].

Payne, J.F. Andrews, C.A. Fancey, L.L. Cook, A.L. and Christian, J.R. (2007). Pilot Study on the Effect of Seismic Air Gun Noise on Lobster (Homarus Americanus) Canadian Technical Report of Fisheries and Aquatic Sciences No.2712:V + 46 (2007).

Perez-Dominguez, R. (2008), 'Fish pilot studies in the Humber Estuary, UK'. Institute of Estuarine & Coastal Studies (IECS), University of Hull, UK. Report produced as part of the European Interreg IIIB HARBASINS project.

Pérez-Domínguez, R. and Vogel, M. (2010). Baseline larval fish assemblages along the Dutch coast, Southern North Sea. Report to Port of Rotterdam. Project Organization Maasvlakte 2 (PMV2). Institute of Estuarine and Coastal Studies University of Hull, UK Report: ZBB727-F- 201.

Poloczanska, E.S., Brown, C.J., Sydeman W.J., Kiessling, W., Schoeman, D.S., Moore, P.J., Brander, K., Bruno, J.F., Buckley, L.B., Burrows, M.T., Duarte, C.M., Halpern, B.S., Holding, J., Kappel, C.V., O'Conner, M.I., Pandolfi, J.M., Parmesan, C., Schwing, F., Thompson, S. and Richardson, A.J. (2013). Global imprint of climate change on marine life. *Nature Climate Change* 3: 919-925.

Popper A.N., and Hawkins A.D. (2018). The importance of particle motion to fishes and invertebrates. The Journal of the Acoustical Society of America 143, 470 (2018); doi: 10.1121/1.5021594.

Popper, A. N. Hawkins, A. D. Fay, R. R. Mann, D. Bartol, S. Carlson, Th. Coombs, S. Ellison, W. T. Gentry, R. Hal vorsen, M. B. Lokkeborg, S. Rogers, P. Southall, B. L. Zeddies, D. G. and Tavolga, W. N. (2014) 'Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI'. Springer and ASA Press, Cham, Switzerland.

Popper, A.N., and Hawkins A.D. (2021). Fish hearing and how it is best determined. ICES Journal of Marine Science. 78. 10.1093/icesjms/fsab115.

PowerGen Renewables Offshore Ltd. (2001). Scroby Sands Offshore Wind farm Environmental Impact Assessment.

Prakash, S. and Srivastava, S. (2019). Impact of Climate Change on Biodiversity: An Overview. *International Journal of Biological Innovations*, 01: 60–65.

Proctor, N., Musk, W., 2001. Fish impingement assessment: Final report. Humber Power Ltd. Institute of Estuarine and Coastal Studies, University of Hull, report no. ZO109-F2001.

Proctor, R., Holt, J., Harris, J., Tappin, A. and Boorman, D., 2000. Modelling the Humber estuary catchment and coastal zone. In Estuarine and Coastal Modeling. ASCE. 1259-1274.

Putland, R., Farcas, A., Merchant, N., (2021). Validation report: 2020 data. Joint Monitoring Programme for Ambient Noise North Sea (JOMOPANS).

Reach I.S. Latto P. Alexander D. Armstrong S. Backstrom J. Beagley E. Murphy K. Piper R. And Seiderer L.J. (2013) Screening Spatial Interactions between Marine Aggregate Application Areas and Atlantic spawning herring Potential Spawning Areas. A Method Statement produced for the British Marine Aggregates Producers Association.

Regnier, T., Gibb, F. and Wright, P. (2019). Understanding Temperature Effects on Recruitment in the Context of Trophic Mismatch. *Scientific Reports*, 9.

Richardson WJ, Greene CR Jr, Malme CI, Thomson DH (1995) Marine mammals and noise. Academic Press, New York, 577 p.

Roach, M, Revill A and Johnson, M.J Co-existence in practice: a collaborative study of the effects of the Westermost Rough offshore wind development on the size distribution and catch rates of a commercially important lobster (Homarus gammarus) population, ICES Journal of Marine Science, Volume 79, Issue 4, May 2022, Pages 1175–1186, https://doi.org/10.1093/icesjms/fsac040

Roberts L. (2015). Behavioural responses by marine fishes and macroinvertebrates to underwater noise (Doctoral dissertation, University of Hull).

Roberts, L. Cheesman, S. Elliott, M. and Breithaupt, T. (2016). Sensitivity of Pagurus bernhardus (L.) to substrate-borne vibration and anthropogenic noise. Journal of Experimental Marine Biology and Ecology, 474: 185–194.

RWE (2022) Awel y Môr Environmental Statement. Chapter 6: Fish and Shellfish Ecology. PINS Document Reference: 6.2.5. APFP Regulation 5(2)(a).

Sabatini, M. & Hill, J.M. 2008. Nephrops norvegicus Norway lobster. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: https://www.marlin.ac.uk/species/detail/1672 [Accessed March 2023].

Samson JE, Mooney TA, Gussekloo SWS and Hanlon RT (2016). A Brief Review of Cephalopod Behavioral Responses to Sound. In Popper A.N., and Hawkins A.D. Springer Science+Business Media, New York. The effects of noise on aquatic life, II: 969 – 976.

Sand, O. Enger P. S. Karlsen H. E. and Knudesen, F. R. (2001) Detection of Infrasound in Fish and Behavioural Responses to Intense Infrasound in Juvenile Salmonids and European Silver Eels: A Mini Review, Am. Fish Soc. Symp. 26: 183 - 193.

Sigray, P. and Andersson, M.H. (2011) Particle Motion Measured at an Operational Wind WTGs in Relation to Hearing Sensitivity in Fish. J. Acoustic Soc. Am. 130(1): 200-207.

Skaret, G. Axelsen, B. E. Nøttestad, L. Ferno, A. and Johannessen, A. (2005). The behaviour of spawning herring in relation to a survey vessel. ICES Journal of Marine Science, 62: 1061–1064.

Spiga I., Caldwell G.S. and Bruintjes R. (2016). Influence of Pile Driving on the Clearance Rate of the Blue Mussel, Mytilus edulis (L.). In: Fourth International Conference on the Effects of Noise on Aquatic Life. 2016, Dublin, Ireland: Acoustical Society of America.

The Infrastructure Planning (Environmental Impact Assessment) Regulations (2017). Available online at: https://www.legislation.gov.uk/uksi/2017/572/contents/made [Accessed March 2023].

Tougaard, J. and Henriksen, O. D. (2009) Underwater Noise Form Three Types of Offshore Wind WTGss: Estimation of Impact Zones for Harbour Porpoises and Harbour Seals. J. Acoust. Soc. Am. 125: 3766-3773.

Tricas, T., and Gill, A. (2011). Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Page 255 of 256 Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

Tyler-Walters, H. & Sabatini, M. 2017. Arctica islandica Icelandic cyprine. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: https://www.marlin.ac.uk/species/detail/1519 [Accessed March 2023].

Tyler-Walters, H. 2007. Cerastoderma edule Common cockle. In Tyler-Walters H. and Hiscock K. Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: https://www.marlin.ac.uk/species/detail/1384 [Accessed March 2023].

Van der Kooij, J., Engelhard, G.H. and Righton, D.A., 2016. Climate change and squid range expansion in the North Sea. Journal of Biogeography, 43(11): 2285-2298.

Vattenfall (2019), Norfolk Boreas Offshore Wind Farm Environmental Statement. Chapter 11 Fish and Shellfish Ecology. PINS Document Reference: 6.1.11. APFP Regulation 5(2)(a)

Wahlberg, M. and Westerberg, H. (2005), 'Hearing in fish and their reactions to sounds from offshore wind farms'. Marine Ecology Progress Series, 288: 295-309.

Westerberg, H. (2000). Effect of HVDC cables on eel orientation. Pages 70-76 in Technische Eingriffe in marine Lebensraume. Bundesamtes für Naturschutz, Germany.

Westerhagen, H. V (1988). Sublethal Effects of Pollutants on Fish Eggs and Larvae. In: Fish Physiology. Academic Press, New York. Volume 11, Part A: 253-234.

Wilhelmsson D. and Malm T., 2008. Fouling assemblages on offshore wind power plants and adjacent substrata. Estuarine, Coastal and Shelf Science, 79(3): 459-466.

Winslade, P. (1971) Behavioural and embryological studies on the lesser sandeel Ammodytes marinus (Raitt). PhD thesis, Univ. East Anglia: 174.

Wright, P. J., Jensen, H., Tuck, I. (2000) The influence of sediment type on the distribution of the lesser sandeel, Ammodytes marinus. Journal of Sea Research, 44: 243–256.

Yano, K., H. Mori, K. Minamikawa, S. Ueno, S. Uchida, K. Nagai, M. Toda, and M. Masuda. (2000). Behavioral Response of Sharks to Electric Stimulation. Bulletin of Seikai National Fisheries Research Institute 78: 13- 30.

Zhang, Y, Shi F, Song J, Zhang X and Yu S (2015). Hearing characteristics of cephalopods: Modelling and environmental impact study. Integrative Zoology 10 (1): 141–151.