DOGGER BANK D WIND FARM

Preliminary Environmental Information Report

Volume 1

Chapter 11 Fish and Shellfish Ecology

Document Reference No: 1.11 **Date:** June 2025 **Revision:** V1

sse Renewables equinor

www.doggerbankd.com

Document Title: **Volume 1, Chapter 11 Fish and Shellfish Ecology**	Document BIM No: **PC6250-RHD-XX-OF-RP-EV-0011**
Prepared By: **Royal HaskoningDHV**	Prepared For: **Dogger Bank D Offshore Wind Farm**

Revision No.	Date	Status / Reason for Issue	Author	Checked by	Approved by
V1	17/04/2025	Final	EB / BH	GA	RH

Table of Contents

List of Appendices

Glossary

Term	Definition
Additional Mitigation	Measures identified through the EIA process that are required as further action to avoid, prevent, reduce or, if possible, offset likely significant adverse effects to acceptable levels (also known as secondary (foreseeable) mitigation). All additional mitigation measures adopted by the Project are provided in the Commitments Register.
Array Area	The area within which the wind turbines, inter-array cables and offshore platform(s) will be located.
Commitment	Refers to any embedded mitigation and additional mitigation, enhancement or monitoring measures identified through the EIA process and those identified outside the EIA process such as through stakeholder engagement and design evolution. All commitments adopted by the Project are provided in the Commitments Register.
Design	All of the decisions that shape a development throughout its design and pre-construction, construction / commissioning, operation and, where relevant, decommissioning phases.
Deemed Marine Licence (DML)	A consent required under the Marine and Coastal Access Act 2009 for certain activities undertaken within the UK marine area, which may be granted as part of the Development Consent Order.
Demersal	On or closely associated with the seabed.
Development Consent Order (DCO)	A consent required under Section 37 of the Planning Act 2008 to authorise the development of a Nationally Significant Infrastructure Project, which is granted by the relevant Secretary of State following an application to the Planning Inspectorate.
Effect	An effect is the consequence of an impact when considered in combination with the receptor's sensitivity / value / importance, defined in terms of significance.
Embedded Mitigation	Embedded mitigation includes: • Measures that form an inherent part of the project design evolution such as modifications to the location or design of the development made during the pre-application phase (also known as primary (inherent) mitigation); and • Measures that will occur regardless of the EIA process as they are imposed by other existing legislative requirements or are considered as standard or best practice to manage commonly occurring environmental impacts (also known as tertiary (inexorable) mitigation). All embedded mitigation measures adopted by the Project are provided in the Commitments Register.

Term	Definition
Enhancement	Measures committed to by the Project to create or enhance positive benefits to the environment or communities, as a result of the Project. All enhancement measures adopted by the Project are provided in the Commitments Register.
Environmental Impact Assessment (EIA)	A 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 and includes the publication of an Environmental Statement.
Environmental Statement (ES)	A document reporting the findings of the EIA which describes the measures proposed to mitigate any likely significant effects.
Evidence Plan Process (EPP)	A voluntary consultation process with technical stakeholders which includes a Steering Group and Expert Topic Group (ETG) meetings to encourage upfront agreement on the nature, volume and range of supporting evidence required to inform the EIA and HRA process.
Expert Topic Group (ETG)	A forum for targeted technical engagement with relevant stakeholders through the EPP.
Impact	A change resulting from an activity associated with the Project, defined in terms of magnitude.
Inter-Array Cables	Cables which link the wind turbines to the Offshore Platform(s).
Landfall	The area on the coastline, south-east of Skipsea, at which the offshore export cables are brought ashore, connecting to the onshore export cables at the transition joint bay above Mean High Water Springs.
Mitigation	Any action or process designed to avoid, prevent, reduce or, if possible, offset potentially significant adverse effects of a development. All mitigation measures adopted by the Project are provided in the Commitments Register.
Mitigation Hierarchy	A systematic approach to guide decision-making and prioritise mitigation design. The hierarchy comprises four stages in order of preference and effectiveness: avoid, prevent, reduce and offset.

Term	Definition
Monitoring	Measures to ensure the systematic and ongoing collection, analysis and evaluation of data related to the implementation and performance of a development. Monitoring can be undertaken to monitor conditions in the future to verify any environmental effects identified by the EIA, the effectiveness of mitigation or enhancement measures or ensure remedial action are taken should adverse effects above a set threshold occur. All monitoring measures adopted by the Project are provided in the Commitments Register.
Offshore Development Area	The area in which all offshore infrastructure associated with the Project will be located, including any temporary works area during construction, which extends seaward of Mean High Water Springs. There is an overlap with the Onshore Development Area in the intertidal zone.
Offshore Export Cable Corridor (ECC)	The area within which the offshore export cables will be located, extending from the DBD Array Area to Mean High Water Springs at the landfall.
Offshore Export Cables	Cables which bring electricity from the offshore platform(s) to the transition joint bay at landfall.
Offshore Platform(s)	Fixed structures located within the DBD Array Area that contain electrical equipment to aggregate and, where required, convert the power from the wind turbines, into a more suitable voltage for transmission through the export cables to the Onshore Converter Station. Such structures could include (but are not limited to): Offshore Converter Station(s) and an Offshore Switching Station.
Pelagic	The water column or open sea
Project Design Envelope	A range of design parameters defined where appropriate to enable the identification and assessment of likely significant effects arising from a project's worst-case scenario. The Project Design Envelope incorporates flexibility and addresses uncertainty in the DCO application and will be further refined during the EIA process.
Safety Zones	A statutory, temporary marine zone demarcated for safety purposes around a possibly hazardous offshore installation or works / construction area.
Scoping Opinion	A written opinion issued by the Planning Inspectorate on behalf of the Secretary of State regarding the scope and level of detail of the information to be provided in the Applicant's Environmental Statement. The Scoping Opinion for the Project was adopted by the Secretary of State on 02 August 2024.
Scoping Report	A request by the Applicant made to the Planning Inspectorate for a Scoping Opinion on behalf of the Secretary of State. The Scoping Report for the Project was submitted to the Secretary of State on 24 June 2024.

Term	Definition
Scour Protection	Protective materials used to avoid sediment erosion from the base of the wind turbine foundations and offshore platform foundations due to water flow.
Study Areas	A geographical area and / or temporal limit defined for each EIA topic to identify sensitive receptors and assess the relevant likely significant effects.
The Applicant	SSE Renewables and Equinor acting through 'Doggerbank Offshore Wind Farm Project 4 Projco Limited'.
The Project	Dogger Bank D Offshore Wind Farm Project, also referred to as DBD in this PEIR.
Trenchless Techniques	Trenchless cable or duct installation methods used to bring offshore export cables ashore at landfall, facilitate crossing major onshore obstacles such as roads, railways and watercourses and where trenching may not be suitable. Trenchless techniques included in the Project Design Envelope include Horizontal Directional Drilling (HDD), auger boring, micro-tunnelling, pipe jacking / ramming and Direct Pipe.
Wind Turbines	Power generating devices located within the DBD Array Area that convert kinetic energy from wind into electricity.

11 Fish and Shellfish Ecology

11.1 Introduction

1. This chapter of the Preliminary Environmental Information Report (PEIR) presents the preliminary results of the Environmental Impact Assessment (EIA) of the Dogger Bank D Offshore Wind Farm Project (hereafter 'the Project' or 'DBD') on fish and shellfish ecology.

2. **Chapter 4 Project Description** provides a description of the key infrastructure components which form part of the Project and the associated construction, operation and maintenance and decommissioning activities presented in **Section 4.5**.

3. The primary purpose of the PEIR is to support the statutory consultation activities required for a Development Consent Order (DCO) application under the Planning Act 2008. The information presented in this PEIR chapter is based on the baseline characterisation and assessment work undertaken to date. The feedback from the statutory consultation will be used to inform the design where appropriate / and presented in an Environmental Statement (ES), which will be submitted with the DCO application.

4. This PEIR chapter:

- Describes the baseline environment relating to fish and shellfish ecology;
- Presents an assessment of the likely significant effects on fish and shellfish ecology during the construction, operation and maintenance, and decommissioning phases of the Project alone and cumulatively with other projects;
- Identifies any assumptions and limitations encountered in compiling the environmental information; and
- Sets out proposed mitigation measures to avoid, prevent reduce or, if possible, offset potential significant adverse environmental effects identified during the EIA process and, where relevant, monitoring measures or enhancement measures to create or enhance positive effects.

5. This chapter should be read in conjunction with the following related chapters. Inter-relationships are discussed further in **Section 11.10.1**:

- **Chapter 8 Marine Physical Processes**;
- **Chapter 9 Marine Water and Sediment Quality**;
- **Chapter 10 Benthic and Intertidal Ecology**;
- **Chapter 12 Marine Mammals**;
- **Chapter 13 Offshore Ornithology**; and
- **Chapter 14 Commercial Fisheries**.

6. Additional information to support the fish and shellfish ecology assessment includes:

- **Volume 2, Appendix 8.3 Physical Process Modelling Report**;
- **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**;
- **Volume 2, Appendix 10.4 Array Area Habitat Mapping Report**;
- **Volume 2, Appendix 11.1 Consultation Responses for Fish and Shellfish Ecology**;
- **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report**; and
- **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**.

11.2 Policy and Legislation

11.2.1 National Policy Statements

7. Planning policy on energy National Significant Infrastructure Projects (NSIP) is set out in the National Policy Statements (NPS). The following NPS are relevant to the fish and shellfish ecology assessment:

- Overarching NPS for Energy (EN-1) (DESNZ, 2023a); and
- NPS for Renewable Energy Infrastructure (EN-3) (DESNZ, 2023b).

8. The fish and shellfish ecology chapter has been prepared with reference to specific requirements in the above NPS. The relevant parts of the NPS are summarised in **Table 11-1**, along with how and where they have been considered in this PEIR chapter.

Table 11-1 Summary of Relevant National Policy Statement Requirements for Fish and Shellfish Ecology

NPS Reference and Requirement	How and Where Considered in the PEIR
NPS for Energy (EN-1)	
Section 5.4.22: “The design of Energy 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 UK and more widely across Europe (transboundary effects) requires consideration, depending on the location of development.”	Fish and shellfish species which may be likely receptors of impacts are identified in **Section 11.6** and are assessed in **Section 11.7** and **Section 11.8**.
Paragraph 5.4.35: “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 • 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.”	Embedded mitigation measures are set out in **Section 11.4.3.**
NPS for Renewable Energy Infrastructure (EN-3)	
Section 2.8.147: “Fish in the context of this NPS also includes elasmobranchs (sharks and rays)).”	Elasmobranchs and shellfish (e.g., crabs shellfish are considered in this chapter, see **Section 11.6.1.5** and **Section 11.6.1.9**.
Section 2.8.148: “There is the potential for the construction and decommissioning phases, including activities occurring both above and below the seabed, to impact fish communities, migration routes, spawning activities and nursery areas of particular species.”	The effects of construction, operation and maintenance, and decommissioning, are considered with respect to fish communities, migration routes, spawning activities and nursery areas of particular species in **Section 11.7** and **Section 11.8**.
Section 2.8.149: “There are potential impacts associated with energy emissions into the environment (e.g. noise or electromagnetic fields (EMF)), as well as potential interaction with seabed sediments”	Underwater noise and EMF are assessed in **Section 11.7**.

NPS Reference and Requirement	How and Where Considered in the PEIR
Section 2.8.150: “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 (e.g. HRA sites and MCZs)”	Fish and shellfish species which may be likely receptors of impacts are identified in **Section 11.6**.
Section 2.8.151: “Applicant assessments should identify the 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 EMF on sensitive fish species.”	Underwater noise and EMF are assessed in **Section 11.7**. Underwater noise modelling has included (Unexploded Ordnance) UXO clearance with an assessment at a high level. It is noted that any UXO clearance would be subject to a separate marine licence application post-consent and is considered within the cumulative assessment as appropriate.
Section 2.8.245: “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.”	EMF in terms of electric and magnetic fields are considered within this assessment, see **Section 11.7.2.7**.
Section 2.8.246: “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.”	EMF in terms of electric and magnetic fields are considered within this assessment, see **Section 11.7.2.7**.
Section 2.8.247: “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.”	Given the target burial depth of 3.5 m, and the findings of the EMF assessment (**Section 11.7.2.7**) based on the latest available data, the EMF strengths predicted at the seabed are not anticipated to be at a level which warrants a Project-specific monitoring campaign.
Section 2.8.249: “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.”	Embedded mitigations that may reduce noise impacts on fish receptors are set out in **Section 11.4.3.**

11.2.2 Other Policy and Legislation

9. Other policy and legislation relevant to the fish and shellfish ecology assessment is summarised in the following sections.

11.2.2.1 National

10. UK legislation concerning marine habitats and species includes the following:

- The Conservation of Habitats and Species Regulations 2017 (as amended)[1];
- The Conservation of Offshore Marine Habitats and Species Regulations 2017; and
- The Marine and Coastal Access Act 2009 (MCAA).

11. The Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 are collectively referred to as the 'Habitats Regulations'. Full detail of this legislation is provided in **Chapter 3 Policy and Legislative Context**. Under the Habitats Regulations, marine European sites are designated under the European Habitats Directive[2] to protect marine Annex I habitats (i.e. marine habitats that are listed under Annex I of the Habitats Directive as natural habitats types of community interest) and Annex II species (i.e. marine species that are listed under Annex II of the Habitats Directive as animal and plant species of community interest). For fish and shellfish ecology relevant European sites are Special Areas of Conservation (SAC). Habitats Regulations Assessment (HRA) is a necessary component of any marine development wherein there may be adverse effects on the status of qualifying features that consequently jeopardise achievement of SAC conservation objectives. In the context of fish features, the relevant SACs are estuarine and riverine, rather than open water marine, and the potential for effect on these SACs arises from effects on migratory fish features travelling to and from these fluvial sites.

12. Under the MCAA, Marine Conservation Zones (MCZs) have been designated in English and Welsh marine areas. MCZs are intended to conserve functioning marine ecosystems by affording protection to broadscale habitats and features of conservation interest (FOCI). MCZs Assessment is a necessary component of marine development wherein there may be adverse effects on the status of qualifying features that consequently jeopardise MCZs conservation objectives.

13. In line with the above, this chapter is supplemented by a Report to Inform Appropriate Assessment (RIAA) and a MCZs Assessment Report.

14. In addition, there are a number of other pieces of national legislation, policy, and guidance applicable to the assessment of fish and shellfish ecology. These include:

- The Marine Policy Statement (MPS) (HM Government, 2011) sets out the framework for marine planning and taking decisions affecting the marine environment. The high-level objective of 'Living within environmental limits' covers the points relevant to fish and shellfish ecology, this requires that:
  - Biodiversity is protected, conserved and where appropriate recovered and loss has been halted;
  - Healthy marine and coastal habitats occur across their natural range and can support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems; and
  - Our oceans support viable populations of representative, rare, vulnerable, and valued species.
- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards (Natural England, 2022);
- Strategic Review of Offshore Windfarm Monitoring Data Associated with FEPA Licence Conditions (Cefas, 2010);
- Renewable UK (2013) Cumulative Effect Assessment guidelines, guiding principles for cumulative impacts assessments in offshore windfarms (OWFs);
- Review of post-consent OWFs monitoring data associated with licence conditions (Marine Management Organisation (MMO), 2014);
- Sound Exposure Guidelines for Fishes and Sea Turtles Monitoring (Popper *et al.*, 2014); and
- Guidelines for Ecological Impact Assessment in the UK and Ireland (Chartered Institute of Ecology and Environmental Management, 2024).

11.2.2.2 Local

15. There are a number of pieces of local legislation, policy, and guidance applicable to the assessment of fish and shellfish ecology. These include:

- The East Inshore and East Offshore Marine Plans contain policies of relevance to fish and shellfish ecology:

1.

[1] As amended by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019.

[2] Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

  - BIO1 states: "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". Areas of ecological importance, for example spawning and nursery grounds, are characterised within **Section 11.6** and assessed in **Section 11.7** and **Section 11.8**. The conservation status of relevant species is listed within **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report**.
  - ECO1 states: "*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 impacts are assessed within **Section 11.8**.
- The North East Inshore and North East Offshore Marine Plans contain policies of relevance to fish and shellfish ecology:
  - NE-UWN-1 states: "*Proposals that result in the generation of impulsive sound must contribute data to the UK Marine Noise Registry as per any currently agreed requirements. Public authorities must take account of any currently agreed targets under the Marine Strategy Part One Descriptor 11*". It is the Project's intention to record relevant planned and completed activities that generate impulsive noise in the Joint Nature Conservation Committee (JNCC) Marine Noise Registry.
  - NE-CBC-1 states: "*Proposals must consider cross-border impacts throughout the lifetime of the proposed activity. Proposals that impact upon one or more marine plan areas or terrestrial environments must show evidence of the relevant public authorities (including other countries) being consulted and responses considered*". Details of the consultation undertaken by the Project for fish and shellfish ecology can be found in **Section 11.3**, and consultation on wider topics can be found in **Chapter 7 Consultation**.

11.3 Consultation

16. Topic-specific consultation in relation to fish and shellfish ecology has been undertaken in line with the process set out in **Chapter 7 Consultation**. A Scoping Opinion from the Planning Inspectorate was received on 2nd August 2024, which has informed the scope of the assessment presented within this chapter (as outlined in **Volume 2, Appendix 11.1 Consultation Responses for Fish and Shellfish Ecology**).

17. Feedback received through the ongoing Expert Topic Group (ETG) meetings and wider technical consultation meetings with relevant stakeholders has also been considered in the preparation of this chapter. Details of technical consultation undertaken to date on fish and shellfish ecology are provided in **Table 11-2**.

Table 11-2 Technical Consultation Undertaken to Date on Fish and Shellfish Ecology

Meeting	Stakeholder(s)	Date(s) of Meeting / Frequency	Purpose of Meeting
ETG Meetings			
ETG1 (Marine Physical Processes, Benthic Ecology and Fish and Shellfish Ecology)	Natural England Marine Management Organisation (MMO) Environment Agency North Eastern Insure Fisheries and Conservation Authority (NEIFCA) Cefas	13th September 2023	Discussion and feedback on approach to EIA with agreements requested for: • Study Area chosen; • Approach to data collection; and • Impacts scoped in.
ETG 1 (Marine Physical Processes, Benthic Ecology and Fish and Shellfish Ecology)	Natural England MMO Environment Agency Cefas	30th October 2024	Discussion and feedback on consultation responses with agreements requested for: • Approach to the underwater noise assessment; and • Approach to herring and sandeel suitability mapping.

18. **Volume 2, Appendix 11.1 Consultation Responses for Fish and Shellfish Ecology** summarises how consultation responses received to date are addressed in this chapter.

19. This chapter will be updated based on refinements made to the Project Design Envelope and to consider, where appropriate, stakeholder feedback on the PEIR. The updated chapter will form part of the ES to be submitted with the DCO application.

11.4 Basis of the Assessment

20. The following sections establish the basis of the assessment of likely significant effects, which is defined by the Study Area(s), assessment scope, and realistic worst-case scenarios. This section should be read in conjunction with **Volume 2, Appendix 1.2 Guide to PEIR**, **Volume 2, Appendix 6.2 Impacts Register** and **Volume 2, Appendix 6.3 Commitments Register**.

11.4.1 Study Area

21. The fish and shellfish ecology Study Area (hereafter referred to as 'the Study Area') has been defined as the International Council for the Exploration of the Sea (ICES) statistical rectangles 40F1, 40F2, 39F0, 39F1, 39F2, 39F3, 38F0, 38F1, 38F2, 38F3, 37E9, 37F0, 36E9 and 36F0. The Study Area covers a total of 57,315.37km^2 and includes ICES rectangles that overlap with the DBD Array Area and proposed offshore export cable corridor (offshore ECC), which together form the Offshore Development Area (ODA). The minimum distance between the ODA, and the Study Area boundary is 7km.

22. The extent of the Study Area provides a regional context for fish and shellfish ecology, including potential effects outside of the DBD Array Area and offshore ECC as shown on **Figure 11-1**.

23. In the case of long-distance underwater noise impacts, a 'Wider Study Area' will be used. The extent of this Wider Study Area has been determined by the outcomes of site-specific underwater noise modelling which informs this PEIR. Given that worst-case piling noise impact ranges are predicted to be 44km (see **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**), the Wider Study Area is defined as a 45km buffer around the Offshore Project Area shown on **Figure 11-2**.

11.4.2 Scope of the Assessment

24. A number of impacts have been scoped out of the fish and shellfish ecology assessment. These impacts are outlined in the Impacts Register provided in **Appendix 6.2**, along with supporting justification and are in line with the Scoping Opinion (discussed in **Section 11.3**) and the project description outlined in **Chapter 4 Project Description**.

25. Impacts scoped into the assessment relating to fish and shellfish ecology are outlined in **Table 11-3** and discussed further in **Section 11.7**.

26. A full list of impacts scoped in / out of the fish and shellfish ecology assessment is summarised in the Impacts Register provided in **Volume 2, Appendix 6.2 Impacts Register**. A description of how the Impacts Register should be used alongside the PEIR chapter is provided in **Chapter 6 Environmental Impact Assessment Methodology**.

Table 11-3 Fish and Shellfish Ecology – Impacts Scoped into the Assessment

Impact ID	Impact and Project Activity	Rationale
Construction		
FSE-C-02	Temporary habitat loss / physical disturbance – through construction activities	Some fish and shellfish species with low mobility and association with the seabed, including the egg and larval stages of certain species, will be prone to direct physical disturbance during the construction phase from the installation of the wind farm infrastructure (namely foundations, scour protection and cables).
FSE-C-04	Increased suspended sediment and sediment-redeposition – through construction activities	Construction activities causing increased suspended sediment concentrations and associated sediment settlement have the potential to cause indirect effects, and result in a change in predation success for species reliant on hunting by sight. Sediment plumes may result in the smothering of demersal eggs and alter habitats of importance to fish and shellfish species for foraging or breeding purposes. This is particularly true for species of limited mobility and those species that have specific substrate requirements.
FSE-C-06	Remobilisation of contaminated sediments if present - offshore ECC – through construction activities	There is potential for existing contaminants within the sediments to be remobilised during the installation of cables in the offshore ECC (see **Chapter 9 Marine Water and Sediment Quality**).
FSE-C-07	Underwater noise and vibration – through construction activities	Underwater noise generated by pile driving, UXO clearance and other construction activities may result in disturbance and displacement of fish species and have the potential to affect spawning behaviour, nursery areas and migration patterns.
FSE-C-08	Changes in fishing pressure – during construction activities	The construction of offshore infrastructure could result in changes to fishing activity within the ODA but also in the wider area due to displacement of fishing activity into other areas (see **Chapter 14 Commercial Fisheries**). This could in turn result in changes to fishing pressure on fish and shellfish populations.
Operation & Maintenance		
FSE-O-02	Temporary habitat loss / physical disturbance – maintenance activities	Maintenance activities may disturb the seabed leading to temporary habitat loss or physical disturbance. For example, conducting repairs on the inter-array cables, where they must be brought to the surface and then re-laid, will disturb the seabed.

Impact ID	Impact and Project Activity	Rationale
FSE-O-03	Habitat loss / alteration - foundations and scour protection on the seabed and cable protection	The presence of foundations and scour protection on the seabed and cable protection would result in a relatively small footprint of lost habitat in the context of the habitat from the surrounding region. The level of effect will be dependent upon the habitat type in question, the scarcity of said habitat in the wider area and the presence of a species that are reliant on that habitat.
FSE-O-04	Increased suspended sediment and sediment-redeposition – maintenance activities	Maintenance activities causing increased suspended sediment concentrations and associated sediment settlement have the potential to cause indirect effects, and result in a change in predation success for species reliant on hunting by sight. Sediment plumes may result in the smothering of demersal eggs and alter habitats of importance to fish and shellfish species for foraging or breeding purposes. This is particularly true for species of limited mobility and those species that have specific substrate requirements.
FSE-O-06	Remobilisation of contaminated sediments if present (offshore ECC) – routine maintenance	There is potential for existing contaminants within the sediments to be remobilised during scour and routine maintenance in the offshore ECC (see **Chapter 9 Marine Water and Sediment Quality**).
FSE-O-07	Underwater noise and vibration – operation of wind turbines	The main source of underwater noise during operation (in addition to ambient noise) originates form the wind turbine gearbox and generator, in addition to any surface vessels undertaking O&M activities. Whilst elevated noise levels from operational turbines are likely to be restricted to the area immediately surrounding the turbines, this impact is scoped in for further consideration.
FSE-O-08	Changes in fishing pressure - O&M activities	O&M activities could result in changes to fishing activity within the ODA but also in the wider area due to displacement of fishing activity into other areas (see **Chapter 14 Commercial Fisheries**). This could in turn result in changes to fishing pressure on fish and shellfish populations.
FSE-O-09	EMF effects – transmission of electricity	In areas where it is not possible to bury cables to the target burial depth of 3.5m (e.g. at crossings or in hard substrate) there may be sections of surface laid cables with cable protection. The EMF of these cables may have the potential to interact with electro- or magneto- sensitive species.
FSE-O-10	Sediment heating from export cables – transmission of electricity	When operational and transmitting electricity, buried offshore export cables have the potential to heat the surrounding sediment. Whilst the evidence suggests this effect is likely to be highly limited (see **Section 11.7.2.7**), this impact is scoped in specifically to consider effects on burying sandeel, which has the potential to bury close to the cable.
FSE-O-11	Introduction of hard substrate – presence of concrete and steel structures	Concrete and steel structures may be colonised by a range of benthic invertebrate species, potentially increasing ecological diversity and with the potential to act as fish aggregating devices.
Decommissioning		
FSE-D-02	Temporary habitat loss / physical disturbance – through decommissioning activities	Decommissioning impacts are scoped in; however, details of offshore decommissioning activities are not known at this stage. As discussed in **Section 11.7.3**, decommissioning impacts will be assessed in detail through the Offshore Decommissioning Programme (see **Table 11-4** Commitment ID CO21) where relevant, which will be developed prior to the commencement of offshore decommissioning works. In this assessment, it is assumed that most decommissioning activities would be the reverse of their construction counterparts, and that their impacts would be of similar nature to, and no worse than, those identified during the construction phase.
FSE-D-03	Increased suspended sediment and sediment-redeposition	Removal of infrastructure on, or in, the seabed may cause increased suspended sediment concentrations and associated sediment settlement have the potential to cause indirect effects, and result in a change in predation success for species reliant on hunting by sight. Sediment plumes may result in the smothering of demersal eggs and alter habitats of importance to fish and shellfish species for foraging or breeding purposes. This is particularly true for species of limited mobility and those species that have specific substrate requirements.
FSE-D-04	Increased suspended sediment and sediment-redeposition	Removal of cables and foundations in the seabed.
FSE-D-06	Remobilisation of contaminated sediments if present - offshore ECC	There is potential for existing contaminants within the sediments to be remobilised during the removal of cables in the offshore ECC (see **Chapter 9 Marine Water and Sediment Quality**).

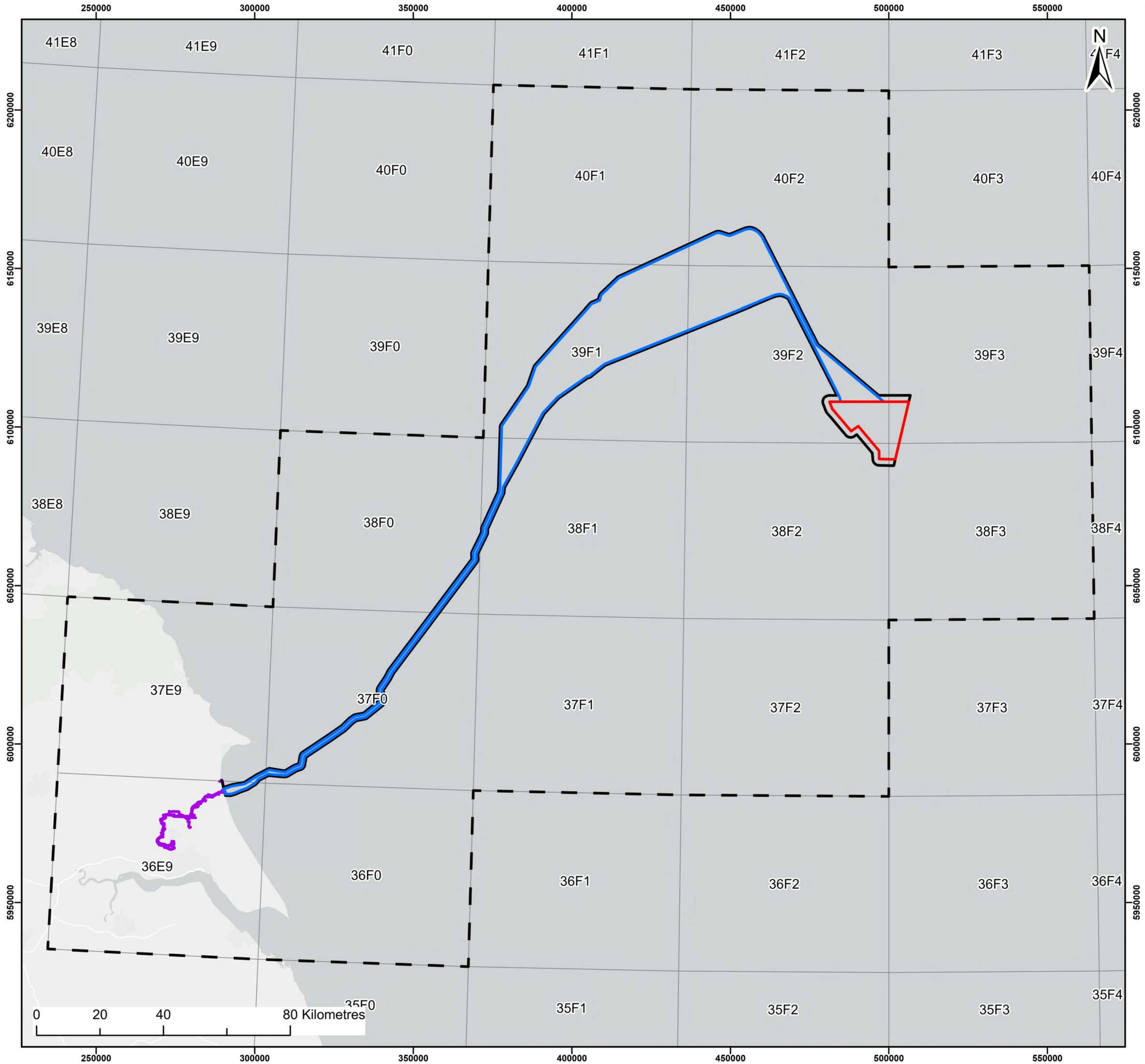
Impact ID	Impact and Project Activity	Rationale
FSE-D-07	Underwater noise and vibration	Removal of infrastructure from the seabed
FSE-D-08	Changes in fishing pressure	Decommissioning activities could result in changes to fishing activity within the ODA but also in the wider area due to displacement of fishing activity into other areas (see **Chapter 14 Commercial Fisheries**). This could in turn result in changes to fishing pressure on fish and shellfish populations.
FSE-D-11	Introduction of hard substrate	Any infrastructure left in-situ at decommissioning will continue to produce the impact already assessed in FSE-O-11.

11.4.3 Embedded Mitigation Measures

27. The Project has made several commitments to avoid, prevent, reduce or, if possible, offset potential adverse environmental effects through mitigation measures embedded into the evolution of the Project's design envelope. These embedded mitigation measures include actions that will be undertaken to meet other existing legislative requirements and those considered to be standard or best practice to manage commonly occurring environmental effects. The assessment of likely significant effects has therefore been undertaken on the assumption that these measures are adopted during the construction, operation and decommissioning phases. **Table 11-4** identifies proposed embedded mitigation measures that are relevant to the fish and shellfish ecology assessment.

28. Full details of all commitments made by the Project are provided within the Commitments Register in **Volume 2, Appendix 6.3 Commitments Register**. A description of how the Commitments Register should be used alongside the PEIR chapter is provided in **Volume 2, Appendix 1.2 Guide to PEIR** and **Chapter 6 Environmental Impact Assessment Methodology**. In addition, a list of draft Outline Marine Management Mitigation Plans (MMMP) which are submitted with the PEIR for consultation is provided in **Section 1.10** of **Chapter 1 Introduction.** These documents will be further refined and submitted along with the DCO application. See **Volume 2, Appendix 1.2 Guide to PEIR** for a list of all PEIR documents.

29. The Commitments Register is provided at PEIR stage to provide stakeholders with an early opportunity to review and comment on the proposed commitments. Proposed commitments may evolve during the pre-application phase as the EIA progresses and in response to refinements to the Project's design envelope and stakeholder feedback. The final commitments will be confirmed in the Commitments Register submitted along with the DCO application.



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area
- Fish and Shellfish Ecology Study Area
- ICES Rectangles

Source: © Haskoning DHV UK Ltd, 2024; Contains OS data © Crown copyright and database rights, 2023; © ICES Spatial Facility, ICES, Copenhagen, 2023; © OpenStreetMap (and) contributors, CC-BY-SA

Project: Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

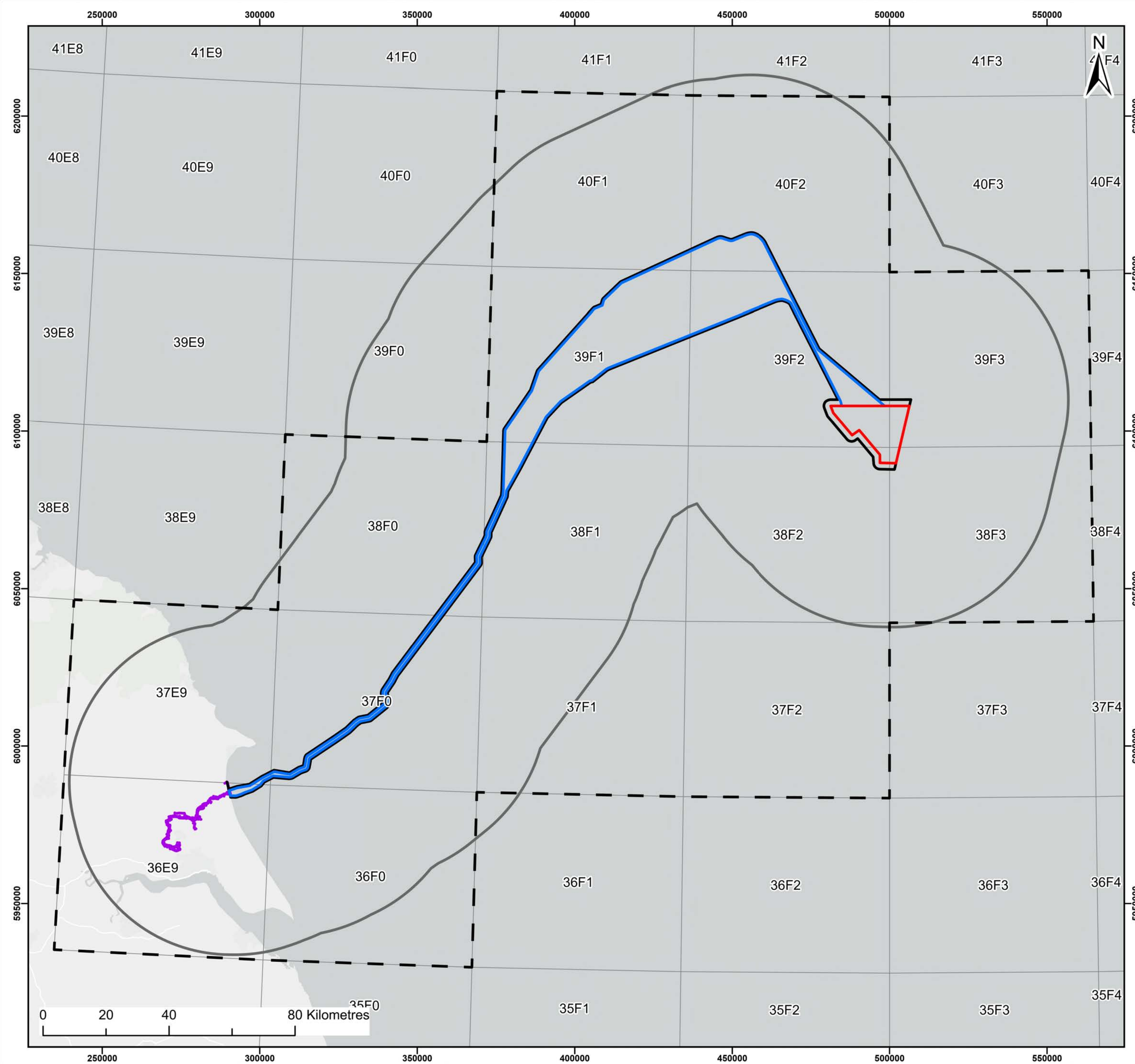
Title: Fish and Shellfish Ecology Study Area

Figure: 11-1 | Drawing No: PC6250-RHD-XX-OF-DR-GS-0204

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:1,200,000
01	08/11/2024	JH	AB	A3	1:1,200,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area
- Fish and Shellfish Ecology Study Area
- Wider Fish and Shellfish Ecology Study Area
- ICES Rectangles

Source: © Haskoning DHV UK Ltd, 2024; Contains OS data © Crown copyright and database rights, 2023; © ICES Spatial Facility, ICES, Copenhagen, 2023; © OpenStreetMap (and) contributors, CC-BY-SA

Project: Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

Title: Wider Fish and Shellfish Ecology Study Area

Figure: 11-2

Drawing No: PC6250-RHD-XX-OF-DR-GS-0205

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:1,200,000
01	08/11/2024	JH	AB	A3	1:1,200,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor

Table 11-4 Embedded Mitigation Measures Relevant to Fish and Shellfish Ecology

Commitment ID	Proposed Embedded Mitigation	How the Embedded Mitigation Will be Secured	Relevance to Fish and Shellfish Ecology Assessment	Relevance to Impact ID
CO21	An Offshore Decommissioning Programme would be provided prior to the construction of the offshore works and implemented at the time of decommissioning, based on the relevant guidance and legislation.	DCO Requirement - Offshore Decommissioning Programme	The plan will consider impacts on fish and shellfish and how they can be minimised.	FSE-D-02 FSE-D-03 FSE-D-04 FSE-D-06 FSE-D-07 FSE-D-08 FSE-D-11
CO22	A piling Marine Mammal Mitigation Protocol (MMMP) will be provided in accordance with the Outline MMMP and will be implemented during construction. The piling MMMP will include details of the embedded mitigation, for the soft-start and ramp-up, as well as details of the proposed mitigation zone and any additional mitigation measures required in order to minimise potential impacts of any physical injury or permanent threshold shift (PTS), for example, the activation of an Acoustic Deterrent Device (ADD) prior to the soft-start, as much as is practicable.	DML Condition - Marine Mammal Mitigation Protocol	Whilst this is primarily a marine mammal mitigation, the measures included will also benefit some sound sensitive fish species, allowing them to move away from the piling activities ahead of more intensive noise levels being reached.	FSE-C-07
CO23	At the landfall, trenchless installation techniques will be implemented and exit pits will be located beyond Mean Low Water Springs (MLWS). Installation will be at a suitable depth below the base of the cliff to avoid potential impacts to the Withow Gap Site of Special Scientific Interest (SSSI).	DCO Requirement - Code of Construction Practice	Through use of horizontal directional drilling (HDD), impacts on fish and shellfish in the upper intertidal are prevented.	FSE-C-02 FSE-C-04 FSE-C-06
CO24	A Cable Specification and Installation Plan will be provided and submitted for approval prior to offshore construction. The Cable Specification and Installation Plan will detail the methods used for construction of offshore export and inter-array cables. Where possible, cable burial will be the preferred method for cable protection. Where cable protection is required, this will be minimised so far as is feasible. All cable protection will adhere to the requirements of Marine Guidance Note (MGN) 654 with respect to changes greater than 5% to the under-keel clearance in consultation with the Maritime and Coastguard Agency (MCA) and Trinity House. Any damage, destruction or decay of cables must be notified to the MCA, Trinity House, Kingfisher and UK Hydrographic Office (UKHO) no later than 24 hours after being discovered.	DML Condition - Cable Specification and Installation Plan	The plan will consider impacts on fish and shellfish and how they can be minimised.	FSE-C-02 FSE-C-04 FSE-C-06 FSE-O-03 FSE-O-11

Commitment ID	Proposed Embedded Mitigation	How the Embedded Mitigation Will be Secured	Relevance to Fish and Shellfish Ecology Assessment	Relevance to Impact ID
CO25	A Project Environmental Management Plan (PEMP) will be provided in accordance with the Outline PEMP and will include: • A Marine Pollution Contingency Plan (MPCP), which will include plans to address the risks, methods and procedures to deal with any spills and collision incidents in relation to all activities carried out below Mean High Water Springs (MHWS) to safeguard the marine environment; • Best practice measures for the storage, use and disposal of lubricant and chemicals will be undertaken throughout the construction phase; • A Chemical Risk Assessment (CRA) to ensure any chemicals, substances and materials to be used will be suitable for use in the marine environment and in accordance with the Health and Safety Executive and the Environment Agency Pollution Prevention Control Guidelines or latest relevant available guidelines; • A marine biosecurity plan detailing how the risk of introduction and spread of invasive non-native species will be minimised; and • Details of waste management and disposal arrangements.	DML Condition - Project Environmental Management Plan	The risk of accidental release of pollutants is sufficiently reduced by these measures to scope this impact out for fish and shellfish ecology.	N/A
CO26	Micro-siting of the offshore cables will be used to minimise the requirement for seabed preparation as far as is practicable.	DML Condition - Cable Specification and Installation Plan	By avoiding the need for sandwave levelling, the magnitude of temporary disturbance on fish and shellfish receptors is reduced.	FSE-C-02 FSE-C-04 FSE-C-06 FSE-C-07 FSE-O-02
CO28	An Offshore Operations and Maintenance Plan (O&M) will be provided prior to commencement of operation and will outline the reasonably foreseeable O&M offshore activities.	DML Condition - Offshore Operations and Maintenance Plan	The plan will aim to make efficiencies in vessel movements by ensuring unnecessary trips to and from site do not take place. This will reduce impacts associated with O&M activities.	FSE-O-02 FSE-O-03 FSE-O-04 FSE-O-06 FSE-O-07 FSE-O-08 FSE-O-09 FSE-O-10 FSE-O-12

30. An **Outline Project Environmental Management Plan 8.6** (PEMP) (document reference number: 8.6) is submitted with the PEIR application, which details measures relevant to fish and shellfish ecology. Indicative embedded mitigation measures included in the plan are summarised below **Table 11-5**.

Table 11-5 Indicative Embedded Mitigation Measures Included in the Outline PEMP

Measures to be Included: Outline PEMP
Pre-construction surveys would be undertaken in advance of any cable and foundation installation works. The methodology of the pre-construction surveys would be agreed with the MMO and Natural England.
The Offshore ECC was selected in consultation with key stakeholders to select route options which minimised impacts on designated sites, such as minimising its length within the Dogger Bank Special Area of Conservation (SAC). The Undertaker have also committed to minimising external cable protection, where possible, along the entirety of the Offshore ECC.
Any seabed material arising from the activities within the DBD Array Area would also likely be disposed of within the Array Area, as it would likely be designated as a disposal site as part of the DCO application. Sediment would not be disposed in or near known sensitive benthic habitats (which may be identified through surveys) and, where possible, would be redeposited within areas of similar sediment type.
The Undertaker would make all reasonable endeavours to bury Offshore Export Cables, thereby reducing electromagnetic fields and the need for surface cable protection. A Cable Specification and Installation Plan (CSIP), including a Cable Burial Risk Assessment would be submitted post-consent which would detail the anticipated export cable protection requirements. As part of the final CSIP a detailed cable laying plan providing details of the need, type, sources, quantity and installation methods for scour protection and cable protection (where required) would also be provided.
The risk of spreading INNS would be mitigated by compliance with the following relevant regulations and guidance: • International Convention for the Prevention of Pollution from Ships (MARPOL). The MARPOL sets out appropriate vessel maintenance; • The Environmental Damage (Prevention and Remediation) (England) Regulations 2015, which set out a polluter pays principle where the operators who cause a risk of significant damage or cause significant damage to land, water or biodiversity would have the responsibility to prevent damage occurring, or if the damage does occur would have the duty to reinstate the environment to the original condition; and • The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention), which provide global regulations to control the transfer of potentially invasive species.

31. A **Draft Outline Marine Management Mitigation Plan (MMMP)** (document reference 8.1) for piling is being submitted with the PEIR, which will detail indicative measures relevant to marine mammals that will be secured in the plan during the post-consent discharge of conditions. Whilst these measures are designed to benefit marine mammals, they are also of benefit to sound sensitive fish species. Indicative embedded mitigation measures which are proposed to be included in the plan are set out in **Table 11-6**.

Table 11-6 Indicative Embedded Mitigation Measures to be Included in the Draft Outline MMMP for Piling

Measures to be Included: Draft Outline MMMP for Piling
Deployment and activation of Acoustic Deterrent Devices (ADDs) for defined period prior to piling
Soft-start and ramp-up in hammer energies
Breaks in piling procedures
Potential for noise reduction methods (e.g. Noise Abatement Systems (NAS))

11.4.4 Realistic Worst-Case Scenarios

32. To provide a precautionary, but robust, assessment at this stage of the Project's development process, a realistic worst-case scenario has been defined in **Table 11-7** for each impact scoped into the assessment (as outlined in **Section 11.7**). The realistic worst-case scenarios are derived from the range of parameters included in the design envelope. They ensure that the assessment of likely significant effects is based on the maximum potential impact on the environment. Should an alternative development scenario be taken forward in the final design of the Project, the resulting effects would not be greater in effect significance. Further details on the design envelope approach are provided in **Chapter 6 Environmental Impact Assessment Methodology**.

33. The realistic worst-case scenarios used to assess impacts on fish and shellfish ecology are defined in **Table 11-7**. Following the PEIR publication, further design refinements will be made based on ongoing engineering studies and considerations of the EIA and stakeholder feedback. Therefore, realistic worst-case scenarios presented in the PEIR may be updated in the ES. The design envelope will be refined where possible to retain design flexibility only where it is needed.

Table 11-7 Realistic Worst-Case Scenarios for Impacts on Fish and Shellfish Ecology

Impact ID	Impact and Project Activity	Realistic Worst-Case Scenario	Rationale
Construction			

FSE-C-02	Temporary habitat loss / physical disturbance – through construction activities	**Array Area:**
		• Maximum scour protection area per foundation including structure footprint for suction buckets of 14,314m² x 113 wind turbine generators (WTG)) = 1,617,482m².
		• Two Offshore Platforms (OPs) with monopile foundations ((25,000m² per monopile foundation including scour protection) = 50,000m².
		• Inter-array cable seabed sand wave levelling (35m width from seabed preparation x 400km length of inter-array cables) = 14,000,000m².
		• Vessel jack up assuming 5 jack up locations per WTG / OP (400m² per jack up leg x 6 legs x 5 jack up operations per WTG x 115 for WTG / OP) = 1,380,000m².
		• Anchoring during WTG installation (based on 16 anchors x 100m² footprint x 113 (1 anchoring events per 113 WTG)) = 180,800m².
		• Anchoring during OP installation (based on 34 anchors per OP x 100m² footprint x 2 OPs) = 6,800m².
		• Anchoring during inter-array cable installation (based on 6 anchors x 100m² x 11.5 anchoring events x 2 vessels) = 13,560m².
		• Worst case scenario total disturbance footprint in the Array Area = 17,248,642m².
		Export cable (includes portion within Array Area and Landfall):
		• Maximum temporary disturbance for seabed preparation within the offshore ECC = 16,608,000m²:
		  ○ Maximum total export cable trench length of 400km x 2 trenches;
		  ○ Maximum width of temporary disturbance is approximately 15m from installation methods and 35m from sand wave levelling on 28.8% of cable route;
		  ○ Disturbance from sand wave levelling (35m width x 230.4km (28.8% of the 800km export cable) = 8,064,000m²; and
		  ○ Disturbance from installation including seabed preparation activities (15m trench width x 569.6km (71.2% of the 800km export cable) = 8,544,000m².
		• Anchoring during offshore export cable installation (based on 6 anchors x 100m² x 24 anchoring events) = 14,400m².
		• Landfall (trenchless exit pits):
		  ○ Number of trenchless duct installations = 3 (includes 2 + 1 spare) and the size of each exit pit – 100m length x 25m width. Maximum extent of temporary disturbance for exit pits = 7,500m².
		  ○ Anchoring during trenchless technique exit installation (based on 6 anchors x 100m² x 12 anchoring events) = 7,200m².
		  ○ Trenchless transition bore spacing = Up to 600mm.
		• Worst-case scenario total disturbance footprint in the offshore ECC – 16,637,100m².
			Temporary habitat loss / physical disturbance relates to seabed preparation and installation activities.
			The persistent / permanent footprint of infrastructure is assessed as an O&M phase impact.
			The worse case scenario for OP is two small platforms as opposed to one large platform, both in terms of extent and volumes, hence only the worst case parameters shown.
			It has been assumed for the worst case that 100% of the inter-array cable would require sand wave levelling. It has therefore been assumed that as the sand wave levelling corridor is 100%, the installation footprint falls within that corridor, therefore no additional disturbance would arise.
			The sand wave levelling width and/or the installation width also include the following activities:
			• Boulder clearance;
			• Route clearance pre-lay grapnel run (PLGR);
			• Crossing preparation; and
			• Archaeological surveys / investigation / relocation.

Impact ID	Impact and Project Activity	Realistic Worst-Case Scenario	Rationale
		Total disturbance footprint – 33,885,742m^2	
FSE-C-04	Increased suspended sediment and sediment-redeposition – through construction activities	**Array Area:** • Seabed preparation volume for a single turbine foundation (suction bucket foundation plus scour protection footprint 14,314m^2 x 2.5m levelling depth) = 35,785m^3. • Seabed preparation volume for 113 turbine foundations = 4,043,705m^3. • Seabed preparation volume for a single offshore platform foundation = 100,000m^3 (monopile foundation plus scour protection footprint 25,000m^2 x 4m levelling depth). • Seabed preparation volume for two offshore platform foundations = 200,000m^3. • Inter-array cable sandwave levelling (35m width from seabed preparation x 400km length of inter-array cables x 4m maximum burial depth) = 56,000,000m^3. • Inter-array cable burial (5m width x 400km length of inter-array cable x 3.5m depth) = 7,000,000m^3. • Worst-case scenario volume for Array Area = 67,243,705m^3. NB, drill arising would not occur in the event that suction bucket is used and therefore the following parameters cannot be added to the maximum seabed levelling for suction bucket described above. • Drill arisings at 50% of WTGs (60m average drill depth x 254.5m^2 drill area (18m drill diameter) x 57 WTGs (rounded up 50%)) = 870,390m^3. • Drill arisings from two OPs (100m average drill depth x 176.7m^2 drill area (15m drill diameter). Based on maximum 12 piles, 50% requiring drilling) = 106,020m^3. • Total drill arisings = 923,404.5m^3. **Export cable (includes portion within Array Area and Landfall):** • Displaced sediment volume during sand wave levelling for Offshore Export Cable installation = 32,256,000m^3 (230,400m length x 4m depth x 35m width). • Displaced sediment volume during trenching for Offshore Export Cable installation = 14,000,000m^3 (800,000m length x 3.5m depth x 5m width). • Landfall (trenchless exit pits): ○ Number of trenchless duct installations = 3 (includes 2 + 1 spare) and size of each exit pit – 100m length x 25m width x 3.5m depth. Total volume of sediment disturbed by exit pits – 26,250m^3. • Worst-case scenario volume for export cables (sand wave levelling + trenching for offshore export cable installation + trenchless exit pits) = 46,282,500m^3. **Overall Total:** • Worst-case total for Project = **113,525,955m^3**.	Seabed preparation (dredging using a trailing suction hopper dredger and installation of a bedding and levelling layer) may be required. The worst-case scenario assumes that sediment would be dredged and returned to the water column at the sea surface during disposal from the dredger vessel. Sand wave levelling may be required prior to offshore cable installation. Any excavated sediment due to sand wave levelling would be disposed of within the offshore development area, meaning there will be no net loss of sediment from the site. It is assumed 100% of inter-array cables will require sand wave levelling. As installation (trenching) results in further disturbance though within the same footprint is an additional activity resulting in movement of sediment and is considered in the modelling scenario. The worse case scenario for OP is two small platforms as opposed to one large platform, both in terms of extent and volumes, hence only the worst case parameters shown. The offshore trenchless technique exit location will be subtidal in 1m to 8m water depth. Sediment displacement is included in the totals for the export cable.
FSE-C-06	Remobilisation of contaminated sediments if present - offshore ECC – through construction activities	Maximum suspension of sediments as described above. No contaminated sediments were recorded exceeding any Action Levels (ALs) within the offshore development area. See **Section 9.6.1.1** in **Chapter 9 Marine Water and Sediment Quality** for more detail.	

Impact ID	Impact and Project Activity	Realistic Worst-Case Scenario	Rationale
FSE-C-07	Underwater noise and vibration – through construction activities	**Greatest single strike effects:** • Diameter monopiles = 18m. • Maximum Hammer Energy = 8,000kJ. • Number of wind turbine monopiles = 113. • Number of offshore platform monopiles = 12. **Greatest cumulative effects within 24 hours:** • Diameter pin piles = 5m. • Maximum hammer energy = 5,000kJ. • Pin piles installed within 24h = 4. • Pile strikes within 24 hours = 38,400. • Piling time within 24 hours = 21h 20m. **UXO clearance** • Maximum high order detonations = 1. • High order clearance charge weight = 907kg. **Other construction sound** ***Seabed clearance:*** Methods could include: Pre-lay grapnel run, boulder grab, plough, sandwave levelling (pre-sweeping) and dredging. ***Inter-array and export cable installation:*** Continuous noise levels associated with a range of cable laying activities have been considered: • Cable laying. • Suction dredging. • Trenching. • Rock placement. • Vessel noise (large). • Vessel noise (medium). ***Maximum length of cables:*** • Inter-array cables: 400km. • Offshore Export Cable: 800km. ***Vessels:*** • Maximum number of vessels on site at any one time: 90.	Given the larger diameter and higher hammer energy, monopiling at maximum hammer energy represents the worst-case for instant effects arising from a single hammer strike. Given that it is expected four pin piles could be installed within 24 hours (compared to two monopiles), the resultant increased number of hammer strikes per 24 hours results in pin piles being the worst-case for cumulative impacts within a 24 hour period.

Impact ID	Impact and Project Activity	Realistic Worst-Case Scenario	Rationale
FSE-C-08	Changes in fishing pressure – during construction activities	The worst-case scenarios are set out in **Chapter 14 Commercial Fisheries**.	The potential for construction of offshore infrastructure to change the distribution of fishing pressure is detailed in **Chapter 14 Commercial Fisheries**.
Operation & Maintenance			
FSE-O-02	Temporary habitat loss / physical disturbance – maintenance activities	**Array Area:** • Seabed disturbance from jacking-up activities over the Project's lifetime (7 visits for WTG over lifetime x (400m^2 per jack up leg x 6 legs x 5 jack up operations per WTG) = 84,000m^2. • Inter-array cable repairs - seabed disturbance over the Project's lifetime (15 visits over project lifetime x 1,000m (distance per year) x 15m width of seabed preparation) = 225,000m^2. • Inter-array cable reburial - seabed disturbance over the Project's lifetime (35 visits over project lifetime (1 per year) x 2,000m (distance per year) x 15m width of seabed preparation) = 1,050,000m^2. • Anchoring during inter-array cable repairs/reburial (based on 6 anchors x 100m^2 x 35 anchoring events) = 21,000m^2. • Total disturbance in Array Area (sum of above) = 1,380,000m^2. **Offshore ECC (includes portion within Array Area):** • Export cable repairs - seabed disturbance over the Project's lifetime (35 visits over project lifetime (1 per year) x 1,000m (distance per year) 15m width of seabed preparation) = 525,000m^2. • Export cable reburial - seabed disturbance over the Project's lifetime (35 visits over project lifetime (1 per year) x 2,000m (distance per year) 15m width of seabed preparation) = 1,050,000m^2. • Anchoring during export cable repairs/reburial (based on 6 anchors x 100m^2 x 35 anchoring events) = 21,000m^2. • Total disturbance in offshore ECC (sum of above) = 1,596,000m^2. **Total disturbance footprint = 2,976,000m^2**.	Temporary habitat loss / physical disturbance relates to seabed O&M activities. The worst-case is based on an average of 200m of cable repaired/replaced every year and an average of 100m of cable reburied every year, with a 10m disturbance width.
FSE-O-03	Habitat loss / alteration - foundations and scour protection on the seabed and cable protection	**Array Area:** • Total worst case turbine footprint with scour protection (14,314m^2 maximum scour protection area per foundation including structure footprint (135m diameter) x 113 WTGs) = 1,617,482m^2. • Total worst-case scour protection for two OPs with monopile foundations ((25,000m^2 per monopile foundation including scour protection) = 50,000m^2. • Inter-array cable rock / remedial protection (10m width of rock berm protection x 40km length of exposed inter-array cables requiring remedial protection) = 400,000m^2. • Total footprint inter-array cable crossing material (100m length of crossing x 10m width of for cable crossings x 5 cable crossings = 5,000m^2. • Total Array Area (sum of the above) = 2,027,482m^2. **Offshore ECC (includes portion within Array Area):** • Total export cable rock / remedial protection (10m width of rock berm protection x 160km length of cable	Total scour protection per turbine includes structure footprint area. Inter-array cable protection assumes 10% of entire length requires protection. Cable protection assumes 20% of entire cable length requires protection. Predicted no. of crossings for Project: • 16 cable crossings per cable; and • 3 pipeline crossings per cable.

Impact ID	Impact and Project Activity	Realistic Worst-Case Scenario	Rationale
		requiring protection) = 1,600,000m^2. • Total footprint of pipeline / cable crossing material (100m length of crossing x 10m width of for cable crossings x 16 cable crossings and 300m length of crossing x 16m width of for pipeline crossings x 3 pipeline crossings) x 2 ECC = 60,800m^2. • Total habitat loss within the offshore ECC (sum of the above) = 1,660,800m^2. **Total disturbance footprint = 3,733,282m^2.**	
FSE-O-04	Increased suspended sediment and sediment-redeposition – maintenance activities	• Inter-array cable repairs - seabed disturbance over the Project's lifetime (15 visits over project lifetime x 1km (distance per year failure expected) x 15m width of seabed preparation x 3.5m depth) = 787,500m^3. • Inter-array cable reburials - seabed disturbance over the Project's lifetime (35 visits over project lifetime (1 per year) x 2km (distance per year failure expected) x 15m width of seabed preparation x 3.5m depth) = 3,675,000m^3. • Export cable repairs - seabed disturbance over the Project's lifetime (35 visits over project lifetime (1 per year) x 1km (distance per year failure expected) x 15m width of seabed preparation x 3.5m depth) = 1,837,500m^3. • Export cable reburials - seabed disturbance over the Project's lifetime (35 visits over project lifetime (1 per year) x 2km (distance per year failure expected) x 15m width of seabed preparation x 3.5m depth) = 3,675,000m^3. • Anchoring during inter-array cable repairs/reburial (based on 6 anchors x 100m^2 x 50 anchoring events x 6.1m depth) = 183,000m^3. **Total increased SSCs (sum of above) = 10,158,000m^3.**	The worst-case is based on the maximum volume of sediment suspended during O&M activities. Remedial reburial and repair of cables may be required using a failure rate of 0.1 failures/yr/100km over the Project's lifetime. As original protection will be repaired or replaced, there will be no changes in the total seabed footprint of cable protection measures.
FSE-O-06	Remobilisation of contaminated sediments if present (offshore ECC) – routine maintenance	No contaminated sediments were recorded exceeding any ALs within the offshore development area. See **Section 9.6.1.1** in **Chapter 9 Marine Water and Sediment Quality** for more detail.	The worst-case is based on the maximum volume of sediment suspended during O&M activities.
FSE_O_07	Underwater noise and vibration – operation of wind turbines	**Operational turbine noise** Modelled operational turbine noise is based on Tougaard *et al. (*2020) equation, with a 6m/s wind speed, and 27MW turbine. Assumed that turbines are operational 24 hours a day. See **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report** for further detail.	Presence of operational wind turbine gearbox and generator will generate noise when operational.
FSE-O-08	Changes in fishing pressure - O&M activities	The worst-case scenarios are set out in **Chapter 14 Commercial Fisheries**.	The potential for operation of offshore infrastructure to change the distribution of fishing pressure is detailed in **Chapter 14 Commercial Fisheries**.
FSE-O-09	EMF effects – transmission of electricity	**Inter-array cables:** Total cable length = 400km. Buried cable length = 360km. Cable protection required for non-buried cable length = 40km. Voltage = 132kV.	Operational cables will generate EMF, the potential received level by fish and shellfish receptors is dependent on the length of operation cabling, the voltage, the current type, and the depth of burial or rock protection.

Impact ID	Impact and Project Activity	Realistic Worst-Case Scenario	Rationale
		Current type: AC. Target burial depth 3.5m. **Offshore export cables:** Total cable length = 800km. Buried cable length = 640km. Non-buried cable length = 160km. Voltage = 500kV. Current type: High Voltage Direct Current (HVDC). Target burial depth 3.5m.	
FSE_O_10	Sediment heating from export cables – transmission of electricity	As per FSE_O_09 worst-case.	Operational cables will generate heat, the potential received level by fish and shellfish receptors is dependent on the length of operation cabling, the voltage, the current type, and the depth of burial or rock protection.
FSE-O-11	Introduction of hard substrate – presence of concrete and steel structures	As per FSE-O-03 worst-case.	The ecological effects of introducing hard infrastructure is dependent on the footprint of subsurface infrastructure presence on the seabed and water column. See FSE-O-03 for calculation of worst-case.
Decommissioning			
FSE-D-02 FSE-D-03 FSE-D-04 FSE-D-06 FSE-D-07 FSE-D-08 FSE-D-11	The final decommissioning strategy of the Project's offshore infrastructure has not yet been decided. For a description of potential offshore decommissioning works, refer to **Chapter 4 Project Description**. It is recognised that regulatory requirements and industry best practice change over time. Therefore, the details and scope of offshore decommissioning works will be determined by the relevant regulations and guidance at the time of decommissioning. Specific arrangements will be detailed in an Offshore Decommissioning Plan (see Commitment ID CO21 in Volume 2, Appendix 6.3 Commitments Register), which will be submitted and agreed with the relevant authorities prior to the commencement of offshore decommissioning works. For this assessment, it is assumed that decommissioning is likely to operate within the parameters identified for construction (i.e. any activities are likely to occur within the temporary construction working areas and require no greater amount or duration of activity than assessed for construction). The decommissioning sequence will generally be the reverse of the construction sequence. It is therefore assumed that decommissioning impacts would likely be of similar nature to, and no worse than, those identified during the construction phase.		

11.5 Assessment Methodology

11.5.1 Guidance Documents

34. The following guidance documents have been used to inform the baseline characterisation, assessment methodology and mitigation design for fish and shellfish ecology:

- Parker *et al*. (2022) Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards. Phase III: Expectations for data analysis and presentation at examination for offshore wind applications;
- CIEEM (2024) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine;
- The British Standards Institution (2015) Environmental impact assessment for offshore renewable energy projects – Guide. PD 6900:2015;
- Cefas (2012) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects;
- MMO (2014b) Review of Post-Consent Offshore Wind Farm Monitoring Data Associated with Licence Conditions, with input from the BTO, NPL and the SMRU; and
- Cefas (2004) Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA requirements: Version 2.

11.5.2 Data and Information Sources

11.5.2.1 Desk Study

35. A desk study has been undertaken to compile baseline information in the previously defined Study Area(s) (see **Section 11.4.1**) using the sources of information set out in **Table 11-8**.

36. Natural populations within the Study Area have been characterised via a review of existing literature, environmental data and fish landings data. Commercial landings data has been sourced from the MMO. Fisheries data provides information on the broad scale spatial and temporal distribution of fishing effort and species landed. However, fisheries reporting is largely limited to commercial species with many non-commercial species discarded at sea, or not selected for the fishing gear type.

37. The North Eastern Inshore Fisheries Conservation Authority (NEIFCA) have been and will continued to be consulted for local inshore fisheries data, such as shellfish potting surveys, that may have been carried out in the region, out to 6nm.

Table 11-8 Desk-Based Sources for Fish and Shellfish Ecology Data

Data Source	Spatial Coverage	Year(s)	Summary of Data Contents
Fish spawning and nursery grounds (Coull *et al.,* 1998; Ellis *et al*., 2012)	UK territorial waters.	1998 and 2012	Both studies map the distribution of predicted spawning and nursery habitats of a number of key fish and shellfish species in waters around the UK.
Marine Information Network (MarLIN)	UK territorial waters.	2024	Details of marine species, biotopes and sensitivity assessments. Broadscale and not specific to the Study Area.
National Biodiversity Network (NBN) Atlas	UK territorial waters (mixed coverage depending on species).	2024	An open access online portal for biological data in the UK. There is UK wide coverage for species distributions, collated from a variety of organisations.
Ocean Biodiversity Information System (OBIS)	Global	2024	A global open-access data source for biological data.
MMO Landings Data (weight and value) by species	UK territorial waters.	2013 to 2023	MMO landings data (weight and value) by species. Data is available for the ICES rectangles relevant to the Study Area.
International Bottom Trawl Survey (IBTS)	European waters.	2023	The IBTS Working Group (IBTSWG) coordinates fishery-independent multispecies bottom trawl surveys within the ICES area. Data collected in spring and autumn provides estimates of stock abundance (CPUE) of commercially important demersal species. Data is available for the ICES rectangles relevant to the Study Area.
ICES International Herring Larvae Surveys (IHLS)	European waters.	2013-2023	ICES programme of IHLS in the North Sea and adjacent areas, in operation since 1967. Provides quantitative estimates of herring larval abundance.

Data Source	Spatial Coverage	Year(s)	Summary of Data Contents
Dogger Bank A, B, C, South, Sofia and Hornsea Four Offshore Wind Farms	The Study Areas of the relevant projects in the Dogger Bank region.	Various	These projects provide a baseline characterisation for fish and shellfish, supported by project site-specific surveys. Some baseline characterisations overlap with the Study Area.
EMODnet broad-scale seabed habitat map for Europe (EUSeaMap) (EMODnet, 2021).	European waters.	2021	EUSeaMap 2021 is a predictive habitat map which covers the seabed of a large area of European waters including the North Sea. Habitats are described in the EUNIS and Marine Strategy Framework Directive predominant habitat classifications and predicted based on a number of physical parameters.

11.5.2.2 Site-Specific Surveys

38. In addition to desk-based sources, site-specific surveys were undertaken to provide detailed baseline information on fish and shellfish ecology. **Table 11-9** summarises surveys that have been completed to inform the ES which are relevant to the fish and shellfish ecology baseline characterisation.

Table 11-9 Site-Specific Survey Data for Fish and Shellfish Ecology

Survey	Spatial Coverage	Year(s)	Summary of Survey Data
Site specific benthic survey (see Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report)	DBD Array Area	2023	Sediment Particle Size Analysis (PSA), drop-down video, macrofaunal community composition (grab sample), sediment chemistry.
Site specific eDNA survey (see Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report)	DBD Array Area	2023	Environmental DNA (eDNA) samples have been collected from approximately 1m below sea surface and approximately 5m from the seafloor, identifying 22 distinct fish taxa in the samples.
Site-specific benthic and eDNA survey (see Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report)	Offshore ECC and repeat of some samples in the DBD Array Area	2024	Sediment Particle Size Analysis (PSA), drop-down video, macrofaunal community composition (grab sample), sediment chemistry and eDNA samples (identifying 11 distinct fish taxa).

39. Site-specific eDNA collected from near the surface and near the seabed within the DBD Array Area and between the DBD Array Area and the landfall (though explicitly within the offshore ECC) has generated presence-absence and relative abundance data for finfish (see **Sections 4.1.5 and 4.2.5** in **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**).

40. A program of geophysical[3] and benthic sampling has been undertaken across the proposed DBD Array Area and offshore ECC (see **Volume 2, Appendix 8.2 Geophysical Survey Report** and **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report** for details). This provides valuable information to characterise the seabed (including particle size analysis and contaminant analysis), alongside information on the benthic assemblage in general. PSA data has been used to inform the habitat suitability for sandeel and herring spawning (**Section 11.6.1.3.1**). Contaminant analysis of benthic grab samples has informed the assessment of 'Remobilisation of Contaminated Sediments if Present – Offshore ECC' (**Section 11.7.1.3** and **Section 11.7.2.4**). Geophysical data is used by **Chapter 10 Benthic and Intertidal Ecology** to characterise benthic habitat, which is then considered by this chapter, where relevant. See also **Volume 2, Appendix 10.4 Array Area Habitat Mapping Report** for further information. Further geophysical survey data for the Offshore ECC will be

1.

[3] Geophysical data is not available for the ECC (only for the Array Area) for PEIR but will be available for the DCO application.

reported on and available to inform the next stage of EIA, and will be considered in the ES.

41. Given that fish are highly mobile, data sets with large-scale coverage are of more relevance for characterising the natural fish and shellfish resource. The existing data described in **Table 11-8** available for this area is sufficient to undertake a robust assessment, as such further site-specific surveys in addition to those outlined above will not be required.

11.5.3 Impact Assessment Methodology

42. The assessment uses the conceptual 'source-pathway-receptor' model. By applying this model, the assessment identifies potential impacts resulting from the proposed development or activities associated with the development on the environment and sensitive receptors within it. This model provides an easy-to-follow assessment process, ensuring transparency and clarity behind any conclusions or judgments made. The aspects of the model are defined as follows:

- Source – the origin of a potential impact (e.g. an activity such as cable installation and the resulting impact such as the re-suspension of sediments);
- Pathway – the means by which a receptor is exposed to the impact (e.g. from the example above, re-suspended sediment could settle and smother the seabed); and
- Receptor – the element of the receiving environment that is impacted, which in the above example could be a shellfish species living on or in the seabed.

43. The following key terms have been used in this assessment:

- **Impact** – used to describe a change via the Project (i.e. increased SSCs etc.);
- **Receptor** – used to define the element of the receiving environment being exposed to the Impact (i.e. sandeel);
- **Effect** – the consequence of an Impact combining with a Receptor, defined in terms of Significance (exact significance dependant on magnitude of impact and the sensitivity of the receptor);
- **Adverse effect** – an alteration of the baseline environment with negative implications for the affected receptor; and
- **Beneficial effect** – an alteration of the baseline environment with positive implications for the affected receptor.

44. **Chapter 6 Environmental Impact Assessment Methodology** sets out the overarching approach to the impact assessment methodology. The topic-specific methodology for the fish and shellfish ecology assessment is described further in this section.

45. Assessment of the impacts on the relevant receptors have been separately applied to the construction, operation and decommissioning phases.

11.5.3.1 Impact Assessment Criteria

11.5.3.1.1 Receptor Sensitivity

46. For each impact, the assessment identifies receptors sensitive to that impact and implements a systematic approach to understanding the impact pathways and the level of magnitude of impacts on given receptors. The definitions of receptor sensitivity and value, magnitude of impact, and the resulting significance of effect, for the purpose of the fish and shellfish ecology assessment, are provided in **Table 11-10** to **Table 11-13**.

47. Receptor sensitivity has been assigned on the basis of species-specific adaptability, tolerance, and recoverability, when exposed to a potential impact. The following parameters have also been taken into account:

- Timing of the impact: whether impacts overlap with critical life-stages or seasons (i.e. spawning, migration); and
- Probability of the receptor-impact interaction occurring (e.g. the potential for a fish receptor to be present within a noise impact range as defined by Popper *et al.* (2014) noise impact thresholds).

48. Throughout the assessment, receptor sensitivities have been informed through review of the available peer-reviewed scientific literature, and assessments available on the MarLIN database and the associated Marine Evidence based Sensitivity Assessment (MarESA) framework. It is acknowledged that the MarLIN assessments have limitations and are not available for all species. However, the MarLIN 'evidence base' remains the largest review yet undertaken on the effects of human activities and natural events on marine species and habitats and includes evidence-based sensitivity assessments that have been used in this impact assessment. Where relevant, limitations have been considered and other information and data accessed, where appropriate. Definitions of receptor sensitivity are provided in **Table 11-10**.

Table 11-10 Definitions of Sensitivity for Fish and Shellfish Receptors

Sensitivity	Definition
High	Individual* receptor (species or stock) has very limited or no capacity to avoid, adapt to, accommodate, or recover from the anticipated impact.
Medium	Individual* receptor (species or stock) has limited capacity to avoid, adapt to, accommodate, or recover from the anticipated impact.

Sensitivity	Definition
Low	Individual* receptor (species or stock) has some tolerance to accommodate, adapt or recover from the anticipated impact.
Negligible	Individual* receptor (species or stock) is generally tolerant to and can accommodate or recover from the anticipated impact.

* In this case individual receptor does not refer to an individual organism but refers to the population or stock of a species.

49. With regard to noise related impacts, the sensitivity criteria adopted are based on internationally accepted peer-reviewed evidence and criteria proposed by consensus of expert committees. Fish criteria were adopted from Popper *et al. (*2014).

50. Due to the high sensitivity of herring *Clupea harengus* and sandeel *Ammodytidae spp*., heat maps of their potential spawning habitats (herring) and potential habitats (sandeel) within the Fish and Shellfish Ecology Study Area have been generated by Kyle-Henney *et al. (*2024) and Reach *et al. (*2024) methodologies respectively. See **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report** for details on the processes followed in producing the figures.

11.5.3.1.2 Impact Magnitude

51. The magnitude of an impact is considered for each predicted impact on a given receptor and is defined geographically, temporally and in terms of the likelihood of occurrence. The definitions of terms relating to the magnitude of a potential impact on fish and shellfish ecology are provided in **Table 11-11**.

Table 11-11 Definitions of Magnitude for Fish and Shellfish Receptors

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the 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 receptors' character or distinctiveness.
Low	Discernible, temporary*, over a minority of the receptor, and / or limited, but discernible, alteration to key characteristics or features of the receptors' character or distinctiveness.
Negligible	Discernible, temporary* 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 receptors' character or distinctiveness.

* Temporary time scale indicated where appropriate for each impact relevant to each receptor

11.5.3.1.3 Effect Significance

52. The potential significance of effect for a given impact, is a function of the sensitivity of the receptor and the magnitude of the impact (see **Chapter 6 Environmental Impact Assessment Methodology** for further details). A matrix is used (see **Table 11-12**) as a framework to determine the significance of an effect. Definitions of each level of significance are provided in **Table 11-13**. Impacts and effects may be deemed as being either positive (beneficial) or negative (adverse).

Table 11-12 Significance of Effect Matrix

		Adverse Magnitude				Beneficial Magnitude			
		High	**Medium**	**Low**	**Negligible**	**Negligible**	**Low**	**Medium**	**High**
Receptor Sensitivity	**High**	Major	Major	Moderate	Minor	Minor	Moderate	Major	Major
	Medium	Major	Moderate	Minor	Negligible	Negligible	Minor	Moderate	Major
	Low	Moderate	Minor	Minor	Negligible	Negligible	Minor	Minor	Moderate
	Negligible	Minor	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Minor

Table 11-13 Definition of Effect Significance

Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level, because they contribute to achieving national, regional, or local objectives, or could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues.
Negligible	No discernible change in receptor condition.
No Change	No impact, therefore, no change in receptor condition.

53. It is important that the matrix (and indeed the definitions of sensitivity and magnitude) is seen as a framework to aid understanding of how a judgement has been reached from the narrative of each effect assessment and it is not a prescriptive formulaic method.

54. Potential effects are described, followed by a statement of whether the effect is significant in terms of The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (as amended). Potential effects identified within the assessment as either major or moderate are regarded as significant in terms of the EIA Regulations 2017. Whilst minor effects (or below) are not significant in EIA terms in their own right, it is important to distinguish these, as they may contribute to significant effects cumulatively or through interactions.

55. Following initial assessment, if the effect does not require additional mitigation (or none is possible), the residual effect would remain the same. If, however, additional mitigation is proposed, an assessment of the post-mitigation residual effect is provided.

11.5.3.2 Cumulative Effects Assessment Methodology

56. The cumulative effects assessment (CEA) considers other plans and projects that may act collectively with the Project to give rise to cumulative effects on commercial fisheries receptors. The general approach to the CEA for commercial fisheries involves screening for potential cumulative effects, identifying a short list of plans and projects for consideration and evaluating the significance of cumulative effects. **Chapter 6 Environmental Impact Assessment Methodology** and **Volume 2, Appendix 6.4 Cumulative Effects Screening Report - Offshore** provides further details on the general framework and approach to the CEA.

11.5.3.3 Transboundary Effect Assessment Methodology

57. The transboundary effect assessment considers the potential for effects to occur as a result of the Project on fish and shellfish ecology receptors within the Exclusive Economic Zone (EEZ) of other European Economic Area (EEA) member states or other interests of EEA member states. **Chapter 6 Environmental Impact Assessment Methodology** provides further details on the general framework and approach to the transboundary effect assessment.

58. The distribution of fish and shellfish species is independent of national geographical boundaries. The assessment for the Project has been undertaken taking account of the distribution of fish stocks and populations irrespective of national jurisdictions.

59. Consideration of suspended sediment transportation dynamics in **Chapter 8 Marine Physical Processes**, **Chapter 9 Marine Water and Sediment Quality** and **Chapter 10 Benthic and Intertidal Ecology** identifies a Zone of Influence (ZoI) for suspended sediment produced by Project activities of less than 9.1km, and therefore transboundary effects resulting from suspension of sediment may occur for this Project.

60. There is a potential for underwater noise from piling during construction to travel into the territorial waters of the Netherlands. The impact ranges for construction piling on fish receptors, as determined by a dedicated modelling study (**Volume 2, Appendix 12.3 Underwater Noise Modelling Report**), are discussed in **Section 11.7.1.4** and further considered in relation to transboundary effects in **Section 11.9**.

11.5.3.4 Assumptions and Limitations

61. This chapter provides a preliminary assessment of the likely significant effects of the Project in relation to fish and shellfish using information available at the time of drafting as described in **Chapter 6 Environmental Impact Assessment Methodology**. This assessment will be refined where relevant and presented in the ES to be submitted with the DCO application.

62. There are numerous datasets on fish and shellfish within the Study Area, and from other existing offshore wind farms surrounding the Project, that have been used to characterise the species assemblage. However, as fish and some shellfish are highly mobile, and are subject to a range of variable environmental (seasonal), biological (spawning) and anthropogenic factors, the available data has limitations including surveys which are temporally and spatially limited, whereby it is acknowledged that such datasets only represent a snapshot of the assemblage at the time of survey.

63. Standard data sources such as Coull *et al. (*1998) and Ellis *et al. (*2012) have been used to inform the extent of spawning and nursery grounds for a number of fish species in relation the Project. Data sources such as Ellis *et al. (*2012) are over 10 years old and so may not reflect current species composition and abundance. The limitation has been mitigated for herring and sandeel with the inclusion of site-specific benthic PSA data, and heatmapping of herring and sandeel habitat suitability using the previous 10 years of ICES IHLS data, Cefas OneBenthic Data, fishing vessel monitoring system (VMS) data and other contemporary data sources as set out in the methods described by Reach *et al. (*2013).

64. Similarly, UK MMO landings data provide a good indication of principal commercial species within the Study Area. However, it is important to consider that commercial fisheries data does not necessarily provide an accurate representation of community or species composition, relative abundance, or biomass. This is because the species and associated quantities available for landing are determined through the system of Total Allowable Catches (TACs) and quotas. Quota allocation varies between regions, fleets, and individual vessels. Therefore, the landings from specific areas are not necessarily proportional to either abundance or biomass, nor is landing data corrected for fishing effort.

65. Furthermore, vessels hold quotas for specific species and, therefore, focus fishing effort on targeting these species. Stock conservation measures (e.g. seasonal closures) may also influence the pattern of landings. A key consideration is, therefore, that the absence of a species from landing statistics does not indicate that it is absent within a given sea area. Commercial landings data therefore provide a useful indication of species composition in a given area but does not represent an exhaustive account of all species.

66. However, these limitations are not considered to materially affect the overall confidence in the assessment outcomes, which are based on a worst-case scenario (see **Section 11.4.4**) and, as set out in **Section 11.5.2** more recent and regional data sources, such as site-specific benthic survey data, site specific eDNA data, the last 10 years of IHLS data, shellfish stock assessments, have been used to supplement the baseline. See **Section 11.5.2** for the data sources used.

11.6 Baseline Environment

11.6.1 Existing Baseline

11.6.1.1 Overview

67. Dogger Bank supports a wide range of fish and shellfish species, many of which have high commercial importance, with the region supporting significant commercial fisheries for over 300 years. The distribution of fish communities in the North Sea is broadly related to changes in water depth and temperature (Daan *et al., 1*990). In shallow waters (50m - 100m depth) in the central and northern North Sea (ICES Divisions IVa and IVb) the commercial fish assemblages are dominated by haddock *Melanogrammus aeglefinus*, whiting *Merlangius merlangus*, herring *Clupea harengus*, dab *Limanda limanda* and plaice *Pleuronectes plattessa*. The Study Area is located within ICES Division IVb. 443. Scientific trawling (independent of commercial data) of the Study Area reveals that the key species contributing to the similarity of fish assemblages in the region are solenette *Buglossidium luteum*, dab, common dragonet *Callionymus lyra*, and sand goby *Pomatoschistus minutus* (Callaway *et al.,* 2002).

68. Environmental DNA (eDNA) analysis of samples collected in site-specific offshore survey campaigns carried out in summer 2023 and autumn 2024, detected the presence of 22 distinct fish taxa and 26 respectively within the Study Area (see **Figure 11-3**). Water samples were collected in the near surface (~1m below surface) and bottom (~5m above seafloor) layers of the water column at 20 different sample locations within the Array Area in 2023 and 17 locations during the 2024 campaign within the Array Area and Offshore ECC, with no repeat stations. Results from both campaigns were largely comparable with Atlantic mackerel *Scomber scombrus* being the most relatively abundant taxon detected in both survey campaigns.

69. Other commonly detected taxa included *Clupeidae*, including sprat *Sprattus sprattus*, herring*, Pleuronectiformes* including plaice, dab and lemon sole *Microstomus kitt*, and the *Ammodytidae* family indicating the presence of sandeel *Ammodytes marinus*. Detected species of conservation concern included Atlantic horse mackerel *Trachurus trachurus*, haddock, cod *Gadus morhua* and Atlantic salmon *Salmo salar* (see **Volume 2, Appendix 10.3 Benthic Ecology Characterisation Report**), which are listed as 'vulnerable' on the International Union for Conservation of Nature (IUCN) Red List. Cod is also listed as a Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) 'Threatened and / or declining species'. A belica *Leucaspius delineatus* a freshwater and invasive species was detected in the 2024 campaign. For the full list of fish taxa detected by eDNA analysis, see **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**.

70. Based on Coull *et al. (*1998) and Ellis *et al. (*2012) data, a number of fish species have been identified as having spawning and / or nursery areas coinciding with the Study Area, as discussed in **Section 11.4.1**.

71. Both mackerel and cod have known populations across the region. Cod are known to use regions within the Study Area as spawning grounds, with peak spawning activity occurring in February following a southerly winter migration. Plaice and dab are the most abundant flat fish found within the region, with plaice playing an important role in local fisheries.

72. Both herring and sandeel have been identified as having spawning and nursery grounds within the Study Area (see **Figure 11-5** to **Figure 11-8**). Both of these species are highly sensitive to changes in substrate composition. Herring populations within the Study Area increase during the summer and autumn, with spawning peaking between August and October, preferring to lay their eggs on the seabed on clean gravel substrates (Coull *et al., 1*998). This specific seabed spawning habitat preference makes herring sensitive to activities that disturb the seabed, with herring also being sensitive to underwater noise.

73. Dogger Bank was until recently an extensive sandeel fishing ground within UK waters, with the species also acting as a key component of food webs across the area, serving as a prey species for a wide range of predators including fish, birds and marine mammals (Cefas, 2007). However, a new byelaw for the Dogger Bank SAC implemented by the MMO prohibits bottom towed fishing gear, and hence the sandeel fishery (MMO, 2022).

74. Within the region, the specific habitats of importance to herring and sandeel are poorly understood and are often present as small and distinct areas within the wider benthic mosaic. In general, sandeel rarely occur in sediments where the mud content (particle size <0.63μm) is greater than 4%, and they are absent in substrates with a mud content greater than 10% (Holland *et al., 2*005; Wright *et al., 2*000).

75. A number of elasmobranch species are found within UK waters, with species including small-spotted catshark *Scyliorhinus canicula*, spurdog *Squalus acanthias* and thornback ray *Raja clavata*, and basking shark *Cetorhinus maximus* (one observed during digital ariel surveys in November 2021) having a known presence within the Study Area. Other elasmobranch species present within UK waters may also have a presence within the Study Area including tope *Galeorhinus galeus*, cuckoo ray *Leucoraja naevus*, blue skate *Dipturus batis*, and flapper skate *Dipturus intermedius*. Blue skate and flapper skate are classed as critically endangered on the IUCN Red List.

76. The migratory species Atlantic salmon *Salmo salar*, sea trout *Salmo trutta*, European eel *Anguilla anguilla*, smelt *Osmerus eperlanus* are all known to have populations within the Study Area. These species transition between freshwater and marine environments throughout their life histories and are likely susceptible to barrier effects that may impact their ability to migrate to and from spawning grounds (Gill *et al.,* 2012).

77. A number of shellfish species are found across the region, including decapod crustaceans such as European lobster *Homarus gammarus*, edible crab *Cancer pagurus*, Norway lobster *Nephrops norvegicus* and brown shrimp *Crangon crangon*. The presence of European lobster and edible crab is associated with areas of rocky reef and exposed coastline within the Study Area, and Norway lobster are more abundant in regions of softer sediment into which they are able to burrow.

11.6.1.2 Commercial Landings Data

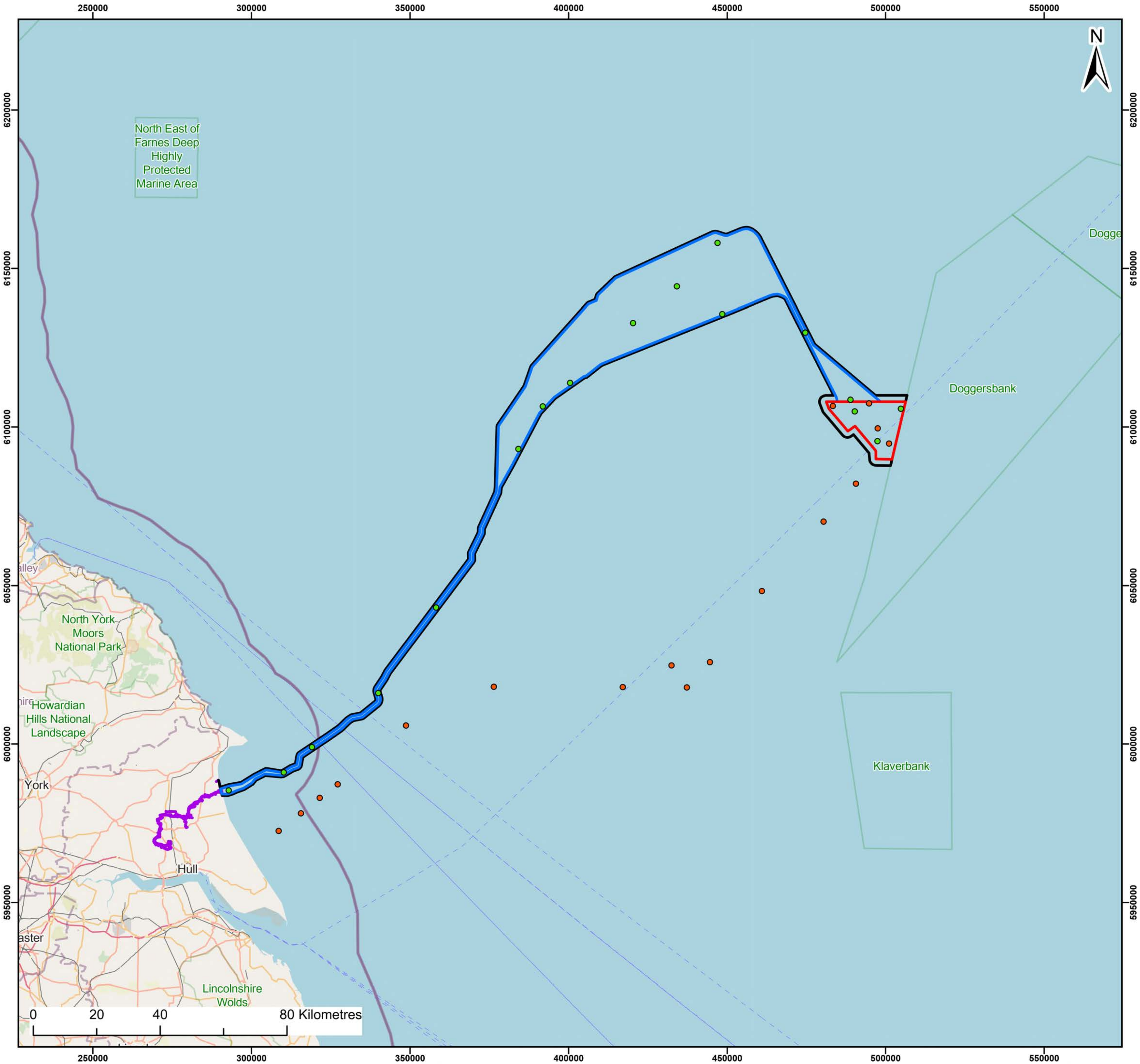
78. Commercial fisheries data can provide a useful insight into the species found in the Study Area. Landings data were sourced from the MMO and included the most recent five years of data available, ranging from 2019-2023, as published within the MMO landings data (MMO, 2024). This includes data from both national and international fleets, and all gear types. See **Chapter 14 Commercial Fisheries** for further details and assessments.

79. **Table 11-14** summarises the top five annual average landings over three tonnes (2019-2023) by species, in terms of quantity (landed weight) and value, for all ICES rectangles within the Study Area. Further detail is presented in **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report**, which sets out annual average landings (above 3 tonnes) for every species.

Table 11-14 Top Five Mean Annual Fisheries Landings Between 2019 – 2023 by Species (over three tonne) in the Study Area

ICES Rectangle	Species Group	Species Name	Landings (tonnes)	Value (£)	Project Area Overlap
36E9	Shellfish	European lobster	54	818,723	
36E9	Shellfish	Brown crab	45	103,475	
36E9	Shellfish	Nephrops	5	14,128	
36F0	Shellfish	Brown crab	2,617	5,471,334	
36F0	Shellfish	European lobster	428	6,672,921	
36F0	Shellfish	King scallop	217	435,047	
36F0	Shellfish	Whelk	134	150,816	
36F0	Demersal	Whiting	10	10,896	Offshore ECC (within 12nm)
37E9	Pelagic	Herring	2,083	1,472,015	
37E9	Shellfish	King scallop	684	1,395,023	
37E9	Shellfish	Brown crab	490	1,075,341	
37E9	Shellfish	European lobster	192	2,927,725	
37E9	Shellfish	Whelk	15	16,026	
37E9	Demersal	Cod	8	12,858	
37E9	Shellfish	Squid	4	17,782	
37F0	Pelagic	Herring	3,578	2,426,364	
37F0	Shellfish	Brown crab	495	1,038,121	
37F0	Shellfish	King scallop	392	790,809	Offshore ECC (within, and beyond 12nm)
37F0	Demersal	Sandeels	132	34,385	
37F0	Demersal	Whiting	61	59,463	
37F1	Demersal	Sandeels	235	59,886	
37F1	Shellfish	Brown crab	120	248,803	Offshore ECC (beyond 12nm)
37F1	Shellfish	Whelk	61	72,877	
37F1	Shellfish	King scallop	28	57,459	

ICES Rectangle	Species Group	Species Name	Landings (tonnes)	Value (£)	Project Area Overlap
37F1	Shellfish	Nephrops	15	47,685	
37F2	Demersal	Sandeels	172	45,084	
37F2	Demersal	Plaice	55	73,222	
37F2	Shellfish	Nephrops	45	129,860	
37F2	Shellfish	Whelk	28	33,475	
37F2	Shellfish	King scallop	11	25,225	
38F0	Pelagic	Herring	545	350,699	
38F0	Shellfish	Brown crab	188	437,864	
38F0	Pelagic	Sprats	108	96,179	
38F0	Shellfish	King scallop	42	78,029	
38F0	Shellfish	Nephrops	5	18,746	
38F1	Shellfish	Brown crab	314	662,276	
38F1	Shellfish	King scallop	134	216,776	
38F1	Demersal	Sandeels	133	34,671	
38F1	Demersal	Plaice	42	54,275	
38F1	Shellfish	Whelk	13	16,727	
38F2	Demersal	Plaice	214	283,321	DBD Array Area
38F2	Demersal	Sandeels	118	31,006	
38F2	Shellfish	King scallop	37	54,411	
38F2	Shellfish	Brown crab	18	36,330	
38F2	Demersal	Dab	5	4,176	
38F3	Demersal	Plaice	142	281,946	
38F3	Demersal	Lemon Sole	5	10,837	
38F3	Demersal	Turbot	4	27,855	
39F1	Demersal	Sandeels	674	181,105	Offshore ECC (beyond 12nm)
39F1	Shellfish	King scallop	373	625,948	
39F1	Shellfish	Brown crab	197	452,112	
39F1	Demersal	Plaice	36	55,448	
39F2	Demersal	Sandeels	846	218,098	Offshore ECC (beyond 12nm) and DBD Array Area
39F2	Demersal	Plaice	130	169,774	
39F2	Demersal	Dab	5	4,027	
39F2	Demersal	Lemon Sole	4	5,640	
39F2	Demersal	Turbot	3	13,102	
39F3	Demersal	Plaice	342	653,243	DBD Array Area
39F3	Demersal	Turbot	10	64,245	
39F3	Demersal	Lemon Sole	9	20,861	
39F3	Demersal	Dab	9	5,916	
39F3	Demersal	Grey gurnard	3	1,740	
40F1	Demersal	Plaice	3	6,867	Offshore ECC (beyond 12nm)
40F1	Shellfish	Nephrops	11	60,729	
40F2	Demersal	Sandeels	660	170,900	
40F2	Demersal	Plaice	26	57,207	
40F2	Shellfish	Nephrops	3	7,995	



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area

eDNA Sample Year

- 2023
- 2024

Source: © Haskoning DHV UK Ltd, 2024; Contains OS data © Crown copyright and database rights, 2023; © ICES Spatial Facility, ICES, Copenhagen, 2023; © OpenStreetMap (and) contributors, CC-BY-SA

Project:

Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

Title:

eDNA sample locations

Figure: 11-3		Drawing No: PC6250-RHD-XX-OF-DR-GS-0600			
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
01	12/05/2025	JH	AB	A3	1:1,200,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables

equinor

11.6.1.3 Spawning and Nursery Grounds

80. Spawning and nursery grounds, defined by Coull *et al. (*1998) and Ellis *et a.l (*2012), have been used to indicate which species may have spawning and nursery grounds within the Study Area. Due to the broad scale of these spawning and nursery maps, the use of these data sources can be considered to represent conservative estimates of the geographical extent of spawning and nursery grounds. It is acknowledged that data sources such as Ellis *et al. (*2012) are over 10 years old and so may not reflect current species composition and abundance. However, further information regarding nursery areas is provided in Aires *et al. (*2014). The study assessed evidence of aggregations of '0 group fish' (fish in the first year of their lives) around the UK coastline. These data were ascertained from species distribution modelling combining observations of species occurrence or abundance with environmental data (Aires *et al., 2*014). The outputs of this process have been suggested to be used as a guide for the most likely locations of aggregations of 0 group fish.

81. In addition, site specific data and recent herring larvae data have been used to further inform the baseline for sandeel and herring spawning (see **Section 11.6.1.3.1**).

82. The Study Area overlaps a number of fish spawning and nursery grounds, and these are displayed on **Figure 11-4** and **Table 11-16**, and listed in **Table 11-15** with their corresponding conservation importance and hearing sensitivities.

Table 11-15 Spatial Overlap between the Fish and Shellfish Ecology Study Area and Spawning and Nursery Areas of Key Fish and Shellfish Species (Coull et al., 1998; Ellis et al., 2012)

Species	Hearing Group	Areas Overlapping the Study Area		Conservation Designation
		Spawning	Nursery	
Plaice	Group 1: Fish with no swim bladder or other gas chamber	Yes (high intensity)	Yes (low intensity)	International Union for Conservation of Nature (IUCN): (Least Concern)
Sandeel *Ammmodytidae,sp.*	Group 1: Fish with no swim bladder or other gas chamber	Yes (high intensity)	Yes (low intensity)	The lesser sandeel is a Priority Species under the UK Post-2010 Biodiversity Framework.
Common sole *Solea solea*	Group 1: Fish with no swim bladder or other gas chamber	Yes (low intensity)	Yes (low intensity)	IUCN: data deficient
Whiting	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Yes (low intensity)	Yes (high intensity)	UK BAP, IUCN (Least Concern)
Cod	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Yes (low intensity)	Yes (high intensity)	IUCN Status Global: (Vulnerable) Europe: (Least Concern)
Spurdog	Group 1: Fish with no swim bladder or other gas chamber	No	Yes (low intensity)	UK BAP, OSPAR, IUCN (Vulnerable)
Tope shark *Galeorhinus galeus*	Group 1: Fish with no swim bladder or other gas chamber	No	Yes (low intensity)	UK BAP, IUCN (Vulnerable)
European hake *Merluccius merluccius*	Group 3: Fish in which hearing involves a swim bladder or other gas volume	No	Yes (low intensity)	UK BAP
Ling *Molva molva*	Group 3: Fish in which hearing involves a swim bladder or other gas volume	No	Yes (low intensity)	UK BAP
Anglerfish *Lophius piscatorius*	Group 1: Fish with no swim bladder or other gas chamber	No	Yes (low intensity)	UK BAP
Herring	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Yes (undetermined intensity)	Yes (high intensity)	UK BAP, IUCN (Least Concern)
Lemon sole	Group 1: Fish with no swim bladder or other gas chamber	Yes (undetermined intensity)	Yes (undetermined intensity)	-

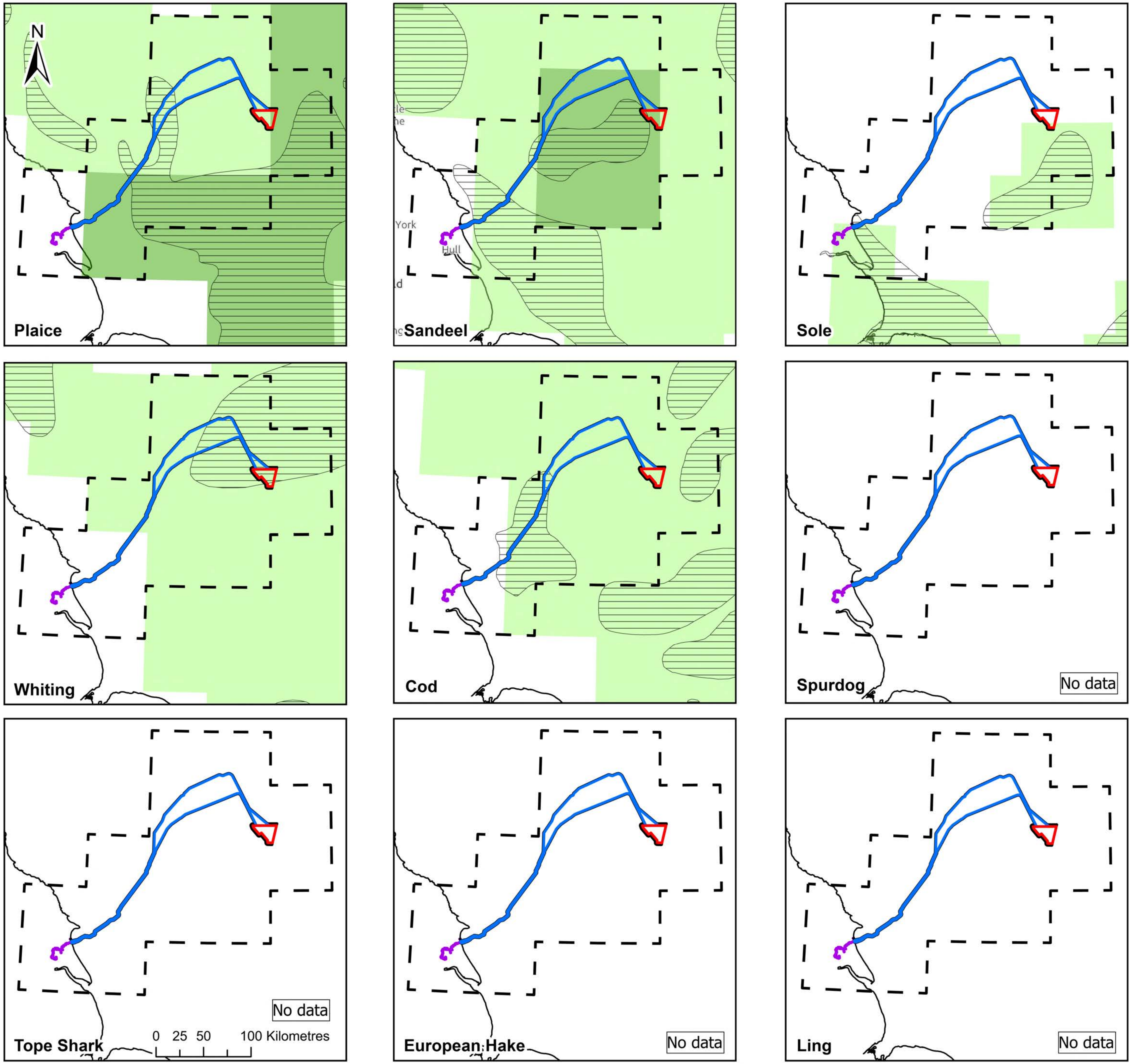
Species	Hearing Group	Areas Overlapping the Study Area		Conservation Designation
		Spawning	Nursery	
Blue whiting *Micromesistius moutassou*	Group 3: Fish in which hearing involves a swim bladder or other gas volume	No	Yes (low intensity)	UK BAP
Mackerel	Group 1: Fish with no swim bladder or other gas chamber	Yes (high intensity)	Yes (low intensity)	UK BAP, IUCN (Least Concern)
Sprat	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Yes (undetermined intensity)	Yes (undetermined intensity)	-

83. **Table 11-16** shows the fish and shellfish species with spawning and nursery grounds that overlap with the Study Area, and the intensity and annual timings of these activities.

Table 11-16 Species with Spawning and / or Nursery Grounds in the Offshore Development Area (Coull et al., 1998; Ellis et al., 2012)

Species	Spawning season in the Offshore Development Area												Nursery ground present?
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Plaice	●	●	Orange									Orange	Yes
Common sole			Orange	●	Orange								Yes
Cod	Orange	●	●	Orange									Yes
Anglerfish													Yes
Whiting		Orange	Orange	Orange	Orange	Orange							Yes
Mackerel					●	●	●	Orange					Yes
Ling													Yes
Sandeel sp.	Orange	Orange									Orange	Orange	Yes
European hake													Yes
Lemon sole	Orange	Orange									Orange	Orange	Yes
Sprat					●	●	Orange	Orange					Yes
Herring								Orange	Orange				Yes
Spurdog													Yes
Tope													Yes
Blue whiting													Yes

Orange = spawning ground, ● = peak spawning



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area
- Fish and Shellfish Ecology Study Area
- Spawning Grounds *(Coul et al, 1998)*

Spawning Grounds ***(Ellis et al, 2010)***

- High Intensity
- Low Intensity

Source: © Haskoning DHV UK Ltd, 2024; © Cefas, 2023 [Data Source, Ellis et al., 2012 and Coul et al., 1998]; © OpenStreetMap (and) contributors, CC-BY-SA

Project:

Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

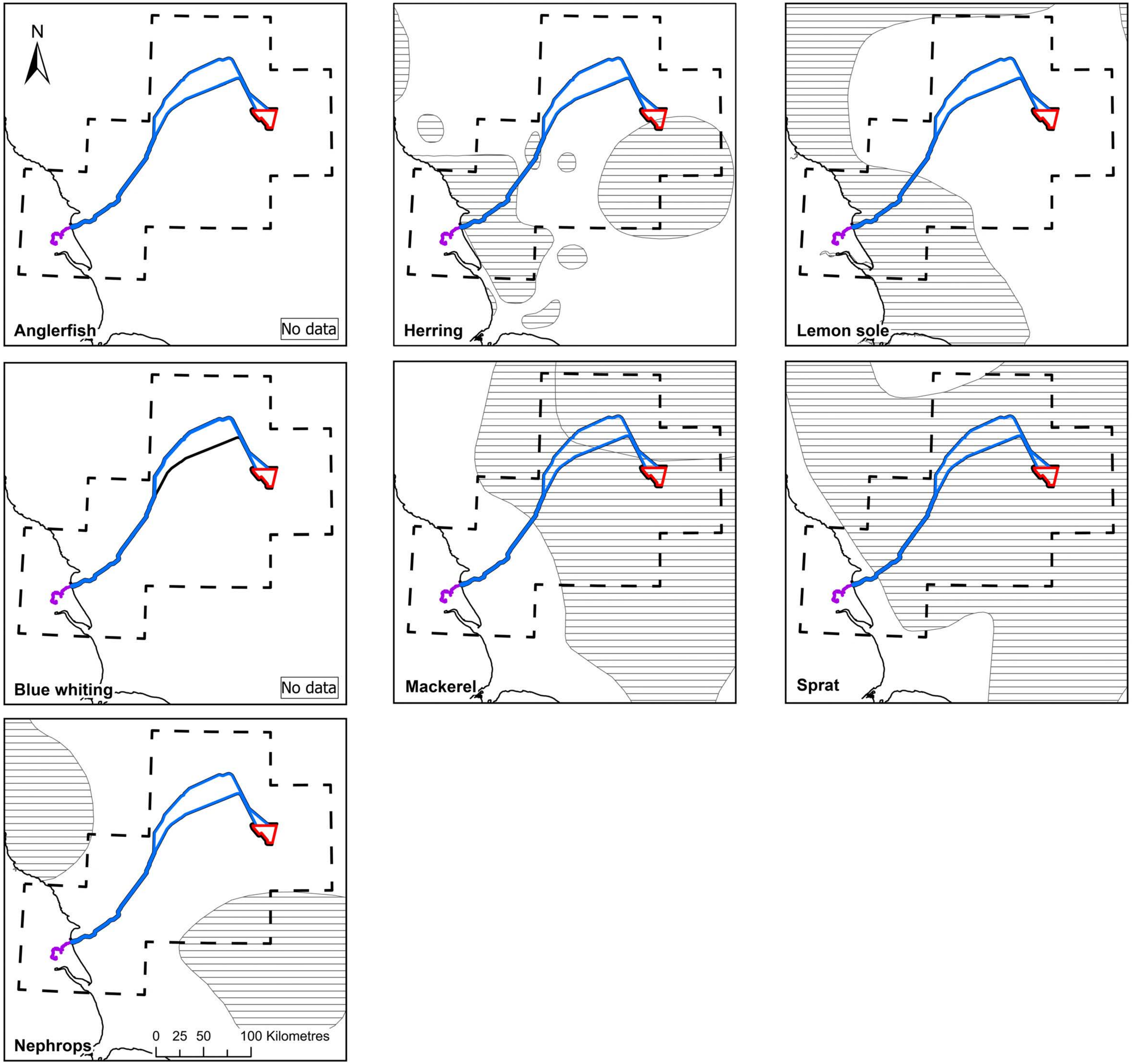
Title:

Spawning and Nursery Grounds Overlapping the Fish and Shellfish Ecology Study Area (Sheet 1 of 4)

Figure: 11-4	Drawing No: PC6250-RHD-XX-OF-DR-GS-0207				
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:4,000,000
01	08/11/2024	JH	AB	A3	1:4,000,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area
- Fish and Shellfish Ecology Study Area
- Spawning Grounds *(Coul et al, 1998)*

Source: © Haskoning DHV UK Ltd, 2024; © Cefas, 2022 [Data Source, Ellis et al., 2012 and Coul et al., 1998]; © OpenStreetMap (and) contributors, CC-BY-SA

Project:

Dogger Bank D
Offshore Wind Farm

DOGGER BANK
WIND FARM

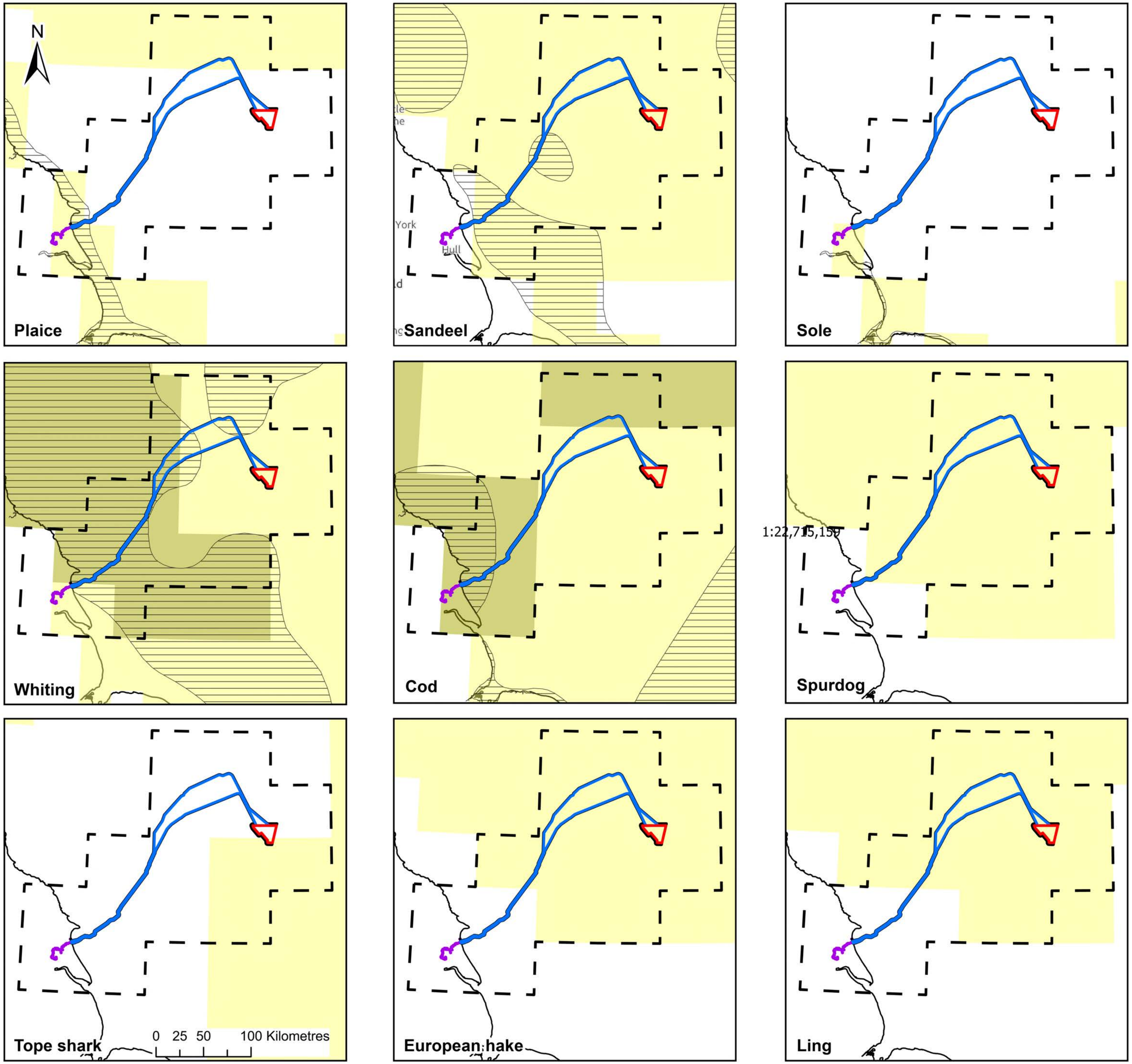
Title:

Spawning and Nursery Grounds Overlapping the
Fish and Shellfish Ecology Study Area
(Sheet 2 of 4)

Figure: 11-4		Drawing No: PC6250-RHD-XX-OF-DR-GS-0206			
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:4,000,000
01	08/11/2024	JH	AB	A3	1:4,000,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area
- Fish and Shellfish Ecology Study Area
- Nursery Grounds 1998 *(Coul et al, 1998)*

Nursery Grounds 2010 ***(Ellis et al, 2010)***

- High Intensity
- Low Intensity

Project: Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

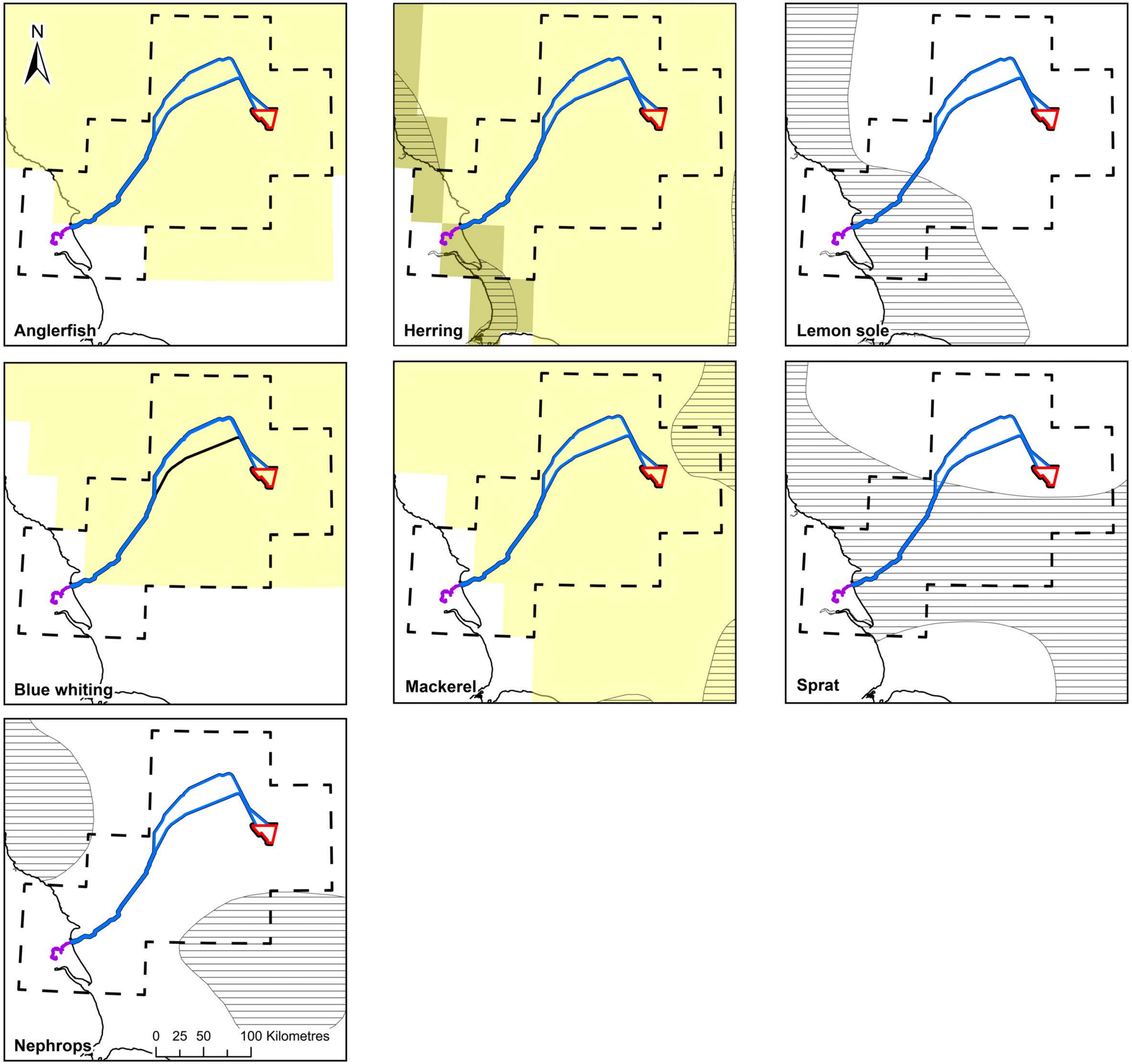
Title: Spawning and Nursery Grounds Overlapping the Fish and Shellfish Ecology Study Area (Sheet 3 of 4)

Figure: 11-4 | Drawing No: PC6250-RHD-XX-OF-DR-GS-0208

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:4,000,000
01	08/11/2024	JH	AB	A3	1:4,000,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Onshore Development Area
- Fish and Shellfish Ecology Study Area
- Nursery Grounds 1998 *(Coul et al, 1998)*

Nursery Grounds 2010 *(Ellis et al, 2010)*

- High Intensity
- Low Intensity

Source: © Haskoning DHV UK Ltd, 2024; © Cefas, 2022 [Data Source, Ellis et al., 2012 and Coul et al., 1998]; © OpenStreetMap (and) contributors, CC-BY-SA

Project: Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

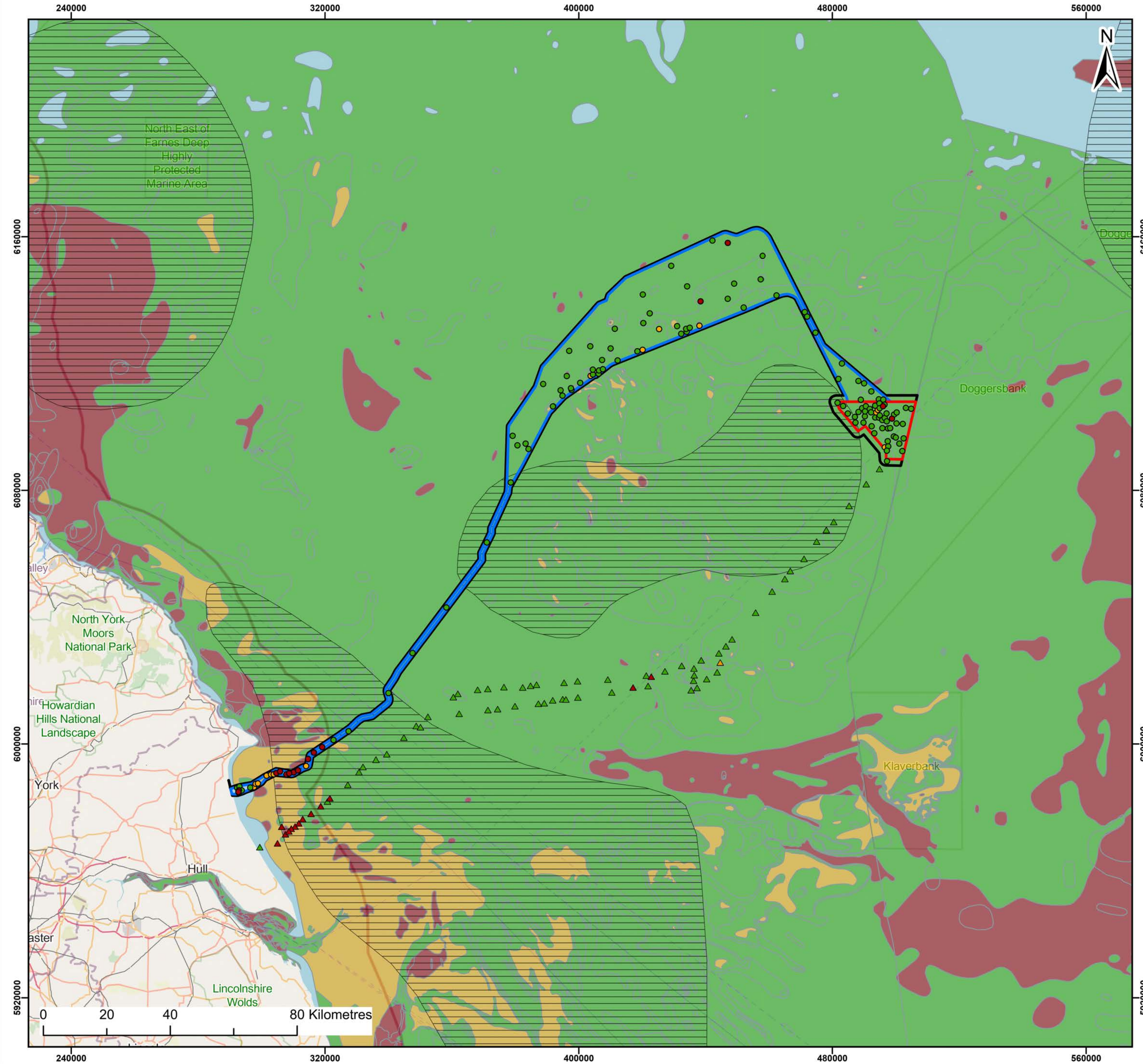
Title: Spawning and Nursery Grounds Overlapping the Fish and Shellfish Ecology Study Area (Sheet 4 of 4)

Figure: 11-4 | Drawing No: PC6250-RHD-XX-OF-DR-GS-0208

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:4,000,000
01	08/11/2024	JH	AB	A3	1:4,000,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore PEIR Corridors
- Spawning Grounds *(Coul et al, 1998)*

Sandeel habitat preference (EMODnet data)

- Preferred
- Marginal
- Unsuitable

Sandeel habitat preference (Particle Size Analysis data)

- Marginal
- Preferred
- Unsuitable
- Marginal (2023 data from old cable corridor)
- Preferred (2023 data from old cable corridor)
- Unsuitable (2023 data from old cable corridor)

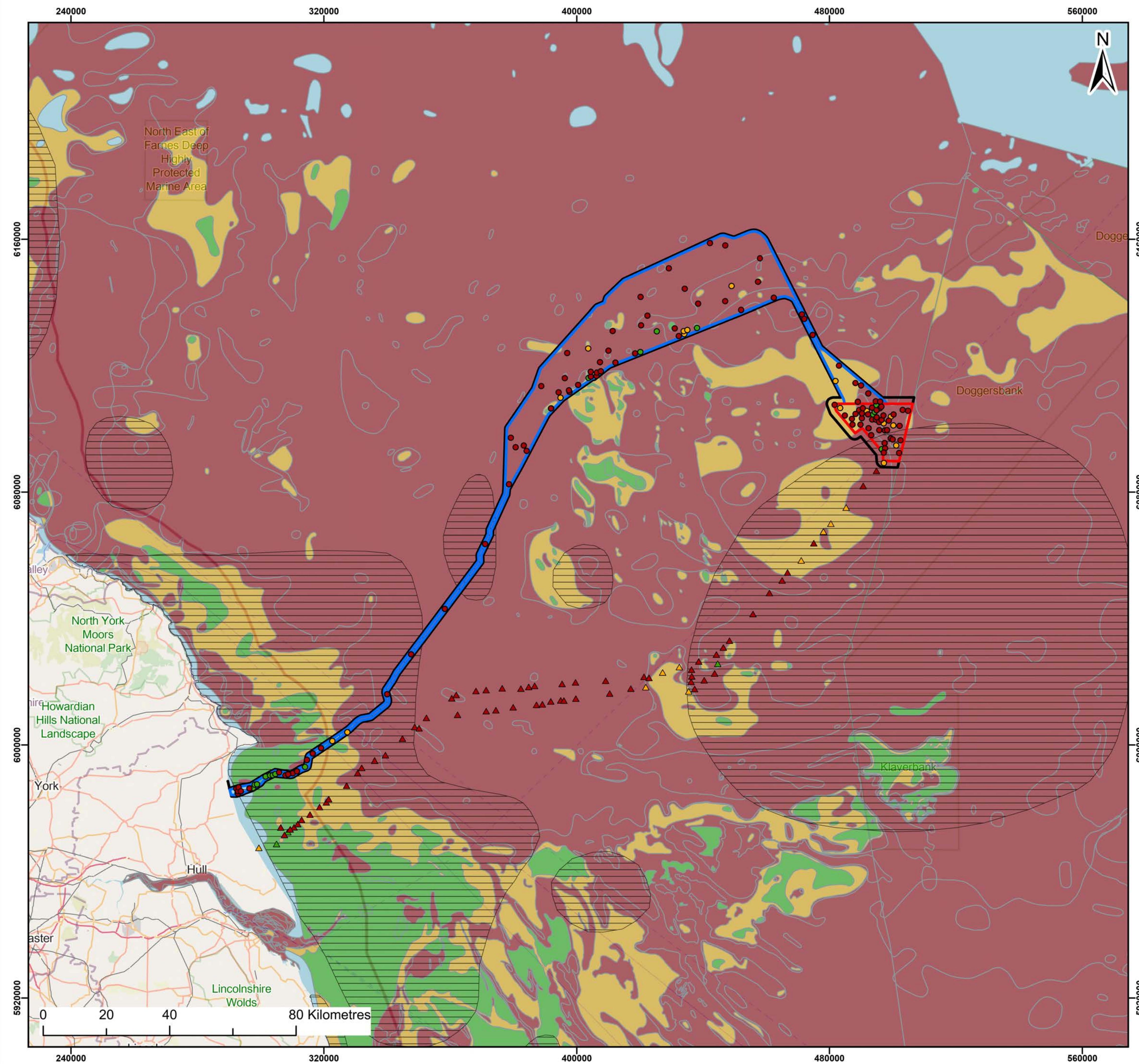
Project:	
Dogger Bank D Offshore Wind Farm	DOGGER BANK WIND FARM

Title:
Sandeel habitat and spawning ground suitability based on site specific PSA data, broadscale sediment data, and *Coull et al. (1998)*

Figure: 11-5	Drawing No: PC6250-RHD-XX-OF-DR-GS-0208				
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:1,200,000
01	08/11/2024	JH	AB	A3	1:1,200,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Export Cable Corridor
- Offshore Development Area
- Spawning Grounds *(Coul et al, 1998)*

Herring habitat preference (EMODnet data)

- Preferred
- Marginal
- Unsuitable

Herring habitat preference (Particle Size Analysis data)

- Marginal
- Preferred
- Unsuitable
- Marginal (2023 data from old cable corridor)
- Preferred (2023 data from old cable corridor)
- Unsuitable (2023 data from old cable corridor)

Source: © Haskoning DHV UK Ltd, 2024; Contains OS data © Crown copyright and database rights, 2023; © Fugro, 2024; © EMODnet, 2024© ICES Spatial Facility, ICES, Copenhagen, 2023; © OpenStreetMap (and) contributors,CC-BY-SA

Project: Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

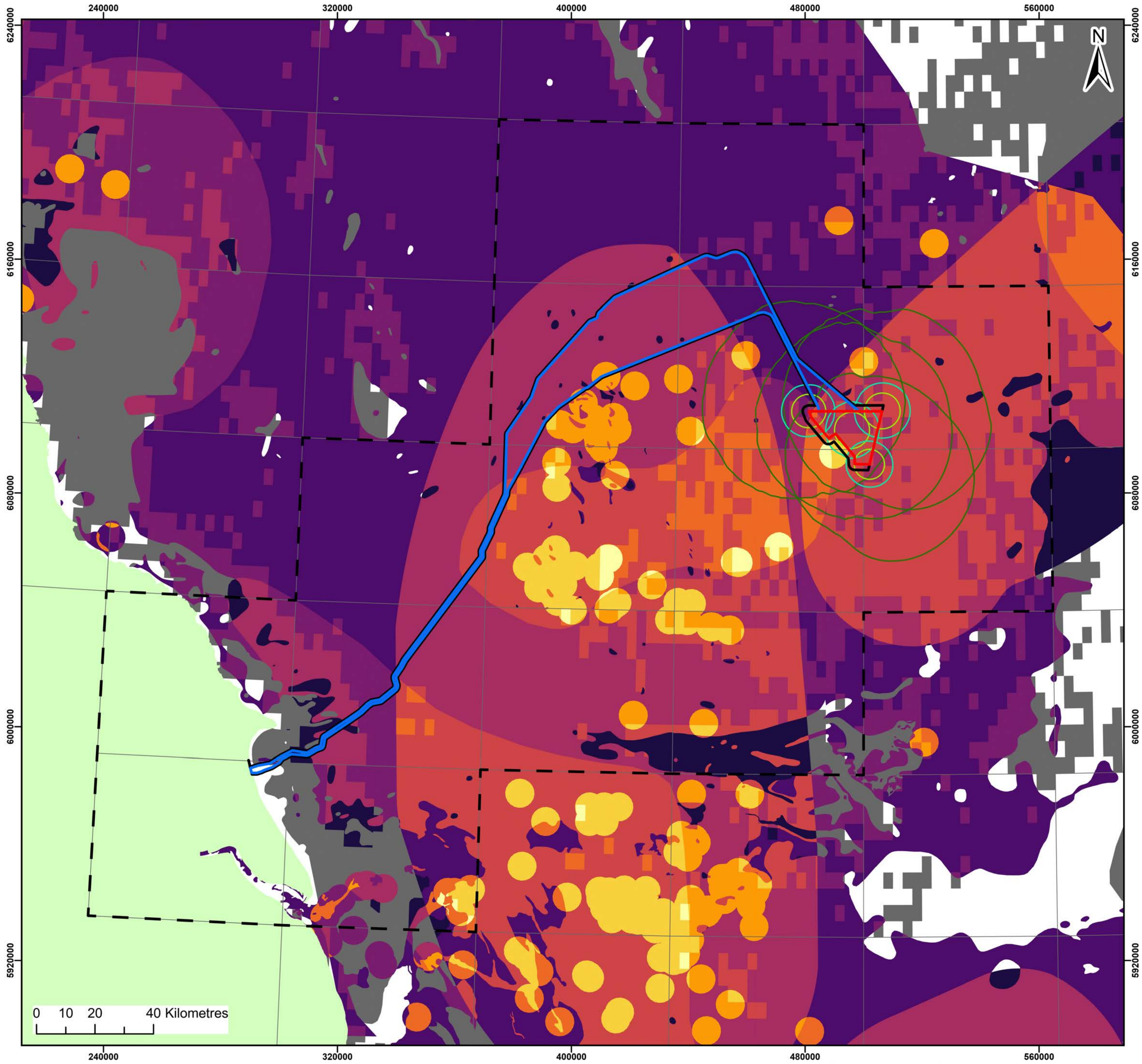
Title: Atlantic herring spawning ground suitability based on site specific PSA data, broadscale sediment data, and *Coull et al. (1998)*

Figure: 11-6 | Drawing No: PC6250-RHD-XX-OF-DR-GS-0209

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	06/05/2025	JH	AB	A3	1:1,200,000
01	08/01/2025	JH	AB	A3	1:1,200,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Fish and Shellfish Ecology Study Area
- ICES Rectangles

Confidence potential supporting habitat

- 0.01 - 0.02 - HIGHER
- 0.02- 0.03
- 0.03 - 0.05
- 0.05 - 0.08
- 0.08- 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 0.75 - LOWER

dBht_Level

- 186
- 203
- 207

Source: © Haskoning DHV UK Ltd, 2024; Contains OS data © Crown copyright and database rights, 2023; © Fugro, 2024; © EMODnet, 2024© ICES Spatial Facility, ICES, Copenhagen, 2023; © OpenStreetMap (and) contributors,CC-BY-SA

Project:

Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

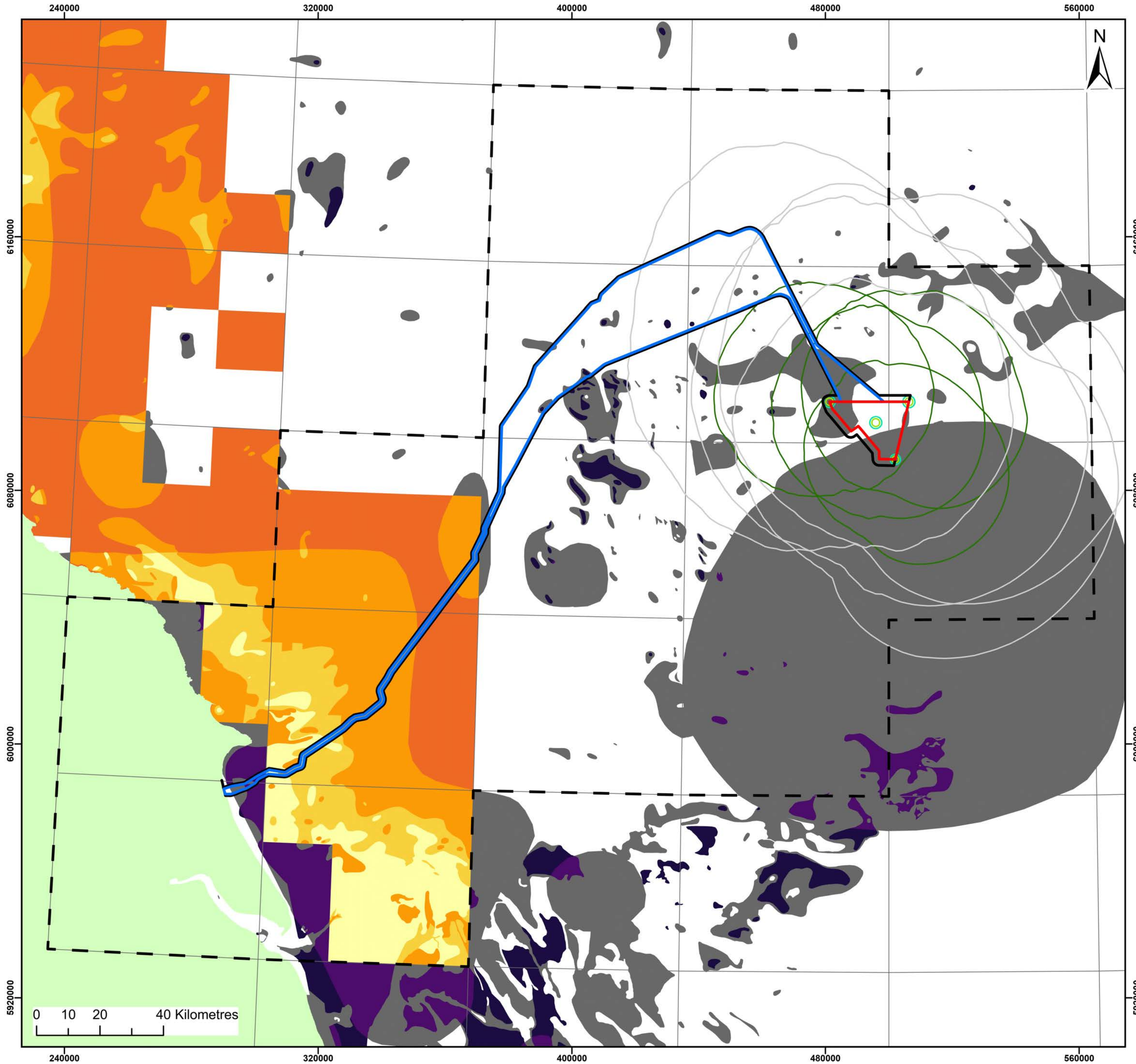
Title:

Potential habitat and spawning ground suitability heatmap for sandeels, based on *Reach et al. (2024)* methods

Figure:	11-7	Drawing No:	PC6250-RHD-XX-OF-DR-GS-0364		
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	15/04/2025	JH	AB	A3	1:1,300,000
01	08/01/2025	JH	AB	A3	1:1,300,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor



Legend:

- Dogger Bank D Array Area
- Offshore Development Area
- Offshore Export Cable Corridor
- Fish and Shellfish Ecology Study Area
- ICES Rectangles

Herring Spawning Potential

- 0.02 - 0.04 - HIGHER
- 0.04 - 0.06
- 0.06 - 0.08
- 0.08 - 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.75 - LOWER

dBht Level

- 135
- 186
- 216
- 219

Project:

Dogger Bank D Offshore Wind Farm

DOGGER BANK WIND FARM

Title:

Potential spawning habitat suitability heatmap for herring, based on *Kyle-Henney et al. (2024)* methods

Figure: 11-8

Drawing No: PC6250-RHD-XX-OF-DR-GS-0363

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
02	15/04/2025	JH	AB	A3	1:1,200,000
01	08/01/2025	JH	AB	A3	1:1,200,000

Co-ordinate system: WGS 1984 UTM Zone 31N

sse Renewables equinor

11.6.1.3.1 Sandeel and Herring Spawning Habitat

84. Both sandeel and herring are thought to be particularly sensitive to disturbance, due to highly specific substrate requirements.

85. Various spatial datasets with coverage of the Project have been utilised to create combined heatmaps of potential herring spawning habitat and sandeel habitat following the new 2024 MarineSpace methods set out in Kyle-Henney *et al*. *(*2024) and Reach *et al*. *(*2024), respectively. For details of the method see **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report**.

86. This provides a regional-scale perspective of the potential for the presence of herring spawning habitat (**Figure 11-6**) and sandeel habitat (**Figure 11-5**)

87.).

88. In addition, site-specific surveys have provided particle size analysis (PSA) of the existing sediment across the Offshore Development Area. This data has been used to assess the suitability of the seabed for demersal spawning species sandeel spp and herring. Where disagreement occurs between the broadscale habitat suitability heatmap, and site-specific PSA data, the PSA data takes precedence, as it is a recent and direct measurement of the sediment habitat suitability at the sampled location in the Offshore Development Area.

11.6.1.3.1.1 Sandeel

89. Sandeels are found in close association with sandy substrate throughout their life cycles, which results in tight zoning of their spawning grounds.

90. Sandeel are a group of shoaling fish, which lie buried in seabed sediments at night, and feed on planktonic prey, such as copepods and crustacean larvae, in mid-water during daylight hours. The most abundant sandeel species in the North Sea is the lesser sandeel *Ammodytes tobianus*. There is a total of five sandeel species in the UK, all found in shallow, turbulent areas of suitable sediment. Sandeel show a preference for medium and coarser (0.25 to <2.0mm diameter) sandy sediments and avoid areas of fine sediment and silt / clay (Lynam *et al., 2*013). Sandeel rarely occur in sediments where the mud content (particle size <0.63µm) is greater than 4%, and they are absent in substrates with a mud content greater than 10% (Holland *et al.,* 2005; Wright *et al.,* 2000).

91. Due to high substrate specificity and limited larval exchange between sandeel populations, sandeel are particularly vulnerable to overfishing and other pressures. Historically there have been large-scale fisheries for sandeel in the North Sea, with the ban on their fishing coming into effect in March 2024. As they are an important trophic link in the region's food chain, between zooplankton and sandeel predators, including piscivorous fish, seabirds and mammals.

92. As many marine predators rely on sandeel, coupled with their vulnerability to changes in habitat, sandeel are of increasing conservation interest and listed as a species of principal importance in the UK and designated as a nationally important marine feature.

93. No sandeel were recorded in the grab sampling across the DBD Array Area. Seven sandeel were recorded in the grab sampling across the offshore ECC and one recorded in the characterisation area of the 2024 benthic surveys. However, it should be noted that grab samples are not an optimal sampling method for directly retrieving sandeel, so a lack of sandeel in a sample is not an indicator that sandeel are not present. Grab samples have greater utility for understanding sandeel presence, when analysing the particle size of the sediment contained within the sample, as discussed below.

94. Various spatial datasets with coverage of the Study Area have been utilised to create combined heatmaps of potential sandeel habitat following the new 2024 MarineSpace methods set out in Reach *et al. (*2024). The spatial datasets utilised in heatmapping are Coull *et al. (*1998) spawning grounds, EMODnet sediment data, Vessel Monitoring System (VMS) fishing data (for vessel using demersal gear) (see **Appendix 11.2** for methods).

95. Based on the sandeel habitat heatmap (**Figure 11-7**), areas of higher potential for presence of sandeel habitat are located outside of the Offshore Development Area, south of the offshore ECC and south-west of the array area. The Array Area itself is located within an area of moderate potential for sandeel habitat. The Offshore ECC avoids the areas of highest potential sandeel habitat and is situated within moderate potential for sandeel habitat for the majority of the Offshore ECC, except within 12nm of shore, where potential reduces to a low potential.

96. When considering sediment type only, with site-specific PSA surveys data and broadscale BGS sediment data (in the absence of the other useful datasets used in the heatmapping described above) it is found that the majority of the Study Area, and indeed the Central North Sea has preferred sandy habitat for sandeel, and that appropriate sediment for sandeel habitat is widely spread across the Study Area. See **Section 8.6.1.7** and **Figure 8-12** and **Figure 8-13** in **Chapter 8 Marine Physical Processes.**

97. shows a broad area of preferred sandeel habitat within the majority of the Offshore Development Area and the North Sea area (due to widespread sand and gravelly sand preferred by the species), with a small area of unsuitable habitat in the offshore ECC near shore. Sandeel are known not to be present in high numbers across this wide area of potentially suitable habitat, so it is considered that the heatmapping approach set out by Reach *et al. (*2024) provides a more useful picture of likely sandeel habitat distribution.

98. Average mud (particle size <0.63μm) content across all samples in the Offshore Development Area is less than 4% (and therefore suitable, on average, to support significant sandeel assemblages (Holland *et al.,* 2005; Wright *et al.,* 2000).

11.6.1.3.1.2 Herring

99. The preferred sediment habitat for herring spawning is gravel, with some tolerance of more sandy sediments, although these are primarily on the edge of any spawning grounds (Stratoudakis *et al.*1998). Atlantic herring spawning beds are typically small, localised features. Actual spawning habitat, or habitat that could be used for spawning activity, likely comprises relatively small seabed features, with discrete spatial extents, although these may be spread across a wide area of suitable seabed spawning habitat at a regional scale. Eggs are laid on the seabed, usually in water 10m to 80m deep, in areas of gravel, or similar coarse habitats (e.g. coarse sand, shell and maerl), with well oxygenated waters (Ellis *et al., 2*012; Bowers, 1980; de Groot, 1980; Rakine, 1986; Aneer, 1989; Stratoudakis *et al., 1*998).

100. Various spatial datasets with coverage of the Study Area have been utilised to create combined heatmaps of potential herring spawning habitat following the new 2024 MarineSpace methods set out in Kyle-Henney *et al. (*2024). The spatial datasets utilised in heatmapping are Coull *et al. (*1998) spawning grounds, EMODnet sediment data, VMS fishing data (for vessels using pelagic gear) (**Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report** for methods).

101. Based on the herring spawning habitat heatmap (**Figure 11-8**), areas of higher potential for presence of herring spawning are located at offshore ECC, approximately 15km from landfall.

102. Considering, site-specific PSA surveys, the predominant sediment type across the DBD Array Area and offshore ECC is fine to medium sand, see **Section 8.6.1.7** of **Chapter 8 Marine Physical Processes.** This shows the broad lack of suitable herring spawning habitat within the Offshore Development Area (largely to due to a lack of gravelly sediment preferred by the species), with a small area of potential suitable habitat in the near shore offshore ECC, within 12nm from shore (**Figure 11-6**). For context, sediment is considered unsuitable for herring spawning if it has >5% mud content and <10% gravel content (Reach *et al., 2*013). Herring do not spawn in areas without gravel, so this data suggests that the Offshore Development Area is unlikely to represent significant suitable habitat for spawning herring. This trend is mirrored in data collected for a previous iteration of the Offshore ECC, which is also shown in **Figure 11-6** for information.

11.6.1.4 Fish and Shellfish Ecology Receptor Groups

103. The fish and shellfish species identified as having a likely presence within the Study Area can be classified by five receptor groups. These receptor groups have been determined based on the similar biological and behavioural traits of the comprising species, resulting in similar or identical sensitivities to the impacts identified in **Section 11.5.3**. The following receptor groups are therefore used throughout **Section 11.7**:

- Elasmobranchs;
- Demersal fish;
- Pelagic fish;
- Diadromous fish; and
- Shellfish.

104. The baseline environment for each receptor group is set out in **Section 11.6.1.5** to **Section 11.6.1.9**. The full list of species considered for each receptor group, their conservation status, and key aspects of their biology, are found in **Table 11.2-1** of **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report.**

11.6.1.4.1 Underwater Noise Receptor Groups

105. The sensitivity of fish species to underwater noise does not vary according to the receptor groups set out in **Section 102**, but rather varies according whether the fish has a swim bladder, and whether this swim bladder forms part of a specialised hearing system. On this basis, sensitivity groups have been defined by Popper *et al. (*2014), in order of highest to lowest sensitivity as follows:

- Fish with a swim bladder that is used in hearing;
- Fish with a swim bladder that is not used in hearing;
- Fish without a swim bladder; and

- Fish eggs and larvae.

106. Fish with a swim bladder involved in hearing include gadoids (e.g. cod, whiting, and ling), and clupeids (e.g. herring and sprat). Fish with a swim bladder that is not used in hearing include Atlantic salmon and sea trout. Fish without a swim bladder include elasmobranchs and pleuronectiforms (otherwise known as flatfish, e.g. plaice, common sole, and lemon sole).

107. Fish are apportioned into these four receptor groups specifically when assessing the impacts of underwater noise.

11.6.1.5 Elasmobranchs

108. Elasmobranchs are cartilaginous fish, with the group comprising sharks and rays. Both demersal and pelagic elasmobranchs are included in this receptor group.

109. At least 57 species of elasmobranch are known to be present in the North Sea, including 37 sharks, 19 species of skates and rays and one rat-fish species (also frequently called rabbitfish or chimaera) (George, 2009).

110. Based on commercial landings data, the only elasmobranch species identified in the Study Area is the velvet belly, which is a species of dogfish shark, the most common deepwater shark in the North East Atlantic. The species has been recorded in depths of 70m to 2,490m. Velvet belly has no commercial value.

111. As set out in **Section 11.6.1.3** the following elasmobranch species are thought to have nursery grounds overlapping with the Study Area:

- Spurdog; and
- Tope shark.

112. Whilst no other elasmobranch spawning or nursery grounds have been identified in the Study Area, adult elasmobranchs of the following species have been recorded in the Study Area:

- Common skate *Dipturus batis*;
- Thornback ray;
- Spotted ray *Raja montagui;* and
- Basking shark.

113. The conservation status of the species mentioned in the section is set out in **Table 11.2-1** of **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report**.

11.6.1.6 Demersal Fish

114. Demersal fish live on, or in close association with, the seabed. This category therefore includes flatfish, that rest on the sea floor, and benthopelagic fish, such as cod, which occupy the water column immediately above the seabed. Demersal fish are predominantly 'bottom-feeders' – foraging for food on, within, or in close association with, the substrate. The distribution of demersal fish is generally driven by abiotic factors, such as sediment type and hydrodynamic regimes, although predator-prey interactions and interspecific competition is also important.

115. Based on commercial landings data, the key demersal fish species likely to occur in the Study Area are whiting, cod, haddock, sandeels, red mullet, grey gurnard, plaice, dab, turbot, lemon sole, and anglerfish (**Section 11.6.1.2**).

116. Demersal fish species have been identified as having spawning and / or nursery grounds overlapping with the Study Area, as detailed in **Section 11.6.1.3**. These species are:

- Anglerfish (nursery grounds only);
- Blue whiting (nursery grounds only);
- Cod (spawning and nursery grounds);
- Common sole;
- European hake (nursery grounds only);
- Lemon sole (spawning and nursery grounds);
- Ling (nursery grounds only);
- Plaice (spawning and nursery grounds);
- Sandeel sp. (spawning and nursery grounds); and
- Whiting (spawning and nursery grounds).

117. Given their potential sensitivity to Project impacts, and their conservation importance due to their key role as a prey species for seabirds and marine mammals, particular attention is given to sandeels in this assessment. Details of the approach to developing the sandeel baseline are set out in **Section 11.6.1.3.1** and are not repeated here.

118. Of the key demersal species identified within the Study Area, the following have conservation importance (with details of conservation listings in **Table 11.2-1** of **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report:**

- Anglerfish;
- Cod;
- Blue whiting; and

- European hake.

11.6.1.7 Pelagic Fish

119. Pelagic fish inhabit the water column, and are not closely associated with the seabed, unlike demersal fish. Hydrographic factors influence the distribution of pelagic fish, through the direction and distance of drift of larvae and eggs in ocean currents. Bathymetry is also important in the selection of spawning and nursery grounds, whilst biotic factors, such as food availability, influence migration patterns between spawning and feeding grounds (Maravelias, 1999). The environmental factors that drive pelagic fish distribution are highly variable; when combined with the high level of mobility displayed by many pelagic species, this causes the temporal and spatial distribution and abundance of pelagic species to vary significantly interannually.

120. Based on commercial landings data, the key pelagic fish species likely to occur in the Study Area are herring, mackerel, and sprat (**Section 11.6.1.2**).

121. Pelagic fish species have been identified as having spawning and/or nursery grounds overlapping with the Study Area, as detailed in **Section 11.6.1.3**. These species are:

- Herring (spawning and nursery grounds);
- Mackerel (spawning and nursery grounds); and
- Sprat (spawning and nursery grounds).

122. As demersal spawners with specific spawning substrate requirements, herring may be particularly sensitive to Project impacts during their spawning season, and particular attention is given to herring in this assessment. Details of the approach to developing the herring baseline are set out in **Section 11.6.1.3.1** and are not repeated here.

11.6.1.8 Diadromous Fish

123. Diadromous fish are those which spend part of their life at sea and part in freshwater, undergoing migrations between the two environments at key points in their life cycles.

124. A number of migratory fish species, such as Atlantic salmon, sea trout, smelt, European eel, sea lamprey *Petromyzon marinus*, and river lamprey *Lampetra fluivatilis* may pass through the wider fish and shellfish ecology Study Area, after leaving rivers in the area, during their more vulnerable life stage in March, April and early May (Atlantic salmon and sea trout); early spring (smelt) and autumn / winter (adult European eels) (Maitland and Campbell, 1992; Malcolm *et al.,* 2010). Most of these species are protected under a range of international protections (see **Table 11.2-1** of **Volume 2, Appendix 11.2 Fish and Shellfish Ecology Technical Report**).

125. Little is known about the distribution of river and sea lamprey during the marine phase of their lifecycle, as reports are varied, suggesting a wide range and use of habitats (Maitland, 2004). The Humber Estuary and the upstream River Derwent are both important migratory routes for river lamprey and sea lamprey, and these species are designated features of the Humber Estuary SAC and River Derwent SAC on this basis.

126. European eels spawn in the Sargasso Sea (Wright *et al.,* 2022), but there are potentially other, more distant, spawning grounds (Chang *et al.,* 2020), and the routes to and from these spawning grounds for European eels remain unclear. Migrating adult European eels are thought to leave (escape) European rivers in autumn and the early stages of winter (predominantly at night); however, very little is known about their behaviour at this time (Orpwood *et al.,* 2015). Studies have reported that eels have been found swimming at depths of 1m to 17m (averaging around 10m depth), with individuals spending very little time on the seabed. It is thought that eels spend very little time low down in the water column due to water temperature below the thermocline being too low. Spring and summer seasonal thermoclines in the Irish Sea will generally fall between 15m to 25m depth. Elvers or young eels generally enter the inland waters of the UK between February and April (also predominantly at night) (Bruijs and Durif, 2009). The young eels (elvers) may also enter the rivers around the Humber Estuary in spring (English Nature, 2000).

127. Atlantic salmon is a widespread species in the UK and is found in several hundred rivers, many of which have adult runs in excess of 1,000. Scottish rivers are the most important in terms of spawning sites. No rivers south of the Esk in Yorkshire (not to be confused with the Esk in the Scottish borders) or east of the Itchen in Hampshire are classified as salmon rivers. This means there are no important salmon rivers on the east coast south of the Study Area. The River Eden flowing into the Humber Estuary is also not classed as a salmon river (Cefas, 2023). The river Esk (Yorkshire) is classed as a salmon river and outflows at Whitby, which is within the Study Area. Forty-three Atlantic salmon were caught with rods in the River Esk (Yorkshire) in 2021 (Environment Agency, 2022).

128. The marine migratory routes of diadromous fish as they transit to and from the Humber Estuary and surrounding rivers, such as the Esk, are unknown, it is therefore assumed that they may transit through the Study Area during their annual migrations.

11.6.1.9 Shellfish

129. The shellfish receptor group comprises the commercially important marine invertebrates present within the Study Area. Other marine invertebrates are considered within **Chapter 10 Benthic and Intertidal Ecology**.

130. The key species identified (see **Section 11.6.1.2**) are:

- European lobster;
- Brown crab;
- King scallops;
- Common whelk;
- Nephrops;
- Velvet crab; and
- Squid.

131. Shellfish are the most important group commercially within the Study Area, and also make up the majority of landings by weight (**Table 11-14**).

132. Given that in general the identified shellfish species have lower mobility and higher site fidelity in comparison to fish species (although it is acknowledged that squid and some crab species undergo annual migrations for breeding), it is assumed that all identified shellfish species spawn within the Study Area.

11.6.2 Predicted Future Baseline

133. The existing baseline conditions within the Study Area described above are considered to be relatively stable. The fish and shellfish baseline environment of the North Sea is primarily influenced by global environmental factors and by commercial fishing activity.

134. The baseline will continue to evolve as a result of global trends which include the effects of climate change, such as increasing sea levels and sea surface temperature, as well as trends at the regional and European level such as changes in fisheries regulations and policies.

135. As a result of The Dogger Bank SAC (Specified Area) Bottom Towed Fishing Gear Byelaw 2022, which prohibits the use of bottom-towed fishing gear within the Dogger Bank SAC, impacts from fishing will be significantly reduced as long as the byelaw remains in place.

136. In addition, in March 2024, the UK government decided to prohibit the fishing of sandeels within English waters of ICES Area 4 (North Sea)[4]. The biological community composition of seabed habitats previously targeted by sandeel fisheries can therefore be expected to undergo change over the coming decade due to the removal of this pressure, should this prohibition remain in place.

11.7 Assessment of Effects

137. The likely significant effects to fish and shellfish ecology receptors that may occur during construction, operation and decommissioning of the Project are assessed in the following sections. The assessment follows the methodology set out in **Section 11.5** and is based on the realistic worst-case scenarios defined in **Section 11.4.4**, with consideration of embedded mitigation measures identified in **Section 11.4.3**.

11.7.1 Potential Effects during Construction

11.7.1.1 Temporary Habitat Loss / Physical Disturbance (FSE-C-02)

138. There is potential for direct physical disturbance of the seabed, and for temporary habitat loss during construction, from activities such as the installation of foundations and cables, seabed preparation, sandwave levelling, and jack-ups. The physical disturbance and temporary habitat loss associated with these construction phase activities have the potential to affect fish and shellfish species, including species for which spawning, or nursery grounds have been defined, as well as those with designated conservation status.

139. The disturbance in the Study Area would be temporally and spatially limited during construction activity, with any disturbance occurring episodically and remaining localised to the activity being carried out at that time (see **Chapter 4 Project Description** for full details of Project infrastructure and construction activities).

140. Siting infrastructure upon the seabed, whether foundation installation, scour protection, or cable protection, will cause a loss/alteration of habitat which will remain throughout the operational phase. It is acknowledged that this impact begins in construction, but it is assessed in detail in for operation (**Section 11.7.2.2**) to avoid duplication of text and assessments, as agreed with the Planning Inspectorate (**Volume 2, Appendix 11.1 Consultation Responses for Fish and Shellfish Ecology**).

1.

[4] https://www.gov.uk/government/consultations/consultation-on-spatial-management-measures-for-industrial-sandeel-fishing/outcome/government-response

11.7.1.1.1 Receptor Sensitivity

11.7.1.1.1.1 Elasmobranchs, Demersal Fish, Pelagic Fish, and Diadromous Fish

141. Pelagic spawning fish species have large spawning grounds with no reliance on specific substrate to lay eggs upon. Habitat loss and disturbance to the seabed therefore has limited capability to affect the spawning of these species.

142. The most sensitive species to this impact are demersal spawners, namely herring and sandeel, which have spawning periods from August to September (herring) and November to February (sandeel) (see **Table 11-16**). These species have a heightened sensitivity to any disturbance of the seabed, and are therefore considered more sensitive to temporary habitat loss / physical disturbance, especially related to spawning and nursery areas.

143. Whilst the nursery grounds of many species overlap with the Study Area, the areas impacted by construction disturbance are small, relative to the size of the entire main nursery grounds, which extend around much of the English and Scottish east coast.

144. Juvenile stocks of fish are less sensitive to physical disturbance than spawning adults, as they have high levels of adaptability and tolerance to transient stress and disturbance, with an ability to move away from construction activities. Furthermore, based on their extensive occurrence within the wider geographic context, any potential disturbance to these areas, due to construction operations, is not predicted to have a significant impact on juvenile fish survival.

145. Other than sandeel all other species in these receptor groups have high levels of mobility and are, therefore, capable of navigating away from any temporary habitat loss / physical disturbance caused by construction activities (EMU, 2004).

146. The sensitivity of sandeel and herring (during spawning season) is therefore considered to be **medium**.

147. The sensitivity of other elasmobranchs, demersal fish, pelagic fish (including herring outside of spawning season), and diadromous fish species is considered to be **low**.

11.7.1.1.1.2 Shellfish

148. The key crustacean species potentially present within the Study Area include, brown crab, brown shrimp, velvet crab, European lobster and Nephrops. All of the above species are relatively mobile and would generally be able to move away from any area of seabed disturbance, although to a lesser extent than fish species. However, it is acknowledged during certain periods, some species exhibit higher site fidelity such as overwintering berried female brown crab. These egg bearing females remain buried and stationary in the sediment over winter periods, whilst eggs mature. They therefore have limited capacity to move away from physical disturbance at a key period in their reproductive cycle.

149. Of the mollusc species assessed, common whelk and king scallops are generally sessile, or at least slow-moving, and therefore have limited tolerance and adaptability to seabed disturbance. Squid are the exception, and being pelagic have much greater capacity to move away from disturbance.

150. Taken together, given the overall reduced tolerance and adaptability compared to fish species, the sensitivity of shellfish is considered to be **medium**.

11.7.1.1.2 Impact Magnitude

151. As detailed in **Section 11.4.4**, a maximum area of approximately 33,885,742m^2 of seabed habitat within the Study Area would be temporarily disturbed or lost/altered during the construction phase. This represents approximately 0.05% of the Study Area.

152. 17,248,642m^2 of seabed will be disturbed within the DBD Array Area, whilst 16,637,100m^2 will be disturbed along the offshore ECC .

153. Whilst some construction activities may occur during the spawning periods of herring and sandeel, these activities are limited in their duration, thus potential effects are predicted to be minimal. As previously stated, based on site specific PSA analysis, suitable sandeel spawning habitat is widely distributed, and therefore not sensitive to highly localised effect.

154. **Figure 11-5** and **Figure 11-6** demonstrates the limited overlap between the Project Area activities with herring spawning grounds and sandeel habitat in comparison the extent of suitable habitat in the wider region.

155. Preferred herring spawning habitat is restricted to the inshore area (within 12nm) (**Figure 11-6** and **Figure 11-8**), however the potential impact of construction activities in this inshore area are mitigated by the embedded commitment to use trenchless techniques, which will avoid Temporary Habitat Loss / Physical Disturbance up to a depth of greater than 5m below mean high water springs. For the remainder of cable laying activity from the trenchless technique cable exit point out to 12nm, the potential disturbance effects of offshore cable laying activities are temporary (suitable sediment type for spawning is expected to return to baseline conditions within one spawning season) and are highly limited in spatial extent, often depositing suspended seabed sediments within a few metres either side of the cable plough, which has a disturbance width of 15m.

156. Recovery of sandeel populations would be expected following construction activities, with the rate of recovery dependent on the recovery of sediments to a condition suitable for sandeel recolonisation. Effects of offshore wind farm construction (Jensen *et al.,* 2004) and operations and maintenance (i.e. post-construction) activities (van Deurs *et al.,* 2012) on sandeel populations have been examined through short term and long term monitoring studies at the Horns Rev offshore wind farm in the Baltic Sea, Denmark. These monitoring studies have shown that offshore wind farm construction and operations, and maintenance, activities have not led to significant adverse effects on sandeel populations and that recovery of sandeel occurs quickly following construction activities.

157. A monitoring study was conducted at the Beatrice Offshore Wind Farm, undertaking a post construction sandeel survey, where sandeel abundance was compared pre and post construction (BOWL, 2021). The results showed that sandeel abundance either increased or remained at similar levels, when comparing abundance from 2014 to 2020, with offshore construction commencing in April 2017.

158. The disturbance in the Study Area would be temporally and spatially limited during construction activity, with any disturbance occurring episodically and remaining localised to the activity being carried out at that time. Infrastructure installation would not occur simultaneously across the Project Area during the construction phase, and once construction / infrastructure installation works are complete in a specific area, recovery of sediments and associated communities are expected to begin soon after (see **Section 10.7.1.1** in **Chapter 10 Benthic and Intertidal Ecology**).

159. The magnitude of impact is therefore considered to be **low.**

11.7.1.1.3 Effect Significance

160. Overall, it is predicted that sensitivity of herring (during spawning season), sandeel, and shellfish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

161. It is predicted that sensitivity of elasmobranchs, demersal fish, pelagic fish (including herring outside of spawning season), and diadromous fish is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

162. No additional mitigation is required.

11.7.1.2 Increased Suspended Sediment and Sediment-Redeposition (FSE-C-04)

163. During construction activities, there may be a temporary increase in SSCs and sediment-redeposition. Suspended sediment has the potential to impair respiratory, filter feeding or reproductive functions, including the disruption of migration / spawning activity. Sediment deposition, especially if it changes the characteristics of the existing seabed sediments, could affect the quality of spawning and nursery habitats.

164. Sands and silts released during seabed preparation and foundation construction activities would be temporarily deposited on the seabed, and are then more likely to be remobilised and redistributed through natural hydrodynamic processes than gravels and clays, which are likely to remain on the seabed for a longer period of time after settlement.

165. As discussed in **Chapter 8 Marine Physical Processes**, the Project Area is predominantly composed of fine to medium sand. Based on the sediment sizes present, in combination with data on the hydrodynamic regimes present, finer suspended sediment is predicted to travel as a passive plume which will extend up to 35.4km from the project activity causing the suspension at source. Other coarser sediments will settle quickly in proximity to their release, within a few hundred metres from the construction activity.

11.7.1.2.1 Receptor Sensitivity

11.7.1.2.1.1 Elasmobranchs, Demersal Fish, Pelagic Fish

166. Adult fish within these receptor groups are highly mobile, and should they encounter an area of increased sediment loading, they are capable of navigating away and avoiding the area. As these species are all highly mobile, there is low risk of smothering or burial, even for demersal fish. This also applies to juvenile fish, which are also mobile and accustomed to average background levels of approximately 2mg/l in the Array area to approximately 15mg/l in the first 10km of the offshore ECC (from the coast to Flamborough Head) and also experience natural increased SSCs up to 3000mg/l during storm events (see **Section 8.6.1.10** in **Chapter 8 Marine Physical Processes**). As demonstrated by these data, increased SSC is naturally more prevalent in nearshore regions.

167. If individuals encounter increased SSC during foraging, there could be a potential effect upon their feeding success from the increased water column sediment loading (Robertson *et al., 2*006). As the increased sediment loading would be relatively short-term (occurring intermittently over part of the construction period) and localised in nature, the likelihood of individuals of these receptor groups encountering an area of increased sediment loading is low. Encounters may be more likely for demersal elasmobranchs and non-elasmobranch demersal fish. Elasmobranch species are more heavily reliant on electromagnetic sensors (e.g. Ampullae of Lorenzini) than visual cues when hunting prey within wide-ranging hunting grounds and are therefore considered tolerant and adaptable to an increase in SSC and sediment settlement. Fish that rely on visual cues for foraging are mobile and will be able to move away from areas of temporarily increased SSC.

168. The sensitivity of the adult and juvenile elasmobranchs, demersal fish, and pelagic fish is therefore considered to be **low**.

169. Most sensitive to this impact are the eggs and larvae of demersal spawners, namely herring and sandeel, which have spawning periods from August to September (herring) and November to February (sandeel) (see **Table 11-16**). The eggs and early-stage larvae of these species have the potential to be smothered by sediment re-deposition.

170. Sandeels have a high degree of site fidelity, driven by a preference for substrate comprised of medium and coarse sand with low silt content for spawning, predation cover and for hibernation. 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., 2*007). Sandeels deposit eggs on the seabed in the vicinity of their burrows between December and January. Grains of sand tend to cling to the eggs and currents often cause the eggs to be covered 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 lowered oxygen concentration, can delay hatching periods, which is considered a necessary adaptation to survival in a dynamic environment (Pérez-Dominguez and Vogel, 2010; Hassel *et al., 2*004). In addition to this, Pérez-Dominguez and Vogel (2010) observed that increased SSCs and smothering to be inconsequential to larval and juvenile sandeels.

171. With regard to the effect of increased SSC and re-deposition of sediments on herring and their spawning activity, previous studies have found that herring eggs are tolerant to elevated SSCs as high as 300mg/l and can tolerate short term exposure (one day) at levels up to 500mg/l (Kiørboe *et al., 1*981). Messieh *et al. (*1981 study), as cited in Engell-Sørensen and Skyt (2001), recorded that herring eggs successfully hatch at SSCs of 7,000mg/l, although the size at hatching was larger when SSCs were lower. These studies conclude that herring eggs suffer no adverse effects from suspended sediment concentrations in excess of the maximum levels expected from the Project during construction, which are 1,700mg/l during trenching of the cable in the immediate locality of trenching. It should be noted that although the survival and development of herring eggs appear to be insensitive to high SSCs, deposition of sediment is expected to be detrimental unless the sediment is quickly removed by currents (Birklund and Wijsmam, 2005). Newly hatched larvae will have limited ability to emerge from sediment if buried by deposition.

172. Site-specific modelling for the Project shows the greatest change in seabed level (via re-deposition) occurs during the seabed trenching phase of cable laying within the offshore ECC with an increase in seabed height of up to about 0.14m for Option 1 and 0.19m for Option 2 predicted within and immediately adjacent to the area of trenching (**Figure 8-27** and **Figure 8-28** of **Chapter 8 Marine physical Processes**). During the sand wave levelling phase, changes in seabed level are spatially restricted to the area of levelling and are typically less than 0.01m. This means that there is potential for highly localised burial of demersal herring eggs in the inshore section of the offshore ECC (see **Figure 11-6** and **Figure 11-8)**, should inshore cable laying works coincide with herring egg deposition. Other areas of the offshore ECC have been shown to be unsuitable for herring spawning (**Figure 11-6** and **Figure 11-8**). This deposition is localised to the immediate vicinity of the cable (see **Figure 8-28** of **Chapter 8 Marine Physical Processes**), leaving the vast majority of the inshore herring spawning ground unimpacted. There is only a pathway for effect during the approximately 2 week period that herring eggs and newly hatched larvae remain upon the seabed (Russel, 1976), in comparison to a herring spawning period (characteristic of the Banks North Sea Autumnal Spawning population in question) that based on work done in the vicinity of the Project, occurs over August to October, but is likely to peak during September (EGL2, 2024; DBS, 2024). Should this temporal overlap of cable trenching works and herring egg deposition occur within the nearshore section of the offshore ECC, the localised nature of any egg/larval burial due to re-deposition, means that the potential for meaningful impact on the reproductive success of the Banks North Sea Autumnal Spawning population is highly limited.

173. Whilst the eggs and larvae of pelagic spawners will have lower sensitivity than demersal spawners, there is some evidence that increased SSC may adhere to pelagic eggs and increase the egg sinking rates (Westerberg *et al., 1*996; Griffin *et al., 2*009). Whilst this does not necessarily inhibit larval development and survival, there may be increased risk of oxygen depletion if eggs on the seabed are subsequently smothered by sediment redeposition.

174. Taken together, despite their tolerance to increased SCC, due to their increased sensitivity to smothering, the sensitivity of the eggs and larvae of elasmobranchs, demersal fish, and pelagic fish, is considered to be **medium**.

11.7.1.2.1.2 Diadromous Fish

175. Migrating diadromous fish may encounter areas of increased SSC during migration to or from freshwater, during the construction phase. However, given the limited spatial extent of SSC plumes, the episodic and short-term nature of their generation, the likelihood of migratory, or marine resident, diadromous fish encountering an area of increased water column sediment loading is low. Furthermore, as they are highly mobile species, should they encounter an area of increased SSCs, they are capable of moving to avoid the area.

176. In addition, given that diadromous fish migrate through estuarine environments, they are naturally tolerant to short term increases in SSC. For example, eels and lamprey tolerate silty, turbid and poor light conditions (Behrmann-Godel and Eckmann, 2003; Hansen *et al., 2*016; Christoffersen *et al., 2*018).

177. As these diadromous fish are all highly mobile, and active in the water column above the seabed, there is no risk of smothering or burial.

11.7.1.2.1.3 Shellfish

178. Crustacean species (brown crab, velvet crab, European lobster, Nephrops) are mobile and can move away from areas of increased water column sediment loading. Some species, including Nephrops, are particularly tolerant to a degree of smothering (Johnson *et al., 2*013). According to the MarESA, shellfish species, such as brown crab, have a low sensitivity to increased SSCs.

179. Common whelk and king scallops have limited mobility with which to move away from areas of increased water column sediment loading, or to prevent themselves from being smothered. However, these species tend to show tolerance to increased SSCs (Mainwaring *et al., 2*014).

180. Similarly to fish, the main sensitivity of shellfish relates to early life stages, particularly eggs. Berried crustaceans such as brown crab may experience lower oxygen concentrations during key stages of egg development, which may reduce the success or quality of larvae within the area of effect. However, berried crustaceans actively fan their eggs to maintain waterflow and oxygenation, and the rate of fanning can be increased to adapt to lower dissolved oxygen levels. Berried females also have the ability to move out of areas with high sediment deposition rates, and therefore mitigate the risk of smothering their eggs (Neal and Wilson, 2008).

181. Given reduced mobility leading to a higher potential for smothering, the sensitivity of shellfish is therefore considered to be **medium**.

11.7.1.2.2 Impact Magnitude

182. The total worst-case scenario volume of sediment with the potential to cause increased suspended sediment and sediment-redeposition associated with the construction phase is 113,525,955m^3 (**Table 11-7**).

183. As detailed in **Chapter 8 Marine Physical Processes**, increased suspended sediment and sediment-redeposition would only occur for a limited duration at specific locations (e.g. piling location), at any given time. Increases in SSCs would occur 20km from release, with any meaningful re-deposition occurring in the immediate vicinity of works.

184. The nature of the impact is short-term, episodic over the construction period, and localised. The predicted suspended sediment concentrations are highest closest to the points of release with maximum of 1mg/l in the surface layer increasing to 2mg/l in the bottom layer. Therefore the magnitude of increased SSC is predicted to be comparable to natural storm events (potentially up to 300mg/l) and therefore within the range of natural variation.

185. The magnitude of impact is therefore considered to be **low**.

11.7.1.2.3 Effect Significance

186. Overall, it is predicted that sensitivity of adult and juvenile elasmobranchs, demersal fish, and pelagic fish is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

187. It is predicted that sensitivity of the eggs and larvae of elasmobranchs, demersal fish, and pelagic fish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

188. It is predicted that sensitivity of shellfish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

189. No additional mitigation is required.

11.7.1.3 Remobilisation of Contaminated Sediments if Present - Offshore ECC (FSE-C-06)

190. Sediment chemical composition within the Study Area is informed by the site-specific surveys undertaken across the DBD Array Area and ECC (see **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**).

191. Surveys undertaken in 2023 provided justification for the scoping out of this impact for the DBD Array Area, however given that a section of the offshore ECC was not surveyed in 2023, this impact remained scoped in for further consideration in light of 2024 survey results for the offshore ECC, which are now available and inform this PEIR.

192. As detailed in **Section 9.6.1.1** of **Chapter 9 Marine Sediment and Water Quality**, recent sediment survey results show that the sediment contamination within the ECC is **negligible**. All contaminant levels across the Offshore Development Area are below relevant Action levels (ALs). This is likely due to the fact that sediment contaminants are typically associated with mud and silt particles, which have limited distribution within the Offshore Development Area. As they are associated with mud and silt particles, any contaminants will not remain in the water column for a significant length of time, and will not travel a great distance from their point of origin. Any contaminant dispersal will occur at very low levels, given the minimal contaminants identified across the Offshore Development Area, with any dispersal remaining under the significant contaminant level thresholds (see **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**). Therefore, should sediment be disturbed during any phase of the Project, there is no pathway for effect.

193. There is therefore no pathway for effect on fish and shellfish receptors and the significance of effect is **negligible** for all receptor groups.

194. No additional mitigation is required.

11.7.1.4 Underwater Noise and Vibration (FSE-C-07)

195. By listening to the sounds around them, fish can obtain substantial information about their environment and some species use sound to communicate (Popper *et al.,* 2019); Popper and Hawkins, 2019). Each species has differing sensitivity to noise and, therefore, the potential impact of a given underwater sound on different species of fish may vary. Anthropogenic sounds can be so intense as to result in death or mortal injury, or lower sound levels may result in temporary hearing impairment, physiological changes including stress effects, changes in behaviour or the masking of biologically important sounds (Popper and Hawkins, 2019; Kastelein *et al., 2*017).

196. Relatively few experiments on the hearing of fish have been carried out under suitable acoustic conditions, and only a few species have valid data that provide actual thresholds (Popper and Hawkins, 2019). However, studies on how noise affects fish and shellfish species have brought to light that there is a lack of clear evidence supporting defined thresholds. This is due to the focus only on sound pressure, and not particle motion, when the latter may be critical to understanding the importance of sound to fish and invertebrates (Popper and Hawkins, 2018).

197. 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., 2*014). These have highlighted some of the shortcomings of impact assessments, including the use of broad criteria for injury and behavioural effects, based on limited studies. The effects of particle motion are not well understood but are considered to be more important for many fish and shellfish species, and particularly invertebrates (i.e. including shellfish), than sound pressure, which has been the main consideration in noise impact assessments to date.

198. The most recent and relevant guidelines for the purposes of this assessment, are the Acoustical Society of America (ASA) Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al., 2*014). These guidelines provide directions and recommendations for setting criteria (including injury and behavioural criteria) for fish. The Popper *et al. (*2014) guidelines broadly group fish into the following categories, based on their anatomy and the available information on hearing of other fish species with comparable anatomies:

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

199. As set out in **Section 11.6.1.4.1**, the four hearing sensitivity groups set out above are the relevant receptor grouping for impact assessment.

200. There have been some studies on the ability of aquatic invertebrates (including shellfish) to respond to noise (e.g. de Soto *et al.,* 2013; Wale *et al.,* 2013; Roberts *et al.,* 2016; Stenton *et al.,* 2022). Whilst these studies demonstrated the potential for noise to negatively impact invertebrates, they are insufficient to make firm conclusions about sensitivity or threshold noise levels where impacts begin to occur. It is highly likely, however, that aquatic invertebrates do detect particle motion, including seabed vibration, and existing evidence indicates these species are primarily sensitive to particle motion at frequencies well below 1kHz (Hawkins and Popper, 2016).

11.7.1.4.1 Injury Criteria

201. The injury criteria used in this noise assessment for impulsive piling are given in Table 11-17. Physiological effects relating to injury criteria are described below (Popper *et al.,* 2014; Hawkins and Popper, 2016):

- **Mortality and potential mortal injury**: Either immediate mortality or tissue and / or physiological damage that is sufficiently severe (e.g. a barotrauma) that death occurs sometime later, due to decreased fitness. Mortality has a direct effect upon animal populations, especially if it affects individuals close to maturity;
- **Recoverable injury**: Tissue and other physical damage, or physiological effects, that are recoverable, but which may place animals at lower levels of fitness, may render them more open to predation, infection, impaired feeding and growth, or lack of breeding success, until recovery takes place; and
- **Temporary Threshold Shift (TTS)**: Short term changes in hearing sensitivity may, or may not, reduce fitness and survival. Impairment of hearing may affect the ability of animals to capture prey and avoid predators, and also cause deterioration in communication between individuals, affecting growth, survival, and reproductive success. After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure.

202. Where insufficient data are available to inform threshold criteria for noise-induced effects, Popper *et al. (*2014) also gives qualitative criteria that summarise the effect of the noise as having either a high, moderate, or low effect on an individual, in either the near-field (tens of metres), intermediate-field (hundreds of metres), or far-field (thousands of metres). These qualitative effects are also included in Table 11-17 (for impulsive piling), Table 11-18 (for continuous noise sources) and Table 11-19 (for explosions e.g. UXO clearance).

11.7.1.4.2 Particle Motion

203. The criteria defined in Table 11-17, Table 11-18 and Table 11-19 all define the noise impacts on fish in terms of sound pressure, or sound pressure-associated functions (i.e. SEL). It has been identified by researchers (e.g. Popper and Hawkins, 2019; Nedelec *et al.,* 2016; Radford *et al.,* 2012) that many species of fish, as well as invertebrates, actually detect particle motion, rather than acoustic pressure. Particle motion describes the back-and-forth movement of a tiny theoretical 'element' of water, substrate or other media, as a sound wave passes, rather than the pressure caused by the action of the force created by this movement. Particle motion is usually defined in reference to the velocity of the particle (often a peak particle velocity), but sometimes the related acceleration or displacement of the particle is used.

Table 11-17 Criteria for Mortality and Potential Mortal Injury, Recoverable Injury and TTS in Species Of Fish due to Impulsive Piling (Popper et al., 2014) (Near = tens of metres; Intermediate =hundreds of meters; Far = thousands of metres

Type of animal	Species included	Parameter	Mortality and potential mortal injury	Recoverable injury	TTS
Group 1 Fish: no swim bladder (particle motion detection)	• All elasmobranchs • Sandeel • Common sole • Plaice • Mackerel • Lampreys • Lemon sole • Anglerfish	Sound exposure level (SEL), dB re 1 μPa²s	>219	>216	>>186
		Peak, dB re 1 μPa	>213	>213	-
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	• Atlantic salmon • Sea trout • Smelt	SEL, dB re 1 μPa²s	210	203	>186
		Peak, dB re 1 μPa	>207	>207	-

Type of animal	Species included	Parameter	Mortality and potential mortal injury	Recoverable injury	TTS
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	• Sprat • Ling • Hake • European eel • Cod • Whiting • Ling • Blue ling • Atlantic herring • European bass	SEL, dB re 1 μPa^{2}s	207	203	186
		Peak, dB re 1 μPa	>207	>207	-
Eggs and larvae	• All species	SEL, dB re 1 μPa^{2}s	>210	(Near) Moderate (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
		Peak, dB re 1 μPa	>207		

Table 11-18 Criteria for Mortality and Potential Mortal Injury, Recoverable Injury and TTS in Species Of Fish from Continuous Noise Sources (Popper et al., 2014) (Near = tens of metres; Intermediate =hundreds of meters; Far = thousands of metres)

Type of animal	Species included	Mortality and potential mortal injury	Recoverable injury	TTS
Group 1 Fish: no swim bladder (particle motion detection)	• All elasmobranchs • Sandeel • Common sole • Plaice • Mackerel • Lampreys • Lemon sole • Anglerfish	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	• Atlantic salmon • Sea trout	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	• Sprat • Ling • Hake • European eel • Cod • Whiting • Ling • Blue ling • Atlantic herring • European bass	(Near) Low (Intermediate) Low (Far) Low	170 dB re 1 μPa (rms) for 48 hours	158 dB re 1 μPa (rms) for 12 hours
Eggs and larvae	• All species	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low

Table 11-19 Criteria for Potential Mortal Injury in Species of Fish from Explosions (Popper et al., 2014). (Near = tens of metres; Intermediate = hundreds of meters; Far = thousands of metres)

Type of animal	Species included	Mortality and potential mortal injury	Recoverable injury	TTS
Group 1 Fish: no swim bladder (particle motion detection)	• All elasmobranchs • Sandeel • Common sole • Plaice • Mackerel • Lampreys • Lemon sole • Anglerfish	229 –234 dB peak	(Near) High (Intermediate) Low (Far) Low	(Near) High (Intermediate) Moderate (Far) Low
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	• Atlantic salmon • Sea trout	229 –234 dB peak	(Near) High (Intermediate) High (Far) Low	(Near) High (Intermediate) Moderate (Far) Low

Type of animal	Species included	Mortality and potential mortal injury	Recoverable injury	TTS
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	• Sprat • Ling • Hake • European eel • Cod • Whiting • Ling • Blue ling • Atlantic herring • European bass	229 –234 dB peak	(Near) High (Intermediate) High (Far) Low	(Near) High (Intermediate) High (Far) Low
Eggs and larvae	• All species	> 13 mm/s peak velocity	(Near) High (Intermediate) Low (Far) Low	(Near) High (Intermediate) Low (Far) Low

204. Note that species in the "Fish where swim bladder is involved in hearing" category (Groups 3 and 4), which are the species most sensitive to noise, are also sensitive to sound pressure. Popper and Hawkins (2018) stated that, in derivation of the sound pressure-based criteria in Popper *et al. (*2014), it may be the unmeasured particle motion detected by the fish, to which the fish were responding: there is a relationship between particle motion and sound pressure in a medium. This relationship is very difficult to define where the sound field is complex, such as close to the noise source, or where there are multiple reflections of the sound wave in shallow water. Even these terms "shallow" and "close" do not have simple definitions. The primary reason for the continuing use of sound pressure as the criteria, despite particle motion appearing to be the physical measure to which so many fish react or sense, is a lack of data (Popper and Hawkins, 2018), both in respect of predictions of the particle motion level as a consequence of a noise source, such as piling, and a lack of knowledge of the sensitivity of a fish, or a wider category of fish, to a particle motion value. There continue to be calls for additional research on the effects of particle motion on fish. Until sufficient data are available to enable revised thresholds based on the particle motion metric, Popper *et al. (*2014) continues to be the best source of criteria in respect to fish impacts (Andersson *et al., 2*017; Popper and Hawkins, 2019).

11.7.1.4.3 Underwater Noise Modelling

205. In order to assess the potential effects of underwater noise generated during construction, operation and maintenance, and decommissioning of the Project, modelling has been carried out. Details of the modelling undertaken are presented in **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**. A summary of this modelling is presented in this section.

11.7.1.4.3.1.1 Pile Driving

206. Modelling of pile driving sound propagation has utilised the INSPIRE v5.2 (Impulsive Noise Propagation and Impact Estimator) sub-sea noise propagation model (see **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**). The INSPIRE model is a semi-empirical noise propagation model, based on the use of a combination of numerical modelling and actual measured underwater noise data. It was designed to calculate the propagation of noise in shallow and mixed water, typical of both conditions around the UK (see **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report** for further details).

207. The modelling considers a wide array of input parameters, including variations in bathymetry and source frequency content, to ensure as detailed results as possible. It should also be noted that, the results presented in this assessment are precautionary, as the worst-case parameters have been selected for:

- Piling hammer energies;
- Soft-start, ramp-up profile and strike rate;
- Duration of piling; and
- Receptor swim speeds.

208. Underwater noise (both sound pressure and particle motion) generated during the installation of the wind turbine and offshore platform (OSP) foundations (pile driving), and by work vessels involved in the installation of cables, wind turbines and OSP(s) (vessel noise) can potentially cause changes to fish and shellfish species in terms of physical injury, physiological stress, mortality or behavioural effects (such as avoidance or acoustic masking).

209. Prior to piling, UXO clearance may be required. Various possible types and sizes of UXO were also modelled (see **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report** for further details). As any UXO clearance would be subject to a separate marine licence, effects are presented for information only and UXO clearance is presented in the cumulative assessment.

210. Pile driving sound modelling was undertaken at four locations within the DBD Array Area:

- North-east corner;
- North-west corner;
- South-east corner; and
- Central (at the location of the Offshore Platform).

211. The above modelling locations were chosen to ensure a representative range of piling noise propagation scenarios, and sensitivity testing was undertaken to ensure that a deep modelling location was chosen, which will provide for greater noise propagation and a representative worst-case.

212. Modelling was undertaken for both monopiles and pin piles, with monopiles producing the worst-case impact ranges. Monopile modelling took into account an 18m diameter pile, with 8,000kJ maximum hammer energy, and two piles driven within 24 hours. Pin pile modelling took into account a 5m diameter pile, with 5,000kJ maximum hammer energy, and four piles driven within 24 hours.

213. The modelled sound levels are interpreted in relation to the Popper *et al.* (2014) thresholds set out in Table 11-17, taking into account both instantaneous (SPL_{peak}) and cumulative (SEL_{cum}) effects. Given the water depths, the north-west modelling location produced the worst-case impact ranges and is presented here. Results for other modelling locations are presented in **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**.

214. To determine the potential for impacts from cumulative sound exposure levels (SEL_{cum}), the soft-start, ramp-up, hammer energy, total duration and strike rate are taken into account. After a soft start, the hammer energy would increase (ramp-up) to the maximum hammer energy required to safely and effectively install the pile.

215. The worst-case piling schedule used to model SEL_{cum} for monopiles and pin-piles is summarised in Table 11-20.

Table 11-20 Pile Driving Modelling Parameters, Including Hammer Energy (kJ), Soft Start and Ramp-Up, and Piling Duration

Parameter	Soft start	Ramp-up	Maximum hammer energy
1 x Monopile			
Hammer energy (kJ)	800	Gradual	8,000
Number of strikes	600	1,800	7,200
Strikes per minute	30	30	30
Duration (minutes)	20	60	240
Total duration (Two piles per 24 hours) is 10.67 hours piling per day			
1 x Pin pile			
Hammer energy (kJ)	500	Gradual	5,000
Number of strikes	600	1,800	7,200
Strikes per minute	30	30	30
Duration (minutes)	20	60	240
Total duration (Four piles per 24 hours) is 21.33 hours piling per day			

216. The following conservatisms are also built into the assessment:

- The maximum hammer energy to be applied and maximum piling duration is assumed for all piling locations; however, as described above, it is unlikely that maximum hammer energy and duration would be required at the majority of piling locations. This because it is expected that soft sandy / silty substrates would be encountered in the majority of piling locations, as evidenced by the site specific grab sampling surveys (see **Section 4.6** in **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**), and therefore less energy would be required to drive the pile into the seabed;
- Piling would not be constant during the piling phases and construction periods. There would be gaps between the installation of individual piles, and, if installed in groups, there could be time periods when piling is not taking place as piles are transported out to the site. There would also be potential delays for weather or other technical issues;

- The duration of piling is based on a worst-case scenario and a very precautionary approach and, as has been shown at other offshore wind farms, the duration used in the impact assessment can be overestimated. For example, during the installation of monopile foundations at the Dudgeon Offshore Windfarm, the impact assessment was based on a likely worst-case estimated time to install each monopile of up to 4.5 hours (in comparison to 5.33 hours for this Project) and the estimated duration of active piling was 301.5 hours (approximately 13 days). However, the actual total duration of active piling to install the 67 monopiles was 65 hours (approximately three days), with the average time for installation per monopile of 71 minutes; approximately 21% of the predicted maximum piling duration (DOWL, 2016);
- The sound produced by each hammer strike is assumed to remain constant over the duration of piling. However, evidence suggests that the sound levels produced by each strike reduce as the pile is driven further into the seabed (Thompson *et al.*, 2020); and
- All fish receptors are assumed to be stationary for the duration of piling, including sequential piling.
- The modelling assumes that the sound produced from each pile strike remains impulsive in character at all distances from the source. In reality, the evidence shows that piling noise loses its impulsive nature over tens of kilometres and transitions to a non-impulsive sound type. This means that if impact ranges are stated to occur at distances greater than tens of kilometres, this is likely to be precautionary and an overestimate (Southall, 2021).

11.7.1.4.3.1.2 Sequential Piling

217. Underwater noise modelling has been undertaken to cover the possible option for more than one pile to be installed, one after the other, in the same 24-hour period. The modelling was based on the worst-case for four pin-piles installed sequentially or two monopiles installed sequentially.

218. This has resulted in a scenario where the worst-case impact ranges for instantaneous (SPL_{peak}) impacts arise from monopiles (due to the higher maximum hammer energy and pile diameter), whereas the worst-case for cumulative (SEL_{cum}) impact within 24-hours arises from pin-piles.

219. Both pin pile and monopile modelling results are presented in this section, and the worst-case impact ranges are used to inform the assessment (regardless of whether they arise from pin piles or monopiles).

11.7.1.4.3.1.3 Modelling Results

220. Table 11-21 presents the results of the worst-case underwater noise modelling using a stationary animal approach. In terms of area, maximum, minimum and mean impact ranges are shown for two monopiles and four sequential pin piles in 24 hours at the Project (worst-case north-west location reported for each scenario).

11.7.1.4.3.1.4 Other Noise Sources

221. Details of the source levels and propagation models used for continuous noise, operational wind turbine noise and UXO clearance can be found in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**. Here, the impact ranges for each construction noise type with respect to fish receptor thresholds, as defined by Popper *et al. (*2014), are reported in **Table 11-22** and **Table 11-23**. UXO impact ranges are included for information purposes to inform a high level assessment. UXO clearance would be assessed in detail in a future marine licence application for clearance works.

11.7.1.4.4 Receptor Sensitivity

222. The sensitivity of receptor groups to underwater noise is based on the sensitivity of their hearing systems, as defined by Popper *et al. (*2014) set out in **Section 11.7.1.4.1**.

223. Species within the “fish where swim bladder is involved in hearing” (Groups 3 and 4) category (see Table 11-17) are pelagic and therefore highly mobile and may depart the area from the onset of ‘soft start’ piling. However, these species are treated as stationary for this assessment, and are susceptible to barotrauma and detect sound pressure, as well as particle motion. Whilst engaged in spawning activity, it is possible that fish are less likely to move away from an undesirable sound source. The sensitivity of fish to noise produced during the construction phase is therefore considered **medium** for “fish where swim bladder is involved in hearing” (Groups 3 and 4).

Table 11-21 Worst-Case Modelled Instant and Cumulative Piling Noise Impacts for the Worst-Case Modelling Location (north-west). Cumulative Impact Ranges Based on Sequential Piling of Two Monopiles and Four Pin Piles Within a 24-Hour Period (using a stationary animal model). For the Full Set of Modelling Results, see Volume 2, Appendix 12.3 Underwater Noise Modelling Report

Fish group	Species included	Impact criteria	Potential impact	Impact areas and ranges							
				Monopile (maximum hammer energy 8,000kJ) (SEL_{cum} relates to two sequential monopiles within 24 hours)				Pin pile (maximum hammer energy 5,000kJ) (SEL_{cum} relates to four sequential pin piles within 24 hours)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
Group 1 – Fish: no swim bladder (particle motion detection)	• All elasmobranchs • Sandeel • Common sole • Plaice • Mackerel • Lamprey • Lemon sole • Anglerfish	>213 dB unweighted SPL_{peak}	Mortality and potential mortal injury	0.04km^2	120m	120m	120m	0.04km^2	110m	110m	110m
		>219 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	4.3km^2	1.2km	1.2km	1.2km	7.6km^2	1.6km	1.5km	1.6km
		>216 dB unweighted SEL_{cum} [stationary]	Recoverable injury	10km^2	1.8km	1.8km	1.8km	17km^2	2.4km	2.3km	2.4km
		>186 dB unweighted SEL_{cum} [stationary]	TTS	3,600km^2	39km	28km	34km	4,500km^2	44km	31km	38km
Group 2 -Fish: swim bladder is not involved in hearing (particle motion detection)	• Atlantic salmon • Sea trout	>207 dB unweighted SPL_{peak}	Mortality and potential mortal injury	0.28km^2	300m	300m	300m	0.23km^2	270m	270m	270m
		210 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	51km^2	4.1km	4.0km	4.0km	83km^2	5.3km	5.1km	5.2km
		203 dB unweighted SEL_{cum} [stationary]	Recoverable injury	260km^2	9.4km	8.7km	9.1km	380km^2	12km	10km	11km
		>186 dB unweighted SEL_{cum} [stationary]	TTS	3,600km^2	39km	28km	34km	4,500km^2	44km	31km	38km

Fish group	Species included	Impact criteria	Potential impact	Impact areas and ranges							
				Monopile (maximum hammer energy 8,000kJ) (SEL_{cum} relates to two sequential monopiles within 24 hours)				Pin pile (maximum hammer energy 5,000kJ) (SEL_{cum} relates to four sequential pin piles within 24 hours)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
Group 3 and 4 - Fish: swim bladder involving in hearing (primarily pressure detection)	• Sprat • Ling • Hake • European eel • Cod • Whiting • Ling • Blue ling • Atlantic herring • European bass	>207 dB unweighted SPL_{peak}	Mortality and potential mortal injury	0.28km²	300m	300m	300m	0.23km²	270m	270m	270m
		207 dB SEL_{cum} unweighted [stationary]	Mortality and potential mortal injury	110km²	6.0km	5.7km	5.9km	170km²	7.5km	7.1km	7.3km
		203 dB SEL_{cum} unweighted [stationary]	Recoverable injury	260km²	9.4km	8.7km	9.1km	380km²	12km	10km	11km
		>186 dB SEL_{cum} unweighted [stationary]	TTS	3,600km²	39km	28km	34km	4,500km²	44km	31km	38km
Based on data from Hawkins *et al.* (2014) relating to the levels of impulsive sound to which sprat (as a proxy for herring) respond.*	• Atlantic herring	135 dB unweighted (SEL_{ss}) modelled from the north-west site	Behavioural disturbance	12,072km²	86km	46km	61km	10,988km²	81km	44km	58km

*It is important to note that the maximum modelled range for the 135dB SEL_{SS} is not a good indicator of potential overlap with herring spawning rounds. **Figure 11-8** should be referred to, to understand the spatial relationship of the 135dB SEL_{SS} behavioural disturbance contours to the likely extent of the nearest herring spawning ground.

Table 11-22 Summary of the Impact Ranges for the Different Noise Sources Related to Construction using the Continuous Noise Criteria from Popper et al. (2014) for Fish (swim bladder involved in hearing)

Popper *et al.* (2014) **L_p**	**Recoverable injury** **170 dB re 1 μPa (48 hours)**	**TTS** **158 dB re 1 μPa (12 hours)**
Dredging (backhoe)	< 50m	< 50m
Dredging (suction)	< 50m	< 50m
Drilling	< 50m	< 50m
Rock placement	< 50m	< 50m
Suction bucket installation	< 50m	60m
Vessel noise (large)	< 50m	< 50m
Vessel noise (medium)	< 50m	< 50

Table 11-23 Summary of the impact ranges for UXO detonation using the explosions Lp,pk noise criteria from Popper et al. (2014) for species of fish

Popper *et al.* (2014) $L_{p,pk}$	**Mortality and potential mortal injury**	
	234 dB	**229 dB**
Low order (0.25kg)	< 50m	60m
25kg + donor	170m	290m
55kg + donor	230m	380m
120kg + donor	300m	490m
240kg + donor	370m	620m
525kg + donor	490m	810m
698kg + donor	530m	890m
907kg + donor	580m	970m

224. In the case of spawning herring, an additional sound threshold is used for behavioural disturbance: 135dB re 1μPa2s SEL_{ss}. This is based on a single study which observed the response of schooling sprat to playbacks of impulsive noise in an enclosed, quiet, coastal sea lough (Hawkins *et al.,* 2014). This experiment used underwater speakers, submerged 3m to 5m below the surface, to play a total of 10 low frequency pulses (with two second intervals) to nearby schools of sprat (the suggested proxy for herring), with a 50% behavioural response level observed at 135dB SEL_{SS}. The behavioural response was typically the temporary dispersal of the shoal beyond the range of the sonar used to detect the shoals. The shoal then reappeared within range over a period of seconds. Fish schools were exposed to a single round of 10 impulsive sound playbacks (with a temporary dispersal of the shoal occurring once within this period), therefore, it is not appropriate to conclude anything about their response over longer periods from this study. Studies on seabass demonstrate that behavioural responses to impulsive noise decrease over repeat exposures (Radford *et al.,* 2016; Neo *et al.,* 2018). Whether this trend can be extrapolated to spawning herring is unclear.

225. The sensitivity of other fish species and shellfish to noise produced during the construction phase of the Project is considered **low**. This includes "fish with no swim bladder" (Group 1), and "fish where swim bladder is not involved in hearing" (Group 2). The majority of fish receptors included within these groups (see Table 11-21) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. Elasmobranchs, sandeels, pleuronectiforms (flatfish), and mackerel do not have a swim bladder or other air-filled cavity. They are incapable of detecting sound pressures and, therefore, particle motion is the only sound stimulus which can be detected (Casper *et al.,* 2012).

226. Studies using lobsters have shown no effect on mortality, appendage loss or ability to regain normal posture after exposure to high impulsive noise levels of over 220dB, although some avoidance behaviour was detected (Payne *et al.,* 2007). Acoustic trauma (microlesions) has been observed in the statocysts of selected cephalopod species following exposure to high energy seismic survey blasts (André *et al.,* 2011). However, there is evidence that impacts of this type are temporary in experimental conditions (Fewtrell and McCauley, 2012).

11.7.1.4.5 Impact Magnitude

227. In the case of spawning herring, the nearest herring spawning grounds, based on a heatmapping approach, are >100km from the nearest piling activity (**Figure 11-8**). When the 135dB SEL_{ss} behavioural disturbance contour is overlaid, it becomes clear that there is no overlap between piling noise from the Project and key high intensity herring spawning grounds located in inshore areas around Flamborough Head. Other impacts, such as mortality, injury, and TTS, do not overlap with these herring spawning hotspots.

228. Another factor to consider is that the latest evidence suggests that piling sound loses its impulsive character as it propagates away from the source. Taking into account recent experimental and field data, Southall (2021) notes that *"it should be recognized that the use of impulsive exposure criteria for receivers at greater ranges (tens of kilometers) is almost certainly an overly precautionary interpretation of existing criteria"*. In the case of the inshore herring spawning grounds, which are located at least 190km distance from piling within the Study Area, coupled with the predicted loss of sound impulsiveness, and the worst-case parameters used in the noise modelling, the 135dB SEL_{ss} impulsive exposure criteria can be considered to be highly precautionary.

229. For this reason, the magnitude of impact on spawning herring is **low.**

230. For other species within the "fish where swim bladder is involved in hearing" (Groups 3 and 4) category, the worst-case SEL_{cum} impact range, assuming a fish remains stationary for 24 hours is 44km for TTS, which is a temporary effect. SEL_{cum} recoverable injury Instant effects such as injury would only occur within 300m of a maximum energy pile, which would require the fish to approach, or remain within 300m of the pile during soft start, ramp up, or full energy piling.

231. Given the localised nature of the impact ranges (see **Figure 11-8**), combined with the limited temporal and spatial extent of piling for the Project, the magnitude of impact upon this group 3 and 4 fish has been assessed as **low**. For the less sensitive group 1 and 2 fish, and shellfish, the impact magnitude is also assessed as **low**.

11.7.1.4.6 Effect Significance

232. Overall, it is predicted that sensitivity of "fish where swim bladder is involved in hearing" (group 3 and 4) is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, the therefore is **not significant** in EIA terms.

233. Overall, it is predicted that sensitivity of group 1 and 2 fish, and shellfish, is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

234. No additional mitigation is required.

11.7.1.5 Changes in Fishing Pressure (FSE-C-08)

235. As discussed in **Chapter 14 Commercial Fisheries Sections 14.7.1.1** and **14.7.1.2**, there is the potential for commercial fishing activity to be displaced from within the Offshore Development Area, due to the presence of work vessels, foundation installation activities, and laying of inter-array cabling. Construction activities may act as a barrier to deployment of mobile fishing gear and may have safety zones. This may, in turn, displace fishing to nearby grounds. Overall, this may result in reduced fishing pressure on commercially exploited species within the Offshore Development Area or increase fishing pressure on fish and shellfish species outside the Offshore Development Area.

11.7.1.5.1 Receptor Sensitivity

236. Variations in sensitivity to fishing pressure exist within receptor groups, for example, populations of slow growing bivalves have a higher sensitivity to physical damage from bottom-towed gear than populations of bivalves that are faster growing, faster to mature, and therefore quicker to recover from any mortality caused by fishing (Rijnsdorp *et al.*, 2018).

237. Roach *et al. (*2018) found that temporary restrictions of fishing areas offer respite for adult lobsters, leading to an increase in abundance and size. Larger and better-quality lobsters were landed once the area was opened again (Roach *et al., 2*018).

238. Overall, all receptor groups have the potential to experience change at the population level if there is a meaningful change in fishing-induced mortality as a result of the Project.

239. The sensitivity of all receptor groups is therefore considered to be **low**.

11.7.1.5.2 Impact Magnitude

240. During Construction of the Project, it is expected that temporary 500m safety zones would be present around foundations, wind turbines and offshore platforms where works are underway. Additionally, a temporary 500m safety distance would also be requested for cable installation and pre-construction activities as per **Table 11-4** (Commitment ID CO17). It is noted that the DBD Array Area is situated within an area in which a byelaw prohibiting mobile gear fishing is in force, thereby limiting the potential for activities within the Array Area to displace fishing activity.

241. As described in **Chapter 14 Commercial Fisheries Sections 14.7.1.1 and 14.7.1.2**, significant impacts (i.e. exceeding minor significance) in respect of loss of fishing grounds, and associated potential for displacement, have not been identified (following mitigation) for any of the fleets active in areas relevant to the Project.

242. The magnitude of impact is therefore considered to be **low** for all receptor groups.

11.7.1.5.3 Effect Significance

243. Overall, it is predicted that the sensitivity of all receptor groups is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

244. No additional mitigation is required.

11.7.2 Potential Effects During Operation

11.7.2.1 Temporary Habitat Loss / Physical Disturbance (FSE-O-02)

245. Maintenance activities may disturb the seabed. For example, when conducting repairs on cables, the cables may be brought to the surface and then re-laid which would disturb the seabed. The extent of disturbance anticipated during the operational phase, including level of temporary habitat loss physical disturbance, is outlined in **Table 11-7**. The extent of disturbance would be lower than that for the construction phase but would occur as intermittent (short term) events throughout the 35-year operational period of the Project.

11.7.2.1.1 Receptor Sensitivity

11.7.2.1.1.1 Elasmobranchs, Demersal Fish, Pelagic Fish, and Diadromous Fish

246. Pelagic spawning fish species have large spawning grounds with no reliance on specific substrate to lay eggs upon. Habitat loss and disturbance to the seabed therefore has limited capability to affect the spawning of these species.

247. The most sensitive species to this impact are demersal spawners, namely herring and sandeel, which have spawning periods from August to September (herring) and November to February (sandeel) (see **Table 11-15**). These species have a heightened sensitivity to any disturbance of the seabed, and are therefore considered more sensitive to temporary habitat loss / physical disturbance, especially related to spawning and nursery areas.

248. Whilst the nursery grounds of many species overlap with the Offshore Development Area, the areas impacted by construction disturbance are small, relative to the size of the entire main nursery grounds, which extend around much of the English and Scottish east coast.

249. Juvenile stocks of fish are less sensitive to physical disturbance than spawning adults, as they have high levels of adaptability and tolerance to transient stress and disturbance, with an ability to move away from construction activities. Furthermore, based on their extensive occurrence within the wider geographic context, any potential disturbance to these areas, due to construction operations, is not predicted to have a significant impact on juvenile fish survival.

250. Other than sandeel all other species in these receptor groups have high levels of mobility and are, therefore, capable of navigating away from any temporary habitat loss / physical disturbance caused by construction activities (EMU, 2004).

251. The sensitivity of sandeel and herring (during spawning season) is therefore considered to be **medium**.

252. The sensitivity of other elasmobranchs, demersal fish, pelagic fish (including herring outside of spawning season), and diadromous fish species is considered to be **low**.

11.7.2.1.1.2 Shellfish

253. The key crustacean species potentially present within the Study Area include, brown crab, brown shrimp, velvet crab, European lobster and Nephrops. These species are relatively mobile and would generally be able to move away from any area of seabed disturbance, although to a lesser extent than fish species. However, it is acknowledged during certain periods, some species exhibit higher site fidelity such as overwintering berried female brown crab. These egg bearing females remain buried and stationary in the sediment over winter periods, whilst eggs mature. They therefore have limited capacity to move away from physical disturbance at a key period in their reproductive cycle.

254. Of the mollusc species assessed, common whelk and king scallops are generally sessile, or at least slow-moving, and therefore have limited tolerance and adaptability to seabed disturbance. Squid are the exception, and being pelagic have much greater capacity to move away from disturbance.

255. Taken together, given the overall reduced tolerance and adaptability compared to fish species, the sensitivity of shellfish is considered to be **medium**.

11.7.2.1.2 Impact Magnitude

256. Due to reduced scope for temporary habitat loss / physical disturbance during operation compared to construction, the magnitude of impact is likely to be lower. However, the magnitude is conservatively scoped to be the same as for construction for all receptor groups.

257. The magnitude of impact is therefore considered to be **low**.

11.7.2.1.3 Effect Significance

258. Overall, it is predicted that sensitivity of herring (during spawning season), sandeel, and shellfish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

259. It is predicted that sensitivity of elasmobranchs, demersal fish, pelagic fish (including herring outside of spawning season), and diadromous fish is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, which is therefore **not significant** in EIA terms.

260. No additional mitigation is required.

11.7.2.2 Habitat Loss / Alteration (FSE-O-03)

261. As detailed in **Table 11-7**, the worst-case area of total habitat loss due to the wind farm infrastructure (including wind turbines, OSP, scour protection and inter-array cable protection) is approximately 3,733,282m^2. As such, less than 0.01% of seabed habitat of the Study Area would potentially be lost to the footprint of infrastructure.

262. It should be noted that, whilst this impact is assessed for the operation and maintenance phase (as this is the time period where the majority of effects would manifest), habitat loss / alteration would also occur during the construction phase, in a staged manner, as foundations and cable protection are progressively installed.

11.7.2.2.1 Receptor Sensitivity / Value

11.7.2.2.1.1 Spawning Grounds

263. The sensitivity of herring and sandeel spawning grounds to habitat loss has been assessed to be **high**, due to the particular sensitivity of demersal spawners to loss of appropriate spawning habitat.

264. As discussed in **Section 11.6.1.3.1** the Study Area, and indeed the Central North Sea has preferred sandy habitat for sandeel (based on sediment type), and that appropriate sediment for sandeel habitat is widely spread across the Study Area.

265. Habitat loss may occur in suitable spawning habitat for other fish species within the Study Area, with a value / sensitivity of **medium** assigned (pelagic spawning so less sensitive).

11.7.2.2.1.2 Nursery Grounds

266. The value / sensitivity of fish nursery grounds has been assessed as **high**, due to the potential for this key life stage to be interrupted.

11.7.2.2.1.3 Shellfish

267. MarESA identifies that for some crustaceans, such as the brown crab or nephrops, substrate removal is likely to remove a proportion of individuals, although some would escape. Those that escape undamaged would quickly recolonise the remaining seabed and migrate to new habitats, if necessary. Therefore, an intolerance of intermediate and a recoverability of moderate has been recorded. The value / sensitivity of crustaceans has been assessed to be **medium**.

11.7.2.2.2 Impact Magnitude

268. The estimated area of worst-case habitat loss within the Array Area is 2,227,482m^2, representing <0.001% of the Array Area. The estimated loss of habitat within the Offshore ECC is 1,660,800m^2, representing <0.01% of the offshore ECC.

11.7.2.2.2.1 Spawning Grounds

11.7.2.2.2.1.1 Herring

269. Assuming that the <0.01% of habitat loss within the Offshore ECC due to cable protection is evenly distributed across the Offshore ECC, then <0.01% of the inshore section of Offshore ECC that overlaps with higher herring spawning habitat potential (See **Figure 11-6** and **Figure 11-8**) would undergo habitat loss. Herring spawning would continue in areas immediately adjacent to any rock protection. This represents a **negligible** magnitude.

11.7.2.2.2.1.2 Sandeel

270. The <0.001% of habitat loss within the Array Area and <0.01 Offshore ECC represents a **negligible** change in the context of the wider extent of sandeel habitat in the Study Area and the wider Study Area

271. and **Figure 11-7**).

272. The effects of permanent habitat loss on sandeel is expected to be limited, given the abundance of similar substrate types and the extensive nature of spawning grounds across the wider Fish and Shellfish Ecology Study Area, giving a negligible magnitude. Considering the high receptor sensitivity and **negligible** magnitude of impact, an effect of minor adverse significance would therefore be expected.

11.7.2.2.2.1.3 Other Species

273. Other fish species are generalists, showing little sensitivity to localised changes in seabed substrate. The areas potentially affected are however small, in comparison to the wider spawning of grounds of the North Sea, giving a **negligible** magnitude.

11.7.2.2.2.2 Nursery Grounds

274. Whilst the nursery grounds of many species potentially overlap with the DBD Array Area (see **Section 11.4.1**), habitat loss is localised and not expected to impact the functioning of these wider nursery grounds. The magnitude of this impact has therefore been assessed as **negligible**.

11.7.2.2.2.3 Shellfish

275. Permanent habitat loss would occur in less than 0.01% of the Study Area as a worst-case, which is an even smaller proportion of the wider habitats in the North Sea, and so would have a highly localised effect that would not be detectable within crustacean populations locally, or more regionally. As such, the magnitude of impact upon crustaceans has been assessed as **negligible**.

11.7.2.2.3 Effect Significance

11.1.1.1.1.1 Spawning Grounds

11.7.2.2.3.1.1 Herring

276. With a **high** sensitivity and **negligible** magnitude of impact, an effect of **minor adverse** significance is expected from habitat loss / alteration associated with the Project. This therefore is **not significant** in EIA terms.

11.7.2.2.3.1.2 Sandeel

277. With a **high** sensitivity and **negligible** magnitude of impact, an effect of **minor adverse** significance is expected from habitat loss / alteration associated with the Project. This therefore is **not significant** in EIA terms.

11.7.2.2.3.1.3 Other species

278. Considering the **medium** receptor sensitivity and negligible magnitude of impact, an effect of **negligible adverse** significance would therefore be expected on other fish spawning grounds from habitat loss / alteration associated with the Project. This therefore is **not significant** in EIA terms.

11.7.2.2.3.2 Nursery Grounds

279. With a **high** sensitivity and **negligible** magnitude of impact, an effect of **minor adverse** significance is expected from habitat loss / alteration associated with the Project. This therefore is **not significant** in EIA terms.

11.7.2.2.3.3 Shellfish

280. Considering the **medium** receptor sensitivity and **negligible** magnitude of impact, an effect of **minor adverse** significance would be expected from habitat loss / alteration associated with the Project. This therefore is **not significant** in EIA terms.

11.7.2.3 Increased Suspended Sediment and Sediment Re-deposition (FSE-O-04)

281. Maintenance activities may disturb the seabed and cause subsequent increases in SSC. For example, when conducting repairs on cables, the cables may be brought to the surface and then re-laid which would suspend sediment from the seabed. The extent of increased SSC and sediment re-deposition anticipated during the operational phase is outlined in **Table 11-7**. The extent of disturbance would be lower than that for the construction phase but would occur as intermittent (short term) events throughout the 35-year operational period of the Project.

11.7.2.3.1 Receptor Sensitivity

282. The rationale for the differing sensitivities of receptor groups to increased suspended sediment and sediment-redeposition is set out in **Section 11.7.1.2.1**.

283. The sensitivity of the adult and juvenile elasmobranchs, demersal fish, and pelagic fish is therefore considered to be **low**.

284. Taken together, despite their tolerance to increased SCC, due to their increased sensitivity to smothering, the sensitivity of the eggs and larvae of elasmobranchs, demersal fish, and pelagic fish, is considered to be **medium**.

11.7.2.3.2 Impact Magnitude

285. Due to reduced scope for increased suspended sediment and sediment-redeposition during Operation compared to construction, the magnitude of impact is likely to be lower. However, the magnitude is conservatively scoped to be the same as for construction for all receptor groups (see **Section 11.7.1.2.2**).

286. The magnitude of impact is therefore considered to be **low**.

11.7.2.3.3 Effect Significance

287. Overall, it is predicted that sensitivity of adult and juvenile elasmobranchs, demersal fish, and pelagic fish is low and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, which is **not significant** in EIA terms.

288. It is predicted that sensitivity of the eggs and larvae of elasmobranchs, demersal fish, and pelagic fish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

289. It is predicted that sensitivity of shellfish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

290. No additional mitigation is required.

11.7.2.4 Remobilisation of Contaminated Sediments if Present - Offshore ECC (FSE-O-06)

291. Sediment chemical composition within the Study Area is informed by the site-specific surveys undertaken across the DBD Array Area and Offshore ECC) (see **Volume 2, Appendix 10.3 Benthic Ecology Baseline Characterisation Report**).

292. Surveys undertaken in 2023 provided justification for the scoping out of this impact for the DBD Array Area, however given that a section of the offshore ECC was not surveyed in 2023, this impact remained scoped in for further consideration in light of 2024 survey results for the offshore ECC.

293. As outlined in **Section 9.6.1.1** of **Chapter 9 Marine Sediment and Water Quality**, recent sediment survey results show that the sediment contamination within the ECC is negligible. Therefore, should sediment be disturbed during any phase of the Project, there is no pathway for effect.

294. There is therefore no pathway for effect on fish and shellfish receptors and the significance of effect is **negligible** for all receptor groups.

295. No additional mitigation is required.

11.7.2.5 Underwater Noise and Vibration (FSE-O-07)

296. The continuous noise associated with Operation, e.g. with wind turbines operational noise, is of a much-reduced decibel source level than that assessed for piling activities during the construction phase in **Section 11.7.1.4**.

11.7.2.5.1 Receptor Sensitivity

297. The sensitivity of receptor groups to underwater noise is based on the sensitivity of their hearing systems, as defined by Popper *et al. (*2014) and set out in **Section 11.7.1.4.4**.

298. Species within the “fish where swim bladder is involved in hearing” (Groups 3 and 4) category (see Table 11-17) are pelagic and therefore highly mobile and may depart a noisy area around an operational turbine. However, these species are treated as stationary for this assessment. The sensitivity of fish to noise produced during the operational phase is therefore considered **medium** for “fish where swim bladder is involved in hearing” (Groups 3 and 4).

299. The sensitivity of other fish species and shellfish to noise produced during the operational phase of the Project is considered **low**.

11.7.2.5.2 Impact Magnitude

300. Impact ranges for fish species from operational turbine noise have been modelled for both 14MW and 27MW turbines and are set out in Table 11-24.

301. These impacts relate to the most sensitive receptor group – fish with a swim bladder involved in hearing.

302. These results demonstrate that a sound sensitive hearing group 3 and 4 fish would need to remain within 50m of an operational turbine for 48h in order for a recoverable injury threshold to breached. The turbine would also have to be operational and creating noise for 48h continuously.

Table 11-24 Summary of the Fixed-Foundation Operational Wind Turbine Noise Impact Ranges using the Continuous Noise Criteria from Popper et al. (2014) for Fish (swim bladder involved in hearing)

Popper *et al.* (2014) $L_{p,}$	Operational Wind Turbine (14 MW)	Operational Wind Turbine (27 MW)
Recoverable injury 170 dB (48 hours)	< 50m	< 50m
TTS 158 dB (12 hours)	< 50m	< 50m

303. The magnitude of impact is therefore considered to be **negligible** for all receptor groups.

11.7.2.5.3 Effect Significance

304. Overall, it is predicted that sensitivity of "*fish where swim bladder is involved in hearing*" (group 3 and 4) is **medium** and the magnitude of impact is **negligible**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

305. Overall, it is predicted that sensitivity of group 1 and 2 fish and shellfish, is **low** and the magnitude of impact is **negligible**. The effect is therefore of **negligible adverse** significance, this therefore is **not significant** in EIA terms.

306. No additional mitigation is required.

11.7.2.6 Changes in Fishing Pressure (FSE-O-08)

307. As discussed in **Chapter 14 Commercial Fisheries**, there is potential for commercial fishing activity to be displaced from within the DBD Array Area, due to the presence of the subsurface structures associated with the wind turbines and offshore platforms. These subsurface structures may act as a barrier to safe deployment of mobile fishing gear.

11.7.2.6.1 Receptor Sensitivity

308. As for construction (**Section 11.7.1.5.1**) variations in sensitivity to fishing pressure exist within receptor groups, for example, populations of slow growing bivalves have a higher sensitivity to physical damage from bottom-towed gear than populations of bivalves that are faster growing, faster to mature, and therefore quicker to recover from any mortality caused by fishing (Rijnsdorp *et al.,* 2018).

309. Overall, all receptor groups have the potential to experience change at the population level if there is a meaningful change in fishing-induced mortality as a result of the Project.

310. The sensitivity of all receptor groups is therefore considered to be **low**.

11.7.2.6.2 Impact Magnitude

311. Fishing activity is expected to return to some degree to the Study Area, during operation. Whilst displacement of fishing from within the Study Area may result in a reduction in mortality risk to commercial species existing in close association with infrastructure within the DBD Array Area, or increased pressure elsewhere, the size of the fishing displacement area (50m safe operating distance around infrastructure) is negligible in the context of the distributional ranges of the populations of fish and shellfish receptors in the wider North Sea. Further, the level of fishing within the DBD Array Area is relatively low (mostly as a result of the byelaw prohibiting bottom-towed gear), and as discussed in **Chapter 14 Commercial Fisheries**, no significant displacement effects are identified during Operation.

312. The magnitude of impact is therefore considered to be **low**.

11.7.2.6.3 Effect Significance

313. Overall, it is predicted that sensitivity of all receptor groups is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

314. No additional mitigation is required.

11.7.2.7 EMF Effects (FSE-O-09)

315. The Project would transmit energy produced along the network of inter-array and export cables, linking the individual wind turbines, the wind turbines to the offshore platforms, and the offshore platforms to landfall. As energy is transmitted, the cables emit low-energy EMF. The electrical and magnetic fields generated increase proportionally to the amount of electricity transmitted.

316. EMF comprise both the electrical (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in microtesla (μT) or milliGauss (mG). It is common practice to block the direct electrical field using conductive sheathing, meaning that the only EMFs that are emitted into the marine environment are the magnetic field and the resultant induced electrical field. It is generally considered impractical to assume that cables can be buried at depths that will reduce the magnitude of the magnetic field, and hence the sediment sea water interface induced electrical field, to below that at which these fields could be detected by certain marine organisms on or close to the seabed (Gill *et al., 2*009; Gill *et al., 2*010). By burying a cable, the magnetic field at the seabed is reduced due to the distance between the cable and the seabed surface as a result of field decay with distance from the cable (CSA, 2019).

11.7.2.7.1 Receptor Sensitivity

11.7.2.7.1.1 Elasmobranchs

317. Elasmobranchs are known to be electrosensitive and magneto-sensitive and have specialised sensory receptors for detecting EMF, known as ampullae of Lorenzini, used for detecting prey, predators and competitors. These species have the potential to be affected by the EMF produced by the Project cables, altering behaviour to investigate the source, and spending additional time hunting prey, thereby reducing food intake and potential overall fitness (Hutchison *et al.,* 2018).

318. The area around which elasmobranchs can detect EMF is limited to a scale of metres around electrical cables buried to a target depth of 0.9m to 1.8m (CSA, 2019), therefore species that spend time on the seafloor, like skates and rays, have the highest chance of interacting with EMF produced by the inter-array cables. Skates and rays, including the thornback ray and spotted ray, primarily feed on bottom-dwelling invertebrates and fish. These prey species produce an average bioelectric field that is less than 10Hz, far lower in frequency than that found in the cables used for the wind farm site (60Hz), and therefore outside of the typical tuned range for elasmobranchs (Snyder *et al., 2*019). EMF also decays very quickly with distance from the cable, which minimises potential exposure. Based on a similar project, the maximum magnetic field at the seabed (assuming a 1m high voltage alternating current (HVAC) buried cable) is expected to be 26.5μT, reducing to 1μT at 4.4m vertically above the seabed (Equinor, 2022). Given the target depth of 3.5m for this project, maximum magnetic field strength would be expected to reduce to 1μT at 3.9m above the seabed. For context, measurements of background levels of magnetic fields in the north-east Atlantic are 50μT (Tasker *et al., 2*010).

319. The sensitivity of this receptor group is therefore considered to be **medium**.

11.7.2.7.1.2 Demersal Fish

320. Demersal species that live on or close to, the seafloor, and in close proximity to the cables, are likely to encounter EMF. However, the demersal fish species identified in the Study Area do not possess electromagnetic receptors to detect EMF at 50Hz and are not deemed sensitive to this stimulus.

321. The sensitivity of this receptor group is therefore considered to be **low**.

11.7.2.7.1.3 Diadromous Fish

322. EMF has the potential to interfere with the navigation of sensitive migratory and pelagic species, by affecting the speed and / or course of their movements through the Study Area, causing subsequent potential issues if they are not able to reach spawning, nursery or feeding grounds. Species such as European eel are thought to use magnetic fields for navigation, and salmonids have the ability to respond to electrical fields (Gill and Bartlett, 2010). Lampreys, like elasmobranchs, possess ampullary electroreceptors, used to survey their surroundings for prey, predators etc.

323. Swedpower (2003) found no measurable impact when subjecting salmon and sea trout to magnetic fields twice the magnitude of the geomagnetic field. Similarly, studies conducted by Marine Scotland Science (Armstrong *et al., 2*016) and Walker (2001), found no evidence of unusual behaviour in Atlantic salmon associated with magnetic fields and EMFs produced by cables. The AC and DC fields used in these studies were significantly higher than would be expected at 0m above the seabed with a cable buried at 1m depth (Normandeau, 2011). It is acknowledged that these results do not demonstrate that diadromous or other pelagic fish cannot detect fields of these types, merely that so far, no significant effects on behaviour have been found.

324. During migrations, diadromous species may travel multiple kilometres per day, and are less likely to swim close to the seafloor (Snyder *et al., 2*019).

325. The sensitivity of this receptor group is therefore considered to be **low**.

11.7.2.7.1.4 Pelagic Fish

326. Pelagic fish, as a group, have reduced sensitivity to EMF, and reduced potential to encounter raised levels of EMF due to the fact that they inhabit the water column rather than the seabed.

327. The sensitivity of this receptor group is therefore considered to be **low**.

11.7.2.7.1.5 Shellfish

328. The effects of EMF on shellfish are not well understood and are highly variable between species and life stages.

329. Some species of crustacean and mollusc are magneto-sensitive (e.g. spiny lobsters, sea slugs) and have been shown to demonstrate a response to magnetic fields (Boles and Lohmann, 2003; Hutchison *et al., 2*020).

330. Brown crab have been shown to associate with EMF areas around subsea cables (Scott *et al., 2*018), and there is recent evidence that chronic exposure to direct current (DC) EMF (2.8mT), over a period of months during embryonic stages, can lead to smaller size of newly hatched larvae and increased deformities (Harsanyi *et al., 2*022), whilst no effects were seen in embryonic development time, larval release time or swimming speed. It should be noted that the Scott *et al.* (2018) and Harsanyi *et al.* (2022) studies exposed animals to constant (24h) EMF strengths of 2.8mT. This field strength is orders of magnitude greater than would be expected from inter-array or export cables and animals were exposed constantly. The results are therefore not applicable to real-world scenarios.

331. EMF strengths of 250 µT were found to have no significant physiological and behavioural impacts on adult brown crab in a laboratory setting, whereas EMF strengths of 500µT and 1000 µT were found to disrupt the L-Lactate and D-Glucose circadian rhythm and alter Total Haemocyte Count, all of which may be potential proxies for disruption in homeostasis, which in turn may be an indicator of a stress response. Brown crab was also found to shelter for longer in shelters subject to EMF strengths of 500 µT and 1000 µT, in comparison to control shelters. This may indicate that these higher EMF strengths attract brown crab, or that they reduce the activity levels of crabs that move into the EMF inadvertently. This study does not state whether AC or DC fields were used, adding uncertainty to its relevance for the Project. Based on a similar project, the maximum magnetic field at the seabed (assuming a 1m HVAC buried cable) is expected to be 26.5µT, reducing to 1µT at 4.4m vertically above the seabed (Equinor, 2022). Given the target depth of 3.5m for this project, maximum magnetic field strength would be expected to reduce to 1µT at 3.9m above the seabed. For context, measurements of background levels of magnetic fields in the north-east Atlantic are 50µT (Tasker *et al., 2*010). The magnetic field at the cable surface had the highest possible exposures and ranged between 1217 and 1653µT (Equinor, 2022). This means that there is a possibility that small fish or shellfish could be exposed to higher levels, if they are small enough to penetrate the rock that constitutes protection for surface laid sections of export cable.

332. The sensitivity of the receptor is therefore considered to be **medium**.

11.7.2.7.2 Impact Magnitude

333. As detailed in **Section 11.7.2.7**, the Project proposes to use inter-array cables that are 132kV, and up to 250mm in diameter. An export cable between the offshore platform and landfall would consist of a 500kV cable. A maximum of 400km of inter-array cables, and 800km of export cable would be installed, based on worst-case scenarios. These cables would transmit alternating current (AC) at 50Hz, or cycles, per second, introducing a weak electric field in the surrounding ocean that is unrelated to the voltage of the cable, but is dependent on the amount of current flow through the cable. In contrast, the offshore export cable may transmit direct current (DC). Cables would be buried to a target depth of 3.5m where conditions allow, substantially reducing the levels of EMF in the surrounding area. Where cable burial is not possible, for example due to hard substrate or for cable crossings, protection would be added to reduce the levels of EMF. EMF strength dissipates rapidly with increasing distance from the source; for example, the average wind farm array cable buried 1m below the seabed would decrease from 7.85µT directly next to the cable (0m) to 1.47µT at 4m distance (Normandeau *et al., 2*011). For context, measurements of background levels of magnetic fields in the north-east Atlantic are 50µT (Tasker *et al., 2*010).

334. Taken together, the impact magnitude of impact is therefore considered to be **negligible**.

11.7.2.7.3 Effect Significance

335. Overall, it is predicted that sensitivity of demersal fish and diadromous fish is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

336. It is predicted that sensitivity of elasmobranchs and shellfish is **medium** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

337. It is predicted that sensitivity of pelagic fish is **negligible** and the magnitude of impact is **low**. The effect is therefore of **negligible adverse** significance, this therefore is **not significant** in EIA terms.

338. No additional mitigation is required.

11.7.2.8 Sediment Heating from Export Cables (FSE-O-10)

339. Operational cables may cause localised heating of surrounding sediment, but this is limited to distances of tens of cm (Boehlert and Gill, 2010; Moray Offshore Windfarm Ltd, 2018), and meaningful effects at the population scale are unlikely for all receptors.

340. At the request of the MMO, this impact has been scoped in specifically in relation to the effects of sediment warming on buried sandeel.

11.7.2.8.1 Receptor Sensitivity

341. Pepin (1991) conducted a review of available data on the temperature response of the early lifestages (egg, yolk-sac larvae and post-larvae) of marine fish species. The study found that egg and yolk-sac lifestage mortality rates (and thus survivorship) were significantly correlated with temperature, but that the post-larvae lifestage was not. The study found that at the egg stage, an increased temperature increased mortality rates, but that at the yolk-sac stage an increased temperature reduced mortality rates. Temperature did not influence the mortality rates of post larvae. Based on this work, if sandeel eggs were exposed to a 1°C temperature increase for the whole lifestage then it would result in a reduced survivorship from 33.2% to 42.9% to 30.8% to 40.5%. Given that the temperature on the surface is expected to be unchanged relative to surrounding ambient temperatures, this effect is not expected.

342. Unlike with eggs, there is no evidence that an increase of 1°C would influence sandeel survival. The results from Pepin (1991) would suggest that adult survival is less influenced by increases of this nature.

343. The sensitivity of sandeel eggs is therefore considered to be **high.**

344. The sensitivity of sandeel larvae and adults is therefore considered to be **medium.**

11.7.2.8.2 Impact Magnitude

345. Recent evidence indicates that the surface temperature difference of non-buried operational power cables in comparison to inert sections of the same cable was negligible at a sensitivity level of 0.06°C (Taormina *et al.,* 2018; 2020). Buried cables will experience less of a seawater cooling effect and may heat surrounding sediment on that basis.

346. Previous modelling for a high voltage interconnector project (NorthConnect, 2018) has considered the sediment heating effects of a HVDC cable at a depth of lowering of 0.5m and ambient sea temperatures of 9°C. The model demonstrates that there will be no sediment heating at the seafloor. This means sandeels are only potentially subject to increased temperature if they bury in the sediment surrounding buried cables.

347. The modelling suggests the increases in sediment temperature above 1°C are limited to a radius of less than 2.5m, with the radius reduced directly above the cable due to the cooling effects of seawater (NorthConnect, 2018). Given that sandeel spawn in December and January, then the baseline water / sediment temperature is likely to be around 4°C to 8°C depending upon water depth (Berx and Hughes, 2008).

348. As demonstrated on **Figure 11-5,** the export cable passes through preferred sandeel habitat (based on sediment type). Considering the sandeel habitat potential heatmap, which utilises multiple data types, the areas of highest potential habitat suitability are avoided by the Offshore ECC (**Figure 11-7**). Given that heating of 1°C is expected to be limited to within 2.5m of a cable buried to 0.5m, a very small proportion of sandeel habitat will be subjected to heating.

349. The magnitude of impact on sandeel larvae and adults buried in the sediment is considered to be **low**.

350. The magnitude of impact on sandeel eggs is therefore considered to be **negligible**.

11.7.2.8.3 Effect Significance

351. Overall, it is predicted that sensitivity of sandeel eggs is **high** and the magnitude of impact is **negligible**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

352. It is predicted that sensitivity of buried sandeel larvae and adults is **medium** and the magnitude of impact is **low.** The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

353. No additional mitigation is required.

11.7.2.9 Introduction of Hard Substrate (FSE-O-11)

354. Man-made structures introduced to the Study Area, such as foundations and scour protection, may be colonised by a range of benthic invertebrate species. The introduction of this hard substrate in predominantly soft sediment areas increases and changes habitat availability and type, resulting in locally altered biodiversity as new species are able to establish and thrive in previously hostile environments (Birchenough and Degraer, 2020; Coolen *et al., 2*020). This potentially increases ecological diversity at a local level, by acting as an artificial reef, and with the potential to act as fish aggregating devices.

355. This local increase in presence of species may in turn attract predatory species, such as marine mammals and seabirds, thereby altering predator prey dynamics at a local level.

356. It should be noted that, whilst this impact is assessed for operation (as this is the time period where the majority of effects would manifest), introduction of hard substrate would also occur during construction, in a staged manner, as foundations and rock protection are progressively installed. However, any hard substrate introduced during Construction would be colonised slowly over time, with the majority of change occurring over operation. This impact would also continue following decommissioning if any infrastructure remains on the seabed.

357. Furthermore, it should be noted that this impact could be considered as beneficial, depending on the species being considered. However, to reflect the fact that any impact represents a change from what might be considered natural or baseline conditions, a precautionary approach is to assume that the impact may be adverse.

11.7.2.9.1 Receptor Sensitivity

11.7.2.9.1.1 Elasmobranchs, Pelagic fish, Diadromous fish

358. The sensitivity of these group to introduction of hard substrate is considered to be **low**, as the presence of discrete pockets of this habitat type is not considered to negatively impact these groups.

11.7.2.9.1.2 Demersal fish

359. Introduced hard substrate may be suitable habitat for species such as cod, whiting and ling which prefer or utilise the rocky seabed. The sensitivity of demersal fish is therefore considered to be **low**.

11.7.2.9.1.3 Shellfish

360. Introduced hard substrate habitat may be suitable for many crustacean species, such as European lobster, brown crab and velvet crab, which prefer or utilise the rocky seabed. In addition, some species of hard substrate encrusting molluscs, such as blue mussel, may benefit from increased availability of habitat, whilst other mollusc species, such as burrowing bivalves and crustaceans (e.g. Nephrops), would lose appropriate habitat in the immediate footprint of the introduced hard substrate.

361. Conversely, the fish aggregating effect of hard substrate may increase predation upon these species.

362. Taken together, the sensitivity of shellfish to the introduction of hard substrate is considered to be **medium**.

11.7.2.9.2 Impact Magnitude

363. 3.97km^2 of hard substrate is expected to be introduced as a worst-case, which constitutes <0.01% of the Study Area.

364. The magnitude of impact is therefore considered to be **low.**

11.7.2.9.3 Effect Significance

365. Overall, it is predicted that sensitivity of elasmobranch, demersal fish, pelagic fish, and diadromous fish, is **low** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

366. It is predicted that sensitivity of shellfish is **medium,** and the magnitude of impact is **low**. The effect is therefore of **minor adverse** significance, this therefore is **not significant** in EIA terms.

367. No additional mitigation is required.

11.7.3 Potential Effects during Decommissioning

368. A decision regarding the final decommissioning policy is yet to be decided as it is recognised that rules and legislation change over time in line with best industry practice. The decommissioning methodology and programme would need to be finalised nearer to the end of the lifetime of the Project to ensure it is in line with the most recent guidance, policy and legislation at that time. Decommissioning would be subject to a separate consent process and suitable environmental impact assessment prior to works commencing.

369. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in **Chapter 4 Project Description** and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all of the wind turbine components and part of the foundations (those above seabed level), removal of some or all of the array and export cables. The Inter-Array and Offshore Export Cables will likely be cut at the cable ends and left in-situ below the seabed, and scour and cable protection would likely be left in-situ other than where there is a specific condition for its removal.

370. During the decommissioning phase, the decommissioning sequence will generally be the reverse of construction and will involve similar types and numbers of vessels and equipment. There is potential for wind turbine foundation and cable removal activities to cause effects that would be comparable to those identified for the construction phase and the operational phase, which are listed in **Table 11-7**.

371. The magnitude of decommissioning effects will be comparable to, or less than, those as assessed during the construction phase. Accordingly, given that all effects were assessed to be **minor adverse** significance, or less, for the identified fish and shellfish ecology receptors during the construction phases, it is anticipated that the same would be valid for the decommissioning phase regardless of the final decommissioning methodologies. Therefore, all would be considered as **not significant** in EIA terms.

11.8 Cumulative Effects

372. Cumulative effects are the result of the impacts of the Project acting in combination with the impacts of other proposed and reasonably foreseeable developments on receptors. This includes plans and projects that are not inherently considered as part of the current baseline.

373. The overarching framework used to identify and assess cumulative effects is set out in **Chapter 6 Environmental Impact Assessment Methodology**. The four-stage approach is based upon the Planning Inspectorate Nationally Significant Infrastructure Projects: Advice on Cumulative Effects Assessment (Planning Inspectorate, 2024) and the Offshore Wind Marine Environmental Assessments: Best Practice Advance for Evidence and Data Standards (Parker *et al.,* 2022). The fourth stage of the process is the assessment stage, which is detailed within the sections below for potential cumulative effects on fish and shellfish ecology receptors.

11.8.1 Screening for Potential Cumulative Effects

374. The first step of the CEA identifies which impacts associated with the Project alone, as assessed under **Section 11.7**, have the potential to interact with other plans and projects to give rise to cumulative effects. All potential cumulative effects to be taken forward in the CEA are detailed in Table 11-25 with a rationale for screening in or out. Only impacts determined to have a residual effect of negligible or greater are included in the CEA. Those assessed as 'no impact' are excluded, as there is no potential for them to contribute to a cumulative effect.

Table 11-25 Fish and Shellfish Ecology – Potential Cumulative Effects

Impact ID	Impact and Project Activity	Potential for Cumulative Effects	Rationale
Construction			
FSE-C-02	Temporary habitat loss / physical disturbance – through construction activities	No	The extent of these impacts is limited both spatially and temporally in relation to identified fish and shellfish receptor groups within the Study Area.
FSE-C-04	Increased suspended sediment and sediment-redeposition – through construction activities	No	
FSE-C-06	Remobilisation of contaminated sediments if present - offshore ECC – through construction activities	No	
FSE-C-07	Underwater noise and vibration – through construction activities	Yes	Underwater noise from the activities of other developments within the Study Area have potential to overlap with impacts generated during the construction of the Project.
FSE-C-08	Changes in fishing pressure – during construction activities	No	The extent of impacts associated with fishing pressure are limited both spatially and temporally in relation to identified fish and shellfish receptor groups within the Study Area.

Impact ID	Impact and Project Activity	Potential for Cumulative Effects	Rationale
Operation & Maintenance			
FSE-O-02	Temporary habitat loss / physical disturbance – maintenance activities	No	The extent of these impacts is limited both spatially and temporally in relation to identified fish and shellfish receptor groups within the Study Area.
FSE-O-03	Habitat loss / alteration - foundations and scour protection on the seabed and cable protection	Yes	Impacts are highly localised, however incremental changes in the region are considered.
FSE-O-04	Increased suspended sediment and sediment-redeposition – maintenance activities	No	The extent of these impacts is limited both spatially and temporally in relation to identified fish and shellfish receptor groups within the Study Area.
FSE-O-06	Remobilisation of contaminated sediments if present (offshore ECC) – routine maintenance	No	
FSE-O-07	Underwater noise and vibration – operation of wind turbines	No	Highly limited noise occurring occasionally over the operational phase of the Project with very localised effects and no piling.
FSE-O-08	Changes in fishing pressure - O&M activities	No	The extent of impacts associated with fishing pressure are limited both spatially and temporally in relation to identified fish and shellfish receptor groups within the Study Area.
FSE-O-09	EMF effects – transmission of electricity	No	Given the scale of Project-alone effect there would be no interaction of effects, additive effects across the Study Area would be negligible across projects.
FSE-O-10	Sediment heating from export cables – transmission of electricity	No	The spatial extent of sediment heating is anticipated to remain within the immediate vicinity of Project cables, with burial minimising impact to negligible significance for most receptor groups. Given the scale of Project-alone effect there would be no interaction of effects, additive effects across the Study Area would be negligible across projects.
FSE-O-11	Introduction of hard substrate – presence of concrete and steel structures	Yes	Impacts are highly localised, however incremental changes in the region are considered.
Decommissioning			
FSE-D-02	Temporary habitat loss / physical disturbance – through decommissioning activities	No	See rationale for equivalent Construction impact.
FSE-D-03	Increased suspended sediment and sediment-redeposition– through decommissioning activities	No	
FSE-D-04	Increased suspended sediment and sediment-redeposition– through decommissioning activities	No	
FSE-D-06	Remobilisation of contaminated sediments if present - offshore ECC– through decommissioning activities	No	

Impact ID	Impact and Project Activity	Potential for Cumulative Effects	Rationale
FSE-D-07	Underwater noise and vibration– through decommissioning activities	No	Unlike Construction, there will be no pile driving. Noise impacts are therefore expected to be highly limited. Given the scale of Project-alone effect there would be no interaction of effects, additive effects across the Study Area would be negligible across projects.
FSE-D-08	Changes in fishing pressure– through decommissioning activities	No	See rationale for equivalent Construction impact.
FSE-D-11	Introduction of hard substrate– through decommissioning activities	No	

11.8.2 Screening for Other Plans / Projects

375. The second step of the CEA identifies a short-list of other plans and projects that have the potential to interact with the Project to give rise to significant cumulative effects during the construction and operational phases. The short-list provided in Table 11-26 has been produced specifically to assess cumulative effects on fish and shellfish ecology receptors. The exhaustive list of all offshore plans and projects considered in the development of the Project's CEA framework is provided in **Volume 2, Appendix 6.4 Cumulative Effects Screening Report - Offshore**.

376. Developments that were fully operational during baseline characterisation, including at the time of site-specific surveys, are considered as part of baseline conditions for the surrounding environment. It is assumed that any residual effects associated with these developments are captured within the baseline information. As such, these developments are not subject to further assessment within the CEA and excluded from the screening exercise presented in Table 11-26.

377. For developments that were not fully operational, including those in planning / pre-construction stages or under construction, during baseline characterisation and operational developments with potential for ongoing impacts, these are included in the screening exercise presented in Table 11-26.

378. The screening exercise has been undertaken based on available information on each plan or project as of 9th December 2024. Information has been obtained from The Crown Estate, 4C Offshore, EMEC, EMODnet, Marine Scotland / Directorate, North Sea Transition Authority, Cefas, KIS-ORCA, National Grid, Oceanwise and Scottish Carbon Capture Storage. It is noted that further information regarding the identified plans and projects may become available between PEIR publication and DCO application submission or may not be available in detail prior to construction. The assessment presented here is therefore considered to be conservative at the time of PEIR publication. The list of plans and projects will be updated at ES stage to incorporate more recent information at the time of writing.

379. Plans and projects identified in Table 11-26 have been assigned a tier based on their development status, the level of information available to inform the CEA and the degree of confidence. A seven-tier system based on the guidance issued by Natural England and the Department of Environmental, Food and Rural Affairs (Defra) has been adopted (Parker *et al.,* 2022).

380. The zone of influence (ZoI) used to identify relevant plans and projects for the fish and shellfish ecology CEA is the Study Area as defined in **Section 11.4.1**.

381. Each plan or project in Table 11-26 has been considered on a case-by-case basis. Only plans and projects with potential for significant cumulative effects with the Project are taken forward to a detailed assessment, which are screened based on the following criteria:

- There is potential that a pathway exists whereby an impact could have a cumulative effect on a receptor;
- The impact on a receptor from the Project and the plan or project in consideration has a spatial overlap (i.e. occurring over the same area);
- The impact on a receptor from the Project and the plan or project in consideration has a temporal overlap (e.g. occurring at the same time);
- There is sufficient information available on the plan or project in consideration and moderate to high data confidence to undertake a meaningful assessment; and
- There is some likelihood that the residual effect (i.e. after accounting for mitigation measures) of the Project could result in significant cumulative effects with the plan or project in consideration.

382. The CEA for fish and shellfish ecology has identified a total of 13 plans and projects where significant cumulative effects could arise in combination with the Project. A detailed assessment of cumulative effects is provided in the section below.

Table 11-26 Short List of Plans / Projects for the Fish and Shellfish Ecology Cumulative Effect Assessment

Project / Plan	Development Type	Status	Tier	Construction / Operation Period	Closest Distance to Array Area (km)	Closest Distance to Offshore ECC (km)	Potential for Significant Cumulative Effects	Rationale
Dogger Bank A Offshore Wind Farm (EN010021)	Offshore Wind Farm and associated export cables	Under construction	2	Construction: 2024 to 2027 Operation: From 2028	43	31	Yes	Potential for cumulative habitat loss.
Dogger Bank B Offshore Wind Farm (EN010021)	Offshore Wind Farm and associated export cables	Under construction	2	Construction: 2024 to 2027 Operation: From 2028	52	9	Yes	
Dogger Bank C Offshore Wind Farm	Offshore Wind Farm and associated export cables	Under construction	2	Construction: 2024 to 2027 Operation: From 2028	0	3	Yes	
Dogger Bank South Offshore Wind Farm (EN010125)	Offshore Wind Farm and associated export cables	Application submitted	4	Construction: 2026 to 2032 Operation: From 2033	71	46	Yes	Potential for cumulative habitat loss. There is also potential for cumulative underwater noise effects during construction as these projects are within 50km of the project. Worst-case recoverable injury and TTS impact range for the Project-alone is 44km.
Dogger Bank South West (EN010125)	Offshore Wind Farm and associated export cables	Application submitted	4	Construction: 2026 to 2032 Operation: From 2033	79	16	Yes	
Hornsea Project Four Offshore Wind Farm (EN010098)	Offshore Wind Farm and associated export cables	Consented	3	Construction: 2025 to 2029 Operation: From 2030	134	31	Yes	Potential for cumulative habitat loss.
Ossian Offshore Wind Farm: Array (EN0210006)	Offshore Wind Farm and associated export cables	Application submitted	4	Construction: 2027 to 2029 Operation: From 2030	160	0	Yes	
Sofia Offshore Wind Farm (EN010051)	Offshore Wind Farm and associated export cables	Under construction	2	Construction: 2024 to 2027 Operation: From 2028	18	23	Yes	
Northern Endurance Partnership Carbon Capture Storage (D/4271/2021)	Carbon Capture Storage	In planning	4	Construction: 2026 to 2029 Operation: From 2030	132	15	Yes	
Eastern Green Link (EGL2)	Interconnector	Pre-construction	3	Construction: 2025 to 2029 Operation: From 2030	356	283	Yes	

Project / Plan	Development Type	Status	Tier	Construction / Operation Period	Closest Distance to Array Area (km)	Closest Distance to Offshore ECC (km)	Potential for Significant Cumulative Effects	Rationale
Eastern Green Link (EGL3) (EN0210003)	Interconnector	In planning	6	Construction: 2027 to 2032 Operation: From 2033	357	285	Yes	
Eastern Green Link (EGL4) (EN0210003)	Interconnector	In planning	6	Construction: 2027 to 2032 Operation: From 2033	163	0	Yes	

11.8.3 Assessment of Cumulative Effects

383. Having established the residual effects from the Project with the potential for a cumulative effect, along with the other relevant plans / projects, the following sections provide an assessment of the level of cumulative effect that may arise. These are detailed below per impact where the potential for significant cumulative effects have been identified as detailed in Table 11-25.

384. As shown in Table 11-25 the impacts with potential pathways for cumulative effects to fish and shellfish ecology include:

- Underwater noise and vibration (construction); and
- Habitat loss / Alteration (operation and maintenance).

11.8.3.1 Cumulative Impact 1: Underwater Noise and Vibration (FSE-C-07)

385. As a result of noise and vibration associated with the construction of other plans / projects in combination with the Project, there is potential for cumulative effects to occur. The assessment of the impact has been evaluated within 50km radius of the Project. This distance encompasses the maximum extent (44km for TTS) of noise impacts, as indicted by the noise modelling in **Section 11.7.1.4.3**.

386. Table 11-26 details the identified plans / projects that have been considered and screened in or out of the noise and vibration cumulative assessment based on their temporal and spatial extents during construction. The construction period considered for the cumulative assessment spans from 2029 to 2035.

387. For fish, the largest recoverable injury ranges (Project-alone) for pile driving are predicted to be 12km, assuming a stationary receptor; and if a fleeing receptor is assumed, the impact ranges are reduced to 0.35km (**Section 4** of **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**), although stationary fish receptors are assumed for the purposes of this assessment. Given the location of projects, cumulative recoverable noise injury impacts could occur for stationary fish receptors if the Project, Dogger Bank South East (DBSE) and Dogger Bank South West (DBSW) conduct piling operations simultaneously.

388. However, active piling will take place during only a brief portion of the entire construction period of the offshore wind farm projects. Additionally, it is unlikely that piling will occur simultaneously at multiple offshore wind farm projects, as the intended construction period for Dogger Bank South is from 2026 to 2032. Therefore, this limits the potential for this Project to significantly contribute to underwater noise and vibration cumulatively.

389. The remaining noise impact that could act cumulatively is TTS or behavioural impacts. TTS and behavioural impacts are of greatest concern for sensitive species which use the area for spawning, and migratory species which may encounter barrier effects, however, consideration has also been given to other fish species.

11.8.3.1.1 Other Noise Sources

11.8.3.1.1.1 UXO Clearance

390. In the case of the Project's requirement to clear UXO, various possible types and sizes of UXO were modelled (see **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report** for further details). As noted in **Section 11.7.1.4.3,** UXO clearance for the Project would be subject to a separate marine licence process post-consent which would take account of the quantities, charge weights and likely UXO clearance methods to provide an accurate assessment. Therefore, this high-level assessment is presented for information purposes only, but does also consider UXO clearance at other projects.

391. As identified in **Section 4** in **Volume 2, Appendix 12.3 Underwater Noise Modelling Report**, the worst-case range for mortality and potential mortal injury from a high order UXO detonation is 970m. In reality, the use of a high order detonation would be unlikely and would only be used as a last resort, with low order deflagration of UXO preferred, with greatly reduced noise as a result. The other projects screened in are taking the same approach to the hierarchy of preferred clearance methods. It is not expected that UXO clearance from the Project would be undertaken at the same time as piling for the Project. The likelihood of UXO clearance being undertaken at the same time from other projects e.g. Dogger Bank South is unlikely with their intended construction period. Therefore, this limits the potential for the Project to significantly contribute to underwater noise and vibration cumulatively.

11.8.3.1.2 Receptor Sensitivity

392. The sensitivity of receptor groups to underwater noise is based on the sensitivity of their hearing systems, as defined by Popper *et al.* (2014) set out in **Section 11.7.1.4.1**

393. As stated in **Section 11.7.1.4.4**, species within the "*fish where swim bladder is involved in hearing*" (Groups 3 and 4) category (Table 11-17) are pelagic and therefore highly mobile and may depart the area from the onset of 'soft start' piling. However, they are the most sensitive species to underwater noise and vibration. Therefore, fish species with a swim bladder used in hearing are determined to have a **medium** sensitivity.

394. The sensitivity of other fish species and shellfish to noise associated with the construction phase of the Project is considered **low**. Including “fish with no swim bladder” (Group 1), and “fish where swim bladder is not involved in hearing” (Group 2). The majority of fish receptors included within these groups (Table 11-21) are mobile and would be expected to vacate the area in which the impact could occur with the onset of ‘soft start’ piling. Elasmobranchs, sandeels, pleuronectiforms (flatfish), and mackerel do not have a swim bladder or other air-filled cavity. They are incapable of detecting sound pressures and, therefore, particle motion is the only sound stimulus which can be detected (Casper *et al., 2*012).

395. All other receptor groups, including fish eggs and larvae, and shellfish species, have an increased tolerance to underwater noise and vibration. Whilst species within these receptor groups are of importance within the North Sea, their populations are likely to recover to baseline levels due to the high fecundity of the majority of fish and shellfish species, and the limited area over which these impacts would result in individual mortalities. Therefore, all other fish and shellfish receptor groups are determined to have a **low** sensitivity to underwater noise and vibration.

11.8.3.1.3 Cumulative Impact Magnitude

396. Dogger Bank South East and Dogger Bank South West have a construction phase that overlaps with construction at DBD therefore it is possible, although unlikely, that piling activities may occur at the same time.

397. Whether mitigation measures are required for seabed works along the DBS Offshore ECCs and spawning herring grounds, is being explored by these projects (see Dogger Bank South, 2024). The current position of these projects is that further mitigation is not required. Impact piling and UXO noise sources pertain to discrete events, with noise and vibrations emissions occurring in the **medium** term (2 – 10 years). With these measures, effects associated with underwater noise and vibration via impact piling and UXO within the Project Area combined with other projects is not materially greater than the magnitude for the Project-alone. Therefore, the magnitude of impact for underwater noise and vibration is considered **low**.

11.8.3.1.4 Cumulative Effect Significance

398. The likelihood of single piling strikes occurring at multiple projects concurrently within an overlapping distance is considered to be extremely low, and there is predicted to be high recoverability to TTS and behavioural disturbance. In addition, the relevant projects have seasonal restrictions on piling along their offshore ECCs which removes the potential for them to interact with the herring spawning grounds of the coast of Flamborough Head. The cumulative magnitude of this impact is considered to be **low**. Combined with the **medium** sensitivity of effect for fish with a swim bladder used in hearing, the cumulative assessment of impact from underwater noise and vibration has a **minor adverse** effect, and is therefore **not significant** in EIA terms.

11.8.3.2 Cumulative Impact 2: Habitat Loss / Alteration (FSE-O-03)

399. For cumulative impacts to occur, for a specific fish and shellfish receptor, other projects / activities would also need to interact with habitat suitable for that specific fish and shellfish receptor (e.g. the requirement for gravelly sand for herring spawning). Suitable habitat for fish and shellfish receptors that is present in the DBD Array Area is also ubiquitous across the wider region. There are also areas in the region which are already impacted, or which do not provide suitable habitat, and therefore are not likely to be impacted cumulatively.

400. In terms of disturbance and habitat loss / alteration (during all Project phases) the habitat types found within the DBD Array Area have a medium to high recoverability (see **Section 10.7.1.1** of **Chapter 10 Benthic and Intertidal Ecology**), whilst the scale of habitat loss /alteration associated with the Project (**Table 11-7**) is small in the context of wider disturbance in the region (from mobile fishing for example). In addition, given the localised nature of the impacts, the overall combined magnitude of these activities would be negligible, relative to the scale of the fish and shellfish receptors potentially affected. Given the above, there would be no significant cumulative effect or elevation beyond the Project-alone assessment (**minor adverse**).

11.8.3.2.1 Receptor Sensitivity

401. The sensitivity of fish and shellfish receptor groups to habitat loss / alteration is determined by a number of factors including life histories, habitat requirements and species extent. The most sensitive receptor groups to habitat loss / alteration are demersal and pelagic fish species, specifically those species that rely on specific seabed types for spawning and habitat. In particular, sandeel and Atlantic herring present a greater level of sensitivity to this impact than other species within the region. The sensitivity of these receptors is therefore considered to be **medium**, in line with the determination made within **Section 11.7.2.2.1**.

11.8.3.2.2 Cumulative Impact Magnitude

402. As a result of the Project’s infrastructure in combination with other plans / projects, cumulative habitat loss / alteration will occur in an additive manner. Worst-case values of habitat loss / alteration expected from the Project alongside the equivalent values relating to the relevant plans / projects included within Table 11-26 are presented within Table 11-27, all of which fall entirely or partially within the Study Area. Note that a number of these developments would fall only partially within the Study Area, with the table presenting total habitat loss / alteration across the full extent of each development.

403. Values have been sourced from the most recent revisions of ESs where available. Selected values represent the worst-case scenario for each development, with actual values having the potential to experience reduction prior to construction.

Table 11-27 Total Area of Worst-Case Habitat Loss / Alteration Anticipated for Developments within the Fish and Shellfish Study Area

Project /Plan	Development Type	Tier	Worst-case Predicted Habitat Loss / Alteration (km^2)
Dogger Bank D Offshore Wind Farm	Offshore Wind Farm and associated export cables	6	2.41
Dogger Bank A Offshore Wind Farm	Offshore Wind Farm and associated export cables	2	3.36
Dogger Bank B Offshore Wind Farm	Offshore Wind Farm and associated export cables	2	4.59 + 1.36
Dogger Bank C Offshore Wind Farm	Offshore Wind Farm and associated export cables	2	3.73 + 1.34
Dogger Bank South Offshore Wind Farm (East & West)	Offshore Wind Farm and associated export cables	4	2.05 + 2.14
Hornsea Project Four Offshore Wind Farm	Offshore Wind Farm and associated export cables	3	2.4 + 1.3
Ossian Offshore Wind Farm	Offshore Wind Farm and associated export cables	4	Currently not known
Sofia Offshore Wind Farm	Offshore Wind Farm and associated export cables	2	3.73 + 1.34
Northern Endurance	Carbon Capture Storage	4	3.58
Aminth Energy Interconnector	Interconnector	7	Currently not known
Eastern Green Link (EGL2)	Interconnector	3	2.4
Eastern Green Link (EGL3)	Interconnector	6	Currently not known
Eastern Green Link (EGL4)	Interconnector	6	Currently not known
Total			34.39

11.8.3.2.3 Cumulative Effect Significance

404. As only a small component of the Fish and Shellfish Ecology Study Area and associated seabed habitat is likely to undergo habitat loss / alteration, the cumulative magnitude of this impact is considered to be low. Combined with the **medium** sensitivity of effect for the demersal fish, and pelagic fish receptor groups with demersal spawning, the cumulative assessment of impact from habitat loss / alteration as a result of changes in substrate has a **minor adverse** effect, and is therefore **not significant** in EIA terms.

11.9 Transboundary Effects

405. As discussed in **Section 11.5.3.3** the distribution of fish and shellfish species is independent of national geographical boundaries. The assessment for the Project has been undertaken taking account of the distribution of fish stocks and populations irrespective of national jurisdictions.

406. Based on the maximum extent of SSC plumes from the Project (see **Section 11.7.1.2**) transboundary effects resulting from suspension of sediment will not occur for this Project (see **Section 8.9** in **Chapter 8 Marine Physical Processes**).

407. There is potential for underwater noise from piling during construction to travel into the territorial waters of the Netherlands. The impact ranges for construction piling on fish receptors, as determined by a dedicated modelling study (**Volume 2, Appendix 12.3 Underwater Noise Modelling Report**), are discussed in **Section 11.7.1.4**. The worst-case 135dB SEL_{ss} impact ranges displayed on **Figure 11-8**, show that precautionary worst-case impact ranges for temporary behavioural disturbance for the most sound sensitive fish species do not overlap herring spawning grounds. This threshold is precautionary for the reasons set out in **Section 11.7.1.4**.

408. Aside from herring (see **Figure 11-8**), the greatest noise impact range for all other fish and shellfish species is 44km for TTS. This 44km ZoI for noise induced TTS does extend into Netherlands waters. As set out in **Section 11.7.1.4**, TTS impacts are predicted to be short term and intermittent, with recovery of fish and shellfish populations to affected areas following completion of piling activities. Overall, the sensitivity of fish and shellfish to piling noise were assessed as low to **medium**, with a magnitude of low, resulting in an effect significance of minor adverse. This finding is also deemed to apply in ensonified areas of Netherlands territorial waters and therefore transboundary effects of piling noise are **minor adverse**, which is **not significant** in EIA terms.

11.10 Inter-Relationships and Effects Interactions

11.10.1 Inter-Relationships

409. Inter-relationships are defined as effects arising from residual effects associated with different environmental topics acting together upon a single receptor or receptor group. Potential inter-relationships between fish and shellfish ecology and other environmental topics have been considered, where relevant, within the PEIR. **Table 11-28** provides a summary of key inter-relationships and signposts to where they have been addressed in the relevant chapters.

Table 11-28 Fish and Shellfish Ecology – Inter-Relationships with Other Topics

Impact ID	Impact and Project Activity	Related EIA Topic	Where Assessed in the PEIR Chapter	Rationale
Construction				
All impacts	All impacts relating to fish and shellfish ecology	**Chapter 11 Marine Mammals**	This chapter informs **Chapter 11 Marine Mammals**	Fish and shellfish species act as a prey species for a wide range of marine mammal receptors. Impacts on Fish and Shellfish Ecology may therefore lead to impacts on Marine Mammals.
All impacts	All impacts relating to fish and shellfish ecology	**Chapter 14 Commercial Fisheries**	This chapter informs **Chapter 14 Commercial Fisheries**	Fish and shellfish species act as a prey species for a wide range of marine mammal receptors. Impacts on Fish and Shellfish Ecology may therefore lead to impacts on Marine Mammals.
FSE-C-04	Increased suspended sediment and sediment-redeposition	**Chapter 9 Marine Water and Sediment Quality**	**Sections 11.7.1.2** and **11.7.2.3**	The level of changes in SSC and sediment re-deposition are assessed in **Chapter 9 Marine Water and Sediment Quality**. This informs the FSE-C-04 impact.
FSE-C-06	Remobilisation of contaminated sediments if present - offshore ECC	**Chapter 9 Marine Water and Sediment Quality**	**Sections 11.7.1.3** and **11.7.2.4**	**Chapter 9 Marine Water and Sediment Quality** assesses the levels of contaminants in sediment and their potential for resuspension. This has informed the assessment of impact FSE-C-06.
Operation & Maintenance				
All impacts	All impacts relating to fish and shellfish ecology	**Chapter 11 Marine Mammals**	This chapter informs **Chapter 11 Marine Mammals**	Fish and shellfish species act as a prey species for a wide range of marine mammal receptors. Impacts on Fish and Shellfish Ecology may therefore lead to impacts on Marine Mammals.
All impacts	All impacts relating to fish and shellfish ecology	**Chapter 14 Commercial Fisheries**	This chapter informs **Chapter 14 Commercial Fisheries**	Fish and shellfish species act as a prey species for a wide range of marine mammal receptors. Impacts on Fish and Shellfish Ecology may therefore lead to impacts on Marine Mammals.

Impact ID	Impact and Project Activity	Related EIA Topic	Where Assessed in the PEIR Chapter	Rationale
FSE-O-04	Increased suspended sediment and sediment-redeposition	**Chapter 9 Marine Water and Sediment Quality**	**Sections 11.7.1.2** and **11.7.2.3**	The level of changes in SSC and sediment re-deposition are assessed in **Chapter 9 Marine Water and Sediment Quality**. This informs the FSE-O-04 impact.
FSE-O-06	Remobilisation of contaminated sediments if present - offshore ECC	**Chapter 9 Marine Water and Sediment Quality**	**Sections 11.7.1.3** and **11.7.2.4**	**Chapter 9 Marine Water and Sediment Quality** assesses the levels of contaminants in sediment and their potential for resuspension. This has informed the assessment of impact FSE-O-06.
Decommissioning				
The details and scope of offshore decommissioning works will be determined by the relevant regulations and guidance at the time of decommissioning and provided in the Offshore Decommissioning Plan (see Commitment ID CO21 in **Table 11-4**). For this assessment, it is assumed that inter-relationships during the decommissioning phase would be of similar nature to those identified during the construction phase.				

11.10.2 Interactions

410. The impacts identified and assessed in this chapter have the potential to interact with each other. Potential interactions between impacts are identified in Table 11-29. Where there is potential for interaction between impacts, these are assessed in Table 11-30 for each receptor or receptor group.

411. Interactions are assessed by development phase ("phase assessment") to see if multiple impacts could increase the overall effect significance experienced by a single receptor or receptor group during each phase. Following from this, a lifetime assessment is undertaken which considers the potential for multiple impacts to accumulate across the construction, operation and decommissioning phases and result in a greater effect on a single receptor or receptor group. When considering synergistic effects from interactions, it is assumed that the receptor sensitivity remains consistent, while the magnitude of different impacts is additive.

Table 11-29 Fish and Shellfish Ecology – Potential Interactions between Impacts

Construction and Operation & Maintenance														
	FSE-C-02	**FSE-C-04**	**FSE-C-06**	**FSE-C-07**	**FSE-C-08**	**FSE-O-02**	**FSE-O-03**	**FSE-O-04**	**FSE-O-06**	**FSE-O-07**	**FSE-O-08**	**FSE-O-09**	**FSE-O-10**	**FSE-O-11**
Temporary habitat loss / physical disturbance (FSE-C-02)		Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Increased suspended sediment and sediment-redeposition (FSE-C-04)	Yes		No	No	No	No	No	No	No	No	No	No	No	No
Remobilisation of contaminated sediments if present - offshore ECC (FSE-C-06)	Yes	No		No	No	No	No	No	No	No	No	No	No	No
Underwater noise and vibration (FSE-C-07)	No	No	No		No	No	No	No	No	No	No	No	No	No
Changes in fishing pressure (FSE-C-08)	No	No	No	No		No	No	No	No	No	No	No	No	No
Temporary habitat loss / physical disturbance (FSE-O-02)	No	No	No	No	No		Yes	Yes	Yes	No	No	No	No	Yes
Habitat loss / alteration (FSE-O-03)	No	No	No	No	No	Yes		No	No	No	No	No	No	No
Increased suspended sediment and sediment-redeposition (FSE-O-04)	No	No	No	No	No	Yes	No		No	No	No	No	No	No
Remobilisation of contaminated sediments if present - offshore ECC (FSE-O-06)	No	No	No	No	No	Yes	No	No		No	No	No	No	No

	FSE-C-02	FSE-C-04	FSE-C-06	FSE-C-07	FSE-C-08	FSE-O-02	FSE-O-03	FSE-O-04	FSE-O-06	FSE-O-07	FSE-O-08	FSE-O-09	FSE-O-10	FSE-O-11
Construction and Operation & Maintenance														
Underwater noise and vibration (FSE-O-07)	No	No	No	No	No	No	No	No	No		No	No	No	No
Changes in fishing pressure (FSE-O-08)	No	No	No	No	No	No	No	No	No	No		No	No	No
EMF effects (FSE-O-09)	No	No	No	No	No	No	No	No	No	No	No		No	No
Sediment heating from export cables (FSE-O-10)	No	No	No	No	No	No	No	No	No	No	No	No		No
Introduction of hard substrate (FSE-O-11)	No	No	No	No	No	Yes	No	No	No	No	No	No	No	
Decommissioning														

The details and scope of offshore decommissioning works will be determined by the relevant regulations and guidance at the time of decommissioning and provided in the Offshore Decommissioning Plan (see Commitment ID CO21 in **Table 11-4**).

For this assessment, it is assumed that interactions during the decommissioning phase would be of similar nature to, and no worse than, those identified during the construction phase.

Table 11-30 Interaction Assessment – Phase and Lifetime Effects

Receptor	Impact ID	Highest Significance Level			Phase Assessment	Lifetime Assessment
		Construction	Operation & Maintenance	Decommissioning		
Fish and shellfish species Specific consideration of inshore herring spawning inluded	FSE-C-02 FSE-C-04 FSE-O-02 FSE-O-03 FSE-O-04 FSE-O-06 FSE-O-11 FSE-D-02 FSE-D-04	**Minor Adverse**	**Minor Adverse**	**Minor Adverse**	**Construction**: No greater than individually assessed impact. The effects resulting from habitat disturbance will be localised, temporary and episodic with limited potential for interaction. In the case of spawning herring in the inshore region, the key impact is sediment re-deposition and the potential to bury eggs, It is not considered that increased SSC in the water column would serve to cause a greater impact on demersal eggs than burial alone, as eggs and larvae are robust to temporary increases in SSC (see **Section 11.7.1.2**). **Operation & Maintenance**: No greater than individually assessed impact. Disturbance to or loss of habitat will be confined to the immediate footprint of the infrastructure / activities. Impact magnitudes are low to negligible. Therefore, no impacts would interact to increase the overall significance level. **Decommissioning**: No greater than individually assessed impact. It is anticipated that the decommissioning impacts will be similar in nature to those of construction.	No greater than individually assessed impact. The greatest magnitude of effect will be the spatial footprint of construction noise (i.e. piling) and the habitat disturbance from seabed preparation, installation of cables, foundation installation. Once these impacts have ceased during the construction phase, all further impacts during construction, operation and decommissioning will be small scale, localised and episodic. This rationale also applies to herring spawning grounds in the inshore section of the Offshore ECC. There is no evidence of long term displacement of fish or shellfish from operational wind farms. It is therefore considered that over the project lifetime these impacts would not interact to change the significance level overall.

11.11 Monitoring Measures

413. No monitoring measures have been proposed for fish and shellfish ecology.

11.12 Summary

414. The assessment has established that there will be some minor adverse residual effects during the construction, operation and decommissioning phases of the Project, which is considered not significant in EIA terms. Effects are generally localised in nature, being restricted to the Project's boundaries and immediate surrounding area. Table 11-31 presents a summary of the preliminary results of the assessment of likely significant effects on fish and shellfish ecology during the construction, operation and decommissioning of the Project.

11.13 Next Steps

415. Between the submission of the PEIR and the final ES as part of the DCO application, the following actions will be undertaken:

- **Consultation and stakeholder engagement** will continue to be undertaken addressing any feedback on this PEIR chapter;
- **Updates to underwater noise modelling**: These updates will address non-material changes, requirement for NAS as per latest UK Government and Defra (2025) policy, and the anticipated Defra noise dB limit for piling operations will be in place by 2028. This will necessitate modelling with mitigation measures to adhere to new best practices;
- **Herring larvae data updates:** Include most recent IHLS data to populate see **Figure 11-8** and **Figure 11-6**;
- **Update of landings data:** Should 2024 data be available, the landings data in **Table 11-9** will be updated; and
- **Any design refinements**: will be captured and reassessed accordingly.

Table 11-31 Summary of Potential Effects Assessed for Fish and Shellfish Ecology

Impact ID	Impact	Embedded Mitigation Measures	Receptor	Receptor Sensitivity	Impact Magnitude	Effect Significance	Additional Mitigation Measures	Residual Effect	Monitoring Measures
Construction									
FSE-C-02	Temporary habitat loss / physical disturbance – through construction activities	CO23 CO24 CO26	All	**Low-medium**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
FSE-C-04	Increased suspended sediment and sediment-redeposition – through construction activities	CO23 CO24 CO26	All	**Low-medium**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
FSE-C-06	Remobilisation of contaminated sediments if present - offshore ECC – through construction activities	CO23 CO24 CO26	All	**Negligible**	**Negligible**	**Negligible**	N/A	**Negligible** **(not significant)**	None
FSE-C-07	Underwater noise and vibration – through construction activities	CO22 CO26	All	**Low-medium**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse** **(not significant)**	None
FSE-C-08	Changes in fishing pressure – during construction activities	CO26	All	**Low**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse** **(not significant)**	None
Operation & Maintenance									
FSE-O-02	Temporary habitat loss / physical disturbance – maintenance activities	CO26 CO28	All	**Low-medium**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse** **(not significant)**	None
FSE-O-03	Habitat loss / alteration - foundations and scour protection on the seabed and cable protection	CO24 CO28	All	**Medium-high**	**Negligible**	**Negligible – Minor adverse (not significant)**	N/A	**Minor adverse** **(not significant)**	None
FSE-O-04	Increased suspended sediment and sediment-redeposition – maintenance activities	CO28	All	**Low-medium**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse** **(not significant)**	None
FSE-O-06	Remobilisation of contaminated sediments if present (offshore ECC) – routine maintenance	CO28	All	**Negligible**	**Negligible**	**Negligible**	N/A	**Negligible** **(not significant)**	None

Impact ID	Impact	Embedded Mitigation Measures	Receptor	Receptor Sensitivity	Impact Magnitude	Effect Significance	Additional Mitigation Measures	Residual Effect	Monitoring Measures
FSE-O-07	Underwater noise and vibration – operation of wind turbines	CO28	All	**Low-medium**	**Negligible**	**Negligible - Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
FSE-O-08	Changes in fishing pressure - O&M activities	CO28	All	**Low**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
FSE-O-09	EMF effects – transmission of electricity	CO28	All	**Low-medium**	**Negligible**	**Negligible-Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
FSE-O-10	Sediment heating from export cables – transmission of electricity	CO28	All	**Medium-High**	**Negligible- low**	**Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
FSE-O-11	Introduction of hard substrate – presence of concrete and steel structures	CO24 CO28	All	**Low-medium**	**Low**	**Minor adverse (not significant)**	N/A	**Minor adverse (not significant)**	None
Decommissioning									
The details and scope of offshore decommissioning works will be determined by the relevant regulations and guidance at the time of decommissioning and provided in the Offshore Decommissioning Plan (see Commitment ID CO21 in **Volume 2, Appendix 6.3 Commitments Register**). This will include a detailed assessment of decommissioning impacts and appropriate mitigation measures to avoid significant effects. For this assessment, it is assumed that impacts during the decommissioning phase would be of similar nature to, and no worse than, those identified during the construction phase.									

References

Aires, C., González-Irusta, J. M., & Watret, R. (2014). Updating Fisheries Sensitivity Maps in British Waters: Scottish Marine and Freshwater Science Volume 5 Number 10. Available at: https://doi.org/10.7489/1555-1

Andersson M H, Andersson S, Ahlsén J, Andersson B L, Hammar J, Persson L K G, Pihl J, Sigray P, Wilkström A (2017). A framework for regulating underwater noise during pile driving. A technical Vindval report, ISBN 978-91-620-6775-5, Swedish Environmental Protection Agency, Stockholm, Sweden.

André, M., Solé, M., Lenoir, M., Durfort, M., Quero, C., Mas, A., Lombarte, A., van der Schaar, M., López-Bejar, M., Morell, M., Zaugg, S., & Houégnigan, L. (2011). Low-frequency sounds induce acoustic trauma in cephalopods. Frontiers in Ecology and the Environment, 9(9), 489–493. Available at: https://doi.org/10.1890/100124

Aneer, G. (1989). 'Herring (*Clupea harengus L.*) spawning and spawning ground characteristics in the Baltic Sea'. Fisheries Research, 8: 169–195.

Behrmann-Godel, J., & Eckmann, R. (2003). A preliminary telemetry study of the migration of silver European eel (*Anguilla anguilla*) in the River Mosel, Germany. Ecology of Freshwater Fish, 12(3), 196–202. Available at: https://doi.org/10.1034/j.1600-0633.2003.000–5.x

Behrens, J. W., Stahl, H. J., Steffensen, J. F., & 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. https://doi.org/10.1242/jeb.000570

Berx, B. and Hughes, S. (2008). Climatology of Surface and Near-bed Temperature and Salinity on the North-West European Continental Shelf for 1971–2000.

Birchenough, Silvana & Degraer, Steven (2020). Introduction Science in support of ecologically sound decommissioning strategies for offshore man-made structures: taking stock of current knowledge and considering future challenges.

Birklund, J. and Wijsman, J. W. M. (2005). Aggregate Extraction: A Review on the Effects on Ecological Functions. Report Z3297/10 SAWDPIT Fifth Framework Project no EVK3-CT-2001-00056. Available online at https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.896.2554&rep=rep1&type=pdf

Boehlert, G.W., and Gill, A.B. (2010). Environmental and ecological effects of ocean renewable energy development: a current synthesis. Oceanography, 23, pp. 68-81.

Boles, L.C. and Lohmann, K.J. (2003). True navigation and magnetic maps in spiny lobsters. Nature 421, pp. 60-63.

Bowers, A.B. (1980). Characteristics of herring (*Clupea harengus*) spawning grounds. ICES CM 1980/H:13.

BOWL (2021). Beatrice Offshore Wind Farm Post-Construction Sandeel Survey–Technical Report.

Bruijs, M. & Durif, C. (2009). Silver Eel Migration and Behaviour. 10.1007/978-1-4020-9095-0_4.

Callaway, R., Alsvåg, J., de Boois, I., Cotter, J., Ford, A., Hinz, H., Jennings, S., Kröncke, I., Lancaster, J., Piet, G., Prince, P., & Ehrich, S. (2002). Diversity and community structure of epibenthic invertebrates and fish in the North Sea. ICES Journal of Marine Science, 59(6), 1199–1214. https://doi.org/10.1006/jmsc.2002.1288

Casper, B.M., M.B. Halvorsen, and A.N. Popper. (2012). Are sharks even bothered by a noisy environment? In: Popper, A.N. and A.D. Hawkins, eds. The effects of noise on aquatic life. New York: Springer Science + Business Media, LLC. Pp. 93-98.

Cefas (2023) .Assessment of Salmon Stocks and Fisheries in England and Wales. Available at: Background: Salmon Stocks and Fisheries England and Wales in 2022 - GOV.UK (www.gov.uk)

Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2007). Multispecies Fisheries Management: A Comprehensive Impact Assessment of the Sand eel Fishery along the English East Coast. CEFAS Contract Report MF0323/01.

Chang, Y.-L. K., Feunteun, E., Miyazawa, Y., & Tsukamoto, K. (2020). New clues on the Atlantic eels spawning behavior and area: The Mid-Atlantic Ridge hypothesis. Scientific Reports, 10(1), 15981. https://doi.org/10.1038/s41598-020-72916-5

Christoffersen, M., Svendsen, J. C., Kuhn, J. A., Nielsen, A., Martjanova, A., & Støttrup, J. G. (2018). Benthic habitat ammaruson in juvenile European eel *Anguilla ammarus*: Implications for coastal habitat management and restoration. Journal of Fish Biology, 93(5), 996–999. Available at: https://doi.org/10.1111/jfb.13807

Coolen, Joop & Boon, Arjen & Crooijmans, Richard & Pelt, Hilde & Kleissen, Frank & Gerla, Daan & Beermann, Jan & Birchenough, Silvana & Becking, L. & Luttikhuizen, Pieternella. (2020). Marine stepping-stones: Connectivity of *Mytilus edulis* populations between offshore energy installations. Molecular Ecology. 29. 686 - 703. 10.1111/mec.15364.

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

CSA Ocean Sciences Inc. and Exponent (2019). Evaluation of Potential EMF Effects on Fish Species of Commercial or Recreational Fishing Importance in Southern New England. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Sterling, VA. OCS Study BOEM 2019-049, 59pp.

Daan, N., Bromley, P. J., Hislop, J. R. G., & Nielsen, N. A. (1990). Ecology of North Sea fish. Netherlands Journal of Sea Research, 26(2), 343–386. https://doi.org/10.1016/0077-7579(90)90096-Y

de Soto, N. A., Delorme, N., Atkins, J., Howard, S., Williams, J., & Johnson, M. (2013). Anthropogenic noise causes body malformations and delays development in marine larvae. Scientific Reports, 3(1), 2831. Available at: https://doi.org/10.1038/srep02831

DESNZ (2023a). Overarching National Policy Statement for Energy (EN-1). November 2023.

DESNZ (2023b). National Policy Statement for Renewable Energy Infrastructure (EN-3). November 2023.

Dogger Bank South Offshore Wind Farms (2024). Heat Mapping Report: Atlantic Herring and Sandeel.

DOWL (2016). Dudgeon Offshore Wind Farm – Piling Summary and Lessons Learned. August 2016.

Eastern Green Link 2 (2024). ERM Response to MMO Comments July 2024.

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. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56pp.

EMU (2004). Sub-sea Cable Decommissioning – A Limited Environmental Appraisal. Report commissioned by British Telecommunications plc, Cable and Wireless and AT&T, Report no. 04/J/01/06/0648/0415.

Engell-Sørensen, K., & Skyt, P. H. (2001). Evaluation of the effect of sediment spill from offshore wind farm construction on marine fish. Report to SEAS, Denmark.

Environment Agency (2022). Salmonid and freshwater fisheries statistics: 2021. Available at: Salmonid and freshwater fisheries statistics: 2021 - GOV.UK (www.gov.uk)

Equinor (2022). Sheringham Shoal and Dudgeon Offshore Wind Farm Extensions Environmental Statement Chapter 9: Fish and Shellfish Ecology.

George, M. (2009). An annotated checklist of North Sea cartilaginous fish species. Journal of Applied Ichthyology, 25, 33–39. https://doi.org/10.1111/j.1439-0426.2009.01303.x

Fewtrell, J. L., & McCauley, R. D. (2012). Impact of air gun noise on the behaviour of marine fish and squid. Marine pollution bulletin, 64(5), 984–993. Available at: https://doi.org/10.1016/j.marpolbul.2012.02.009

Gill, A.B.& Bartlett, M. (2010). Literature review on the potential effects of electromagnetic fields and sub-sea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage Commissioned Report No.401.

Gill, A. B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. and Wearmouth, V. (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Commissioned by COWRIE Ltd (project reference COWRIE-EMF-1-06).

Gill, A. B., Bartlett, M., & Thomsen, F. (2012). Potential interactions between diadromous fishes of U.K. conservation importance and the electromagnetic fields and sub-sea noise from marine renewable energy developments. Journal of Fish Biology, 81(2), 664–695. https://doi.org/10.1111/j.1095-8649.2012.03374.x.

Griffin, F.J., Smith, E.H., Vines, C.A., Cherr, G.N. (2009). Impacts of Suspended Sediments on Fertilization, Embryonic Development, and Early Larval Life Stages of the Pacific Herring, *Clupea pallasi*. Biological Bulletin, 216(2): 175-187. <Go to ISI>://000265282800009.

Groot, S. J. De (1980). The consequences of marine gravel extraction on the spawning of herring, *Clupea harengus Linne*. Journal of Fish Biology, 16: 605–611.

Hansen, M. J., Madenjian, C. P., Slade, J. W., Steeves, T. B., Almeida, P. R., & Quintella, B. R. (2016). Population ecology of the sea lamprey (*Petromyzon marinus*) as an invasive species in the Laurentian Great Lakes and an imperilled species in Europe. Reviews in Fish Biology and Fisheries, 26(3), 509–535. Available at: https://doi.org/10.1007/s11160-016-9440-3

Harsanyi, P., Scott, K., Easton, B. A. A., de la Cruz Ortiz, G., Chapman, E. C. N., Piper, A. J. R., Rochas, C. M. V., & Lyndon, A. R. (2022). The Effects of Anthropogenic Electromagnetic Fields (EMF) on the Early Development of Two Commercially Important Crustaceans, European Lobster, *Homarus gammarus (L.)* and Edible Crab, *Cancer pagurus (L.)*. Journal of Marine Science and Engineering, 10(5), 564. Available at: https://doi.org/10.3390/jmse10050564 (Accessed January 2024).

Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Østensen, Ø., Haugland, E.K., Fonn, M., Høines, Å., & Misund, O.A. (2003). Reaction of sandeel to seismic shooting: a field experiment and fishery statistics study.

Hawkins, A., Roberts, L., & Cheesman, S. (2014). Responses of free-living coastal pelagic fish to impulsive sounds. The Journal of the Acoustical Society of America, 135, 3101–3116. Available at: https://doi.org/10.1121/1.4870697

Hawkins, A. D., & Popper, A. N. (2016). A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science: Journal du Conseil, 74, pp. 635–671.

Holland, G., Greenstreet, S., Gibb, I., Fraser, H., & Robertson, M. (2005). Identifying sandeel *Ammodytes marinus* sediment habitat preferences in the marine environment. Marine Ecology-Progress Series - MAR ECOL-PROGR SER, 303, 269–282. https://doi.org/10.3354/meps303269.

Hutchison, Z., Sigray, P., He, H., Gill, A. B., King, J., & Gibson, C. (2018). Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables. Available at: https://doi.org/10.13140/RG.2.2.10830.97602

Hutchison, Z., Secor, D., & Gill, A. (2020). The Interaction Between Resource Species and Electromagnetic Fields Associated with Electricity Production by Offshore Wind Farms. Oceanography, 33(4), 96–107. Available at: https://doi.org/10.5670/oceanog.2020.409

Jensen, H., Kristensen, P.S., and Hoffmann, E. (2004). Sandeels in the wind farm area at Horns Reef. Report to ELSAM, August 2004. Danish Institute for Fisheries Research, Charlottenlund.

Johnson, M. P., Lordan, C., & Power, A. M. (2013). Habitat and ecology of *Nephrops norvegicus*. Advances in Marine Biology, 64, 27–63.

Kastelein, R.A., Jennings, N., Kommeren, A., Helder-Hoek, L. and Schop, J (2017). Acoustic dose-behavioral response relationship in sea bass (Dicentrarchus labrax) exposed to playbacks of pile driving sounds. Marine Environmental Research 130, 315-324. Available at: http://dx.doi.org/10.1016/j.marenvres.2017.08.010

Kiørboe, T., Frantsen, E., Jensen, C. & Sørensen, G. (1981). Effects of suspended sediment on development and hatching of herring (*Clupea harengus*) eggs. Estuarine, Coastal and Shelf Science, 13(1): pp.107-111. doi:10.1016/S0302-3524(81)80109-0.

Kyle-Henney M., Reach I., Barr N., Warner I., Lowe S., and Lloyd Jones D. (2024). Identifying and Mapping Atlantic Herring Potential Spawning Habitat: An Updated Method Statement.

Lynam, C. P., Halliday, N. C., Höffle, H., Wright, P. J., van Damme, C. J. G., Edwards, M., & Pitois, S. G. (2013). Spatial patterns and trends in abundance of larval sandeels in the North Sea: 1950–2005. ICES Journal of Marine Science, 70(3), 540–553. Available at: https://doi.org/10.1093/icesjms/fst006

Malcolm, I.A., Godfrey, J. And Youngson, A.F. (2010). Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewable. Scottish Marine and Freshwater Science Vol 1 No 14.

Mainwaring, K., Tillin, H., & Tyler-Walters, H. (2014). Assessing the sensitivity of blue mussels (*Mytilus edulis*) to pressures associated with human activities. JNCC Report No: 506. Available at: https://doi.org/10.13140/RG.2.1.4341.6720

Maitland, P. S. and Campbell, R. N. (1992). Freshwater fishes of the British Isles. HarperCollins Publishers, London.368 p.

Maitland, P. S. (2004). Evaluating the ecological and conservation status of freshwater fish communities in the United Kingdom. Scottish Natural Heritage Commissioned Report No. 001 (ROAME No. F01AC6).

Moray Offshore Windfarm (West) Limited (2018). Moray West Offshore Windfarm Offshore EIA Report, Chapter 1 Introduction. Available at: https://marine.gov.scot/sites/default/files/00538033.pdf

Neal, K.J. & Wilson, E. (2008). *Cancer pagurus* Edible crab. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews. Available at: https://www.marlin.ac.uk/species/detail/1179

Nedelec, S. L., Campbell, J., Radford, A. N., Simpson, S. D., & Merchant, N. D. (2016). Particle motion: The missing link in underwater acoustic ecology. Methods in Ecology and Evolution, 7(7), 836–842. https://doi.org/10.1111/2041-210X.12544

Maravelias, C. D. (1999). Habitat selection and clustering of a pelagic fish: Effects of topography and bathymetry on species dynamics. Canadian Journal of Fisheries and Aquatic Sciences, 56(3), 437–450. https://doi.org/10.1139/f98-176

Messieh, S.N., Wildish, D.J. & Peterson, R.H. (1981). Possible Impact from Dredging and Spoil Disposal on the Miramichi Bay Herring Fishery. Canadian Technical Report of Fisheries and Aquatic Sciences, 1008, pp. 1-33.

MMO (2022). The Dogger Bank Special Area of Conservation (Specified Area) Bottom Towed Fishing Gear Byelaw 2022. Available at: https://assets.publishing.service.gov.uk/.

MMO (2023). UK sea fisheries annual statistics report 2022. Available at: https://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2022

Neo, Y. Y., Hubert, J., Bolle, L., Winter, H., & Slabbekoorn, H. (2018). European seabass respond more strongly to noise exposure at night and habituate over repeated trials of sound exposure. Environmental Pollution, 239. Available at: https://doi.org/10.1016/j.envpol.2018.04.018

NorthConnect (2018). Environmental Impact Assessment Report. Chapter 18: Electric and Magnetic Fields & Sediment Heating. Available at: https://marine.gov.scot/sites/default/files/18_emf_sediment_heating_0.pdf

Normandeau, Exponent, Tricas, T., & 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 Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Tricas-Gill-2011.pdf

Orpwood, J.E., Fryer, R.J., Rycroft, P. and Armstrong, J.D. (2015). Effects of AC Magnetic Fields (MFs) ammarusing Activity in European Eels (*Anguilla anguilla*). Scottish Marine and Freshwater Science. Volume 6, Number 8.

Parker, J., Fawcett, A., Banks, A., Rowson, T., Allen, S., Rowell, H., Harwood, A., Ludgate, C., Humphrey, O., Axelsson, M., Baker, A. & Copley, V. (2022c). Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards. Phase III: Expectations for data analysis and presentation at examination for offshore wind applications. Natural England. Version 1.2. 140 pp

Payne, J. F., Andrews, C. A., Fancey, L. L., Cook, A. L., & Christian, J. R. (2007). Pilot Study on the Effects of Seismic Air Gun Noise on Lobster (*Homarus americanus*). Canadian Technical Report of Fisheries and Aquatic Sciences, 2712: v + 46.

Pepin, P. (1991). Effect of temperature and size on development, mortality and survival rates of the pelagic early life history stages of marine fish. Canadian Journal of Fisheries and Aquatic Science 48: 503-518.

Pérez-Domínguez R., and Vogel, M. R. (2010). Baseline larval fish assemblages along the Dutch coast, Southern North Sea. Report to Port Rotterdam. Project Organisation Maasvlakte 2 (PMV2). Institute of Estuarine and Coastal Studies University of Hull, UK. Report ZBB727-F-2001.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., Coombs, S., Ellison, W. T., Gentry, R. L., Halvorsen, M. B., Løkkeborg, S., Rogers, P. H., Southall, B. L., Zeddies, D. G., & Tavolga, W. N. (2014). ASA S3/SC1.4 TR-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 International Publishing. Available at: https://doi.org/10.1007/978-3-319-06659-2

Popper, A. N., & Hawkins, A. D. (2018). The importance of particle motion to fishes and invertebrates. The Journal of the Acoustical Society of America, 143(1), 470–488. https://doi.org/10.1121/1.5021594

Popper, A. and Hawkins, A., (2019). An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of Fish Biology, 94(5), pp.692-713.

Popper, A., Hawkins, A., Sand, O. and Sisneros, J., (2019). Examining the hearing abilities of fishes. The Journal of the Acoustical Society of America, 146(2), pp.948-955.

Radford C. A., Montgomery J. C., Caiger P., Higgs D. M. (2012). Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. Journal of Experimental Biology, 215, 3429 – 3435.

Rankine, P. W. (1986). Herring spawning grounds around the Scottish coast. ICES CM 1986/H:15.

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 herring potential spawning areas. A Method Statement produced for BMAPA.

Reach, I., Kyle-Henney, M., Barr, N., Warner, I., Lowe, S., and Lloyd Jones, D., (2024). Identifying and Mapping Sandeel Potential Supporting Habitat: An Updated Method Statement.

Rijnsdorp, A. D., Bolam, S. G., Garcia, C., Hiddink, J. G., Hintzen, N. T., van Denderen, P. D., & van Kooten, T. (2018). Estimating sensitivity of seabed habitats to disturbance by bottom trawling based on the longevity of benthic fauna. Ecological Applications, 28(5), 1302–1312. https://doi.org/10.1002/eap.1731

Roach, M., Cohen, M., Forster, R., Revill, A. S., and Johnson, M. (2018). The effects of temporary exclusion of activity due windfarm construction on a lobster (*Homarus gammarus*) fishery suggests a potential management approach. – ICES Journal of Marine Science.

Roberts L., Harding, H. R., Voellmy, I., Bruintjes, R., Simpson, S. D., Radford, A. N., Breithaupt, T. & Elliott, M. (2016). Exposure of benthic invertebrates to sediment vibration: From laboratory experiments to outdoor simulated piledriving', Proceedings of Meetings on Acoustics, vol. 27, no. 1, 010029.

Russell, F.S. (1976). The eggs and planktonic stages of British marine fishes, London: Academic Press. 524 pp.

Scott, K., Harsanyi, P., & Lyndon, A. R. (2018). Understanding the effects of electromagnetic field emissions from Marine Renewable Energy Devices (MREDs) on the commercially important edible crab, *Cancer pagurus (L.)*. Marine Pollution Bulletin, 131, 580–588. https://doi.org/10.1016/j.marpolbul.2018.04.062

Snyder, D. B., Bailey, W. H., Palmquist, K., Cotts, R. T. B. & Olsen, K. R. (2019). Evaluation of Potential EMF Effects on Fish Species of Commercial or Recreational Fishing Importance in Southern New England. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Headquarters, Sterling, VA. OCS Study BOEM 2019-049. 59 pp.

Southall, B. L. (2021). Evolutions in Marine Mammal Noise Exposure Criteria. Acoustics Today, 17(2), 52. Available at: https://doi.org/10.1121/AT.2021.17.2.52

Stenton, C. A., Bolger, E. L., Michenot, M., Dodd, J. A., Wale, M. A., Briers, R. A., Hartl, M. G. J., & Diele, K. (2022). Effects of pile driving sound playbacks and cadmium co-exposure on the early life stage development of the Norway lobster, *Nephrops norvegicus*. Marine Pollution Bulletin, 179, 113667. https://doi.org/10.1016/j.marpolbul.2022.113667

Stratoudakis, Y., Gallego, A. and Morrison, J. A. (1998). 'Spatial distribution of developmental egg ages within a herring *Clupea harengus* spawning ground'. Marine Ecology Progress Series, 174: 27–32.

Swedpower (2003). Electrotechnical studies and effects on the marine ecosystem for BritNed Interconnector. Cited in- CMACS (2005). East Anglia THREE Environmental Statement. Appendix 9.2: Electromagnetic Field Environmental Appraisal. Volume 3. Document Reference–6.3.9(2).

Taormina B., Bald J., Want A., Thouzeau G., Lejart M., Desroy N. & Carlier, A. (2018). A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. Renewable and Sustainable Energy Reviews, Vol. 96, pp. 380391, https://doi.org/10.1016/j.rser.2018.07.026

Taormina, B., Quillien, N., Lejart, M., Carlier, A., Desroy, N., Laurans, M., D'Eu, J.-F., Reynaud, M., Perignon, Y., Erussard, H., Derrien-Courtel, S., Le Gal, A., Derrien, R., Jolivet, A., Chavaud, S., Degret, V., Saffroy, D., Pagot, J.-P., & Barillier, A. (2020). Characterisation of the Potential Impacts of Sub-sea Power Cables Associated with Offshore Renewable Energy Projects. Plouzané: France Energies Marines Editions, 74 pages.

Tasker, M. L., Amundin, M., Andre, M., Hawkins, A., Lang, W., Merck, T., Scholik-Schlomer, A., Teilmann, J., Thomsen, F., Werner, S. and Zakharia, M. (2010). Underwater noise and other forms of energy. Marine Strategy Framework Directive Task Group 11 Report

Thompson, B.M., Lawler, A.R. & Bennett, D.B. (1995). Estimation of the spatial distribution of spawning crabs (*Cancer pagurus L.*) using larval surveys of the English Channel. ICES Marine Science Symposia, 199, 139-150.

Tougaard, J., Hermannsen, L., Madsen, P. T (2020). How loud is the underwater noise from operating offshore wind turbines? J. Acoust. Soc. Am. 148 (5). doi.org/10.1121/10.0002453.

Van Deurs, M., Grome, T.M., Kaspersen, M., Jensen, H., Stenberg, C., Sørensen, T.K., Støttrup, J., Warnar, T., and Mosegaar, H. (2012). Short and Long Term Effects of an Offshore Wind Farm on Three Species of Sandeel and their Sand Habitat. Marine Ecology Progress Series, 458, 169-180.

Wale, M. A., Simpson, S. D., & Radford, A. N. (2013). Noise negatively affects foraging and antipredator behaviour in shore crabs. Animal Behaviour, 86(1), 111–118. Available at: https://doi.org/10.1016/j.anbehav.2013.05.001

Westerberg, H., Rännbäek, P., & Frimansson, H. (1996). Effects of Suspended Sediments on Cod Egg and Larvae and on the Behaviour of Adult Herring and Cod. ICES CM E, 19961, 26.

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

Wright, P. J., Jensen, H. and Tuck, I. (2000). The influence of sediment type on the distribution of the lesser sandeel, *Ammodytes marinus*. Journal of Sea Research 44(3-4), pp. 243-256.

Wright, R. M., Piper, A. T., Aarestrup, K., Azevedo, J. M. N., Cowan, G., Don, A., Gollock, M., Rodriguez Ramallo, S., Velterop, R., Walker, A., Westerberg, H., & Righton, D. (2022). First direct evidence of adult European eels migrating to their breeding place in the Sargasso Sea. Scientific Reports, 12(1), 15362. https://doi.org/10.1038/s41598-022-19248-8

List of Figures and Tables

List of Figures

List of Tables

List of Acronyms

Acronym	Definition
ADD	Acoustic Deterrent Device
CaP	Cable Plan
CEA	Cumulative Effect Assessment

Acronym	Definition
CRA	Chemical Risk Assessment
DAS	Discretionary Advice Service
DBD	Dogger Bank D Offshore Wind Farm
DBSE	Dogger Bank South East
DBSW	Dogger Bank South West
DC	Direct Current
DCO	Development Consent Order
eDNA	Environmental DNA
EIA	Environmental Impact Assessment
ECC	Export Cable Corridor
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EMF	Electromagnetic field
EMODnet	European Marine Observation and Data Network
EMP	Environmental Management Plan
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Export Topic Group
EUSeaMap	EMODnet broad-scale seabed habitat map for Europe
FOCI	Features of Conservation Interest
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current

Acronym	Definition
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Surveys
IUCN	International Union for Conservation of Nature
km	Kilometres
MarESA	Marine Evidence based Sensitivity Assessment
MarLIN	Marine Information Network
MARPOL	International Convention for the Prevention of Pollution from Ships
MCAA	Marine and Coastal Access Act
MCZ	Marine Conservation Zone
MMO	Marine Management Organisation
MMMP	Marine Mammal Mitigation Protocol
MPCP	Marine Pollution Contingency Plan
MPS	Marine Policy Statement
MW	Megawatt
NBN	National Biodiversity Network
NEIFCA	North Eastern Inshore Fisheries Conservation Authority
NPS	National Policy Statements
NSIP	Nationally Significant Infrastructure Project
O&M	Operation and Maintenance
OBIS	Ocean Biodiversity Information System
ODA	Offshore Development Area
OSP	Offshore Platform
PEIR	Preliminary Environmental Information Report

Acronym	Definition
PEMP	Project Environmental Monitoring Plan
PSA	Particle Size Analysis
PTS	Permanent Threshold Shift
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SEL	Sound Exposure Level
SEL_{cum}	Cumulative Sound Exposure Level
SEL_{ss}	Single Strike Sound Exposure Level
SPL	Sound Pressure Level
SPL_{peak} ($L_{p,pk}$)	Peak Sound Pressure Level
SSC	Suspended Sediment Concentrations
TAC	Total Allowable Catches
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance
VMS	Vessel Monitoring System