Morecambe Offshore Windfarm: Generation Assets

Environmental Statement

Volume 5

Chapter 10 Fish and Shellfish Ecology

PINS Document Reference: 5.1.10

APFP Regulation: 5(2)(a)

Rev 02

MORECAMBE

Document History

Doc No	MOR001-FLO-CON-ENV-RPT-1100	Rev	02
Alt Doc No	PC1165-RHD-ES-XX-RP-Z-0010		
Document Status	Approved for Use	Doc Date	26 November 2024
PINS Doc Ref	5.1.10	APFP Ref	5(2)(a)

Rev	Date	Doc Status	Originator	Reviewer	Approver	Modifications
01	31 May 2024	Approved for Use	Royal HaskoningDHV	Morecambe Offshore Windfarm Ltd	Morecambe Offshore Windfarm Ltd	n/a
02	26 November 2024	Approved for Use	Royal HaskoningDHV	Morecambe Offshore Windfarm Ltd	Morecambe Offshore Windfarm Ltd	Updates for Deadline 1

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Glossary of Acronyms

AFBI	Agri-food & Biosciences Institute
AfL	Agreement for Lease Area
AL	Action Level
ASA	Acoustical Society of America
AyM	Awel y Môr
BAP	Biodiversity Action Plan
BEIS	Department of Business, Energy and Industrial Strategy[1]
BGS	British Geological Survey
CBRA	Cable Burial Risk Assessment
CEA	Cumulative Effect Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture
CITES	Convention on International Trade in Endangered Species
DCO	Development Consent Order
DECC	Department of Energy and Climate Change[1]
DEFRA	Department for Environment, Food & Rural Affairs
DESNZ	Department for Energy Security and Net Zero
EEA	European Economic Area
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EMODnet	European Marine Observation and Data Network
EPP	Evidence Plan Process
EPS	European Protected Species
ERL	Effects Range - Low
ES	Environmental Statement
ETG	Expert Topic Group
EUNIS	European Nature Information System
FEPA	Food and Environmental Protection Act
FWPM	Freshwater pearl mussel
GBS	Gravity Based Structures
HRA	Habitat Regulations Assessment

[1] The Department of Energy and Climate Change (DECC) was merged with the Department for Business, Energy and Industrial Strategy (BEIS) in 2016. As of February 2023, BEIS is known as the Department for Energy Security and Net Zero (DESNZ).

IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IEC	International Electrotechnical Commission
IoM	Isle of Man
IPMP	In-Principle Monitoring Plan
IUCN	International Union for Conservation of Nature
LSE	Likely Significant Effect
MarESA	Marine Evidence-based Sensitivity Assessment
MarLIN	Marine Life Information Network
MCZ	Marine Conservation Zones
MCZA	Marine Conservation Zone Assessment
MEAS	Merseyside Environmental Advisory Service
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MPS	Marine Policy Statement
NBN	National Biodiversity Network
NE	Natural England
NERC	Natural Environment Research Council
NIGFS	Northern Ireland Ground Fish Survey
NPS	National Policy Statement
NRW	Natural Resources Wales
NSIP	Nationally Significant Infrastructure Project
NWIFCA	North West Inshore Fisheries and Conservation Authorities
OSP	Offshore substation platform
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo/Paris Convention)
OWF	Offshore Windfarm
PDE	Project Design Envelope
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PMF	Priority Marine feature
PSA	Particle Size Analysis
PTS	Permanent Threshold Shift
RIAA	Report to Inform Appropriate Assessment
SAC	Special Area of Conservation
SEL	Sound Exposure Level

SPA	Special Protection Area
SPCPP	Scour Protection and Cable Protection Plan
SPIe	Species of Principle Importance in England
TTS	Temporary Threshold Shift
UK	United Kingdom
UXO	Unexploded Ordnance
WGCSE	Working Group for the Celtic Seas Ecoregion
WGSINS	Working Group on Surveys on Ichthyoplankton in the North Sea and adjacent Seas
WTG	Wind turbine generator
ZoI	Zone of Influence

Glossary of Unit Terms

dB	Decibel
dB re 1 μPa^{2}s	Relative unit used to specify the intensity of an underwater sound
Hz	Hertz
kJ	Kilojoules
km	Kilometre
kV	Kilovolt
m	Metre
μT	Microtesla

Glossary of Terminology

Agreement for Lease (AfL)	Agreements under which seabed rights are awarded following the completion of The Crown Estate tender process.
Applicant	Morecambe Offshore Windfarm Ltd
Application	This refers to the Applicant's application for a Development Consent Order (DCO). An application consists of a series of documents and plans which are published on the Planning Inspectorate's (PINS) website.
Crustacean	An arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp or barnacle.
Demersal	Living on or near the seabed.
Diadromous	Migrating between fresh and salt water.
Elasmobranch	Any cartilaginous fish of the subclass Elasmobranchii which includes sharks, rays and skates.
European sites	Designated nature conservation sites which include the National Site Network (designated within the UK) and Natura 2000 sites (designated in any European Union country). This includes candidate Special Areas of Conservation (cSAC), Sites of Community Importance, Special Areas of Conservation (SAC) and Special Protection Areas (SPA).
Evidence Plan Process (EPP)	A voluntary consultation process with specialist stakeholders to agree the approach, and information to support, the Environmental Impact Assessment (EIA) and Habitats Regulations Assessment (HRA) for certain topics. The EPP provides a mechanism to agree the information required to be submitted to PINS as part of the DCO Application. This function of the EPP helps Applicants to provide sufficient information in their application, so that the Examining Authority can recommend to the Secretary of State whether or not to accept the application for examination and whether an appropriate assessment is required.
Expert Topic Group (ETG)	A forum for targeted engagement with regulators and interested stakeholders through the EPP.
Generation Assets (the Project)	Generation assets associated with the Morecambe Offshore Windfarm. This is infrastructure in connection with electricity production, namely the fixed foundation wind turbine generators (WTGs), inter-array cables, offshore substation platform(s) (OSP(s)) and possible platform link cables to connect OSP(s).
Inter-array cables	Cables which link the WTGs to each other and the OSP(s).
Mollusc	An invertebrate of a large phylum which includes snails, slugs, mussels and octopuses. They have a soft unsegmented body and live in aquatic or damp habitats, and most kinds have an external calcareous shell.

Morgan and Morecambe Offshore Wind Farms: Transmission Assets	The transmission assets for the Morgan Offshore Wind Project and the Morecambe Offshore Windfarm. This includes the OSP(s)[2], interconnector cables, Morgan offshore booster station, offshore export cables, landfall site, onshore export cables, onshore substations, 400kV cables and associated grid connection infrastructure such as circuit breaker infrastructure. Also referred to in this chapter as the Transmission Assets, for ease of reading.
Offshore substation platform(s) (OSP(s))	Fixed structure(s) located within the windfarm site, containing electrical equipment to aggregate the power from the WTGs and convert it into a more suitable form for export to shore.
Pelagic	Of, or relating to, the open sea, species living in the water column.
Platform link cable	An electrical cable which links one or more OSP(s).
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations due to the flow of water.
Study area	This is an area which is defined for each EIA topic, which includes the windfarm site, as well as potential spatial and temporal considerations of the impacts on relevant receptors. The study area for each EIA topic is intended to cover the area within which an effect can be reasonably expected. For this chapter, the greatest impact range arises from underwater noise, and the study area encompasses this range.
Technical stakeholders	Technical consultees are considered to be organisations with detailed knowledge or experience of the area within which the Project is located and/or receptors which are considered in the Environmental Impact Assessment (EIA) and Habitat Regulations Assessment (HRA). Examples of technical stakeholders include Marine Management Organisation, local authorities, Natural England and the Royal Society for the Protection of Birds.
Tidal excursion ellipse	The path followed by a water particle in one complete tidal cycle.
Wind turbine generator (WTG)	A fixed structure located within the windfarm site that converts the kinetic energy of wind into electrical energy.
Windfarm site	The area within which the WTGs, inter-array cables, OSP(s) and platform link cables would be present.
Zone of Influence (ZoI)	The maximum anticipated spatial extent of a given potential impact.

[2] At the time of writing the Environmental Statement (ES), a decision had been taken that the offshore substation platforms (OSP(s)) would remain solely within the Generation Assets application and would not be included within the Development Consent Order application for the Transmission Assets. This decision post-dated the Preliminary Environmental Information Report (PEIR) that was prepared for the Transmission Assets. The OSP(s) are still included in the description of the Transmission Assets for the purposes of this ES as the Cumulative Effects Assessment (CEA) carried out in respect of the Generation/Transmission Assets is based on the information available from the Transmission Assets PEIR.

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10 Fish and Shellfish Ecology

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10 Fish and Shellfish Ecology

10.1 Introduction

10.1 This chapter of the Environmental Statement (ES) considers the potential effects of the proposed Morecambe Offshore Windfarm Generation Assets (the Project) on fish and shellfish ecology. This chapter provides an overview of the existing environment, followed by an assessment of the potential effects and associated mitigation, where identified, for the construction, operation and maintenance, and decommissioning phases.

10.2 The Project includes the generation assets to be located within the windfarm site (wind turbine generators (WTGs), inter-array cables, offshore substation platform(s) (OSP(s)) and possible platform link cables to connect OSP(s)). The Environmental Impact Assessment (EIA) of the transmission assets, including offshore export cables to landfall and onshore infrastructure, is part of a separate Development Consent Order (DCO) application as outlined in **Chapter 1 Introduction** (Document Reference 5.1.1).

10.3 This assessment has been undertaken with specific reference to the relevant legislation and guidance, of which the primary sources are the National Policy Statements (NPS). Details of these, and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Effect Assessment (CEA), are presented in **Chapter 6 EIA Methodology** (Document Reference 5.1.6) and **Section 10.4** of this chapter.

10.4 The assessment should be read in conjunction with the following linked ES chapters and supporting documentation:

- **Chapter 7 Marine Geology, Oceanography and Physical Processes** (Document Reference 5.1.7) (assessment informs this chapter)
- **Chapter 8 Marine Sediment and Water Quality** (Document Reference 5.1.8) (assessment informs this chapter)
- **Chapter 11 Marine Mammals** (Document Reference 5.1.11) (informed by this chapter e.g. effects to prey species)
- **Chapter 12 Offshore Ornithology** (Document Reference 5.1.12) (informed by this chapter e.g. effects to prey species)
- **Chapter 13 Commercial Fisheries** (Document Reference 5.1.13) (informed by this chapter e.g. effects to commercial species)

10.5 Inter-relationships with these chapters are further described in **Section 10.9**.

10.6 Additional information to support the fish and shellfish ecology assessment includes underwater noise modelling undertaken for the Project, as presented in **Appendix 11.1 Underwater Noise Assessment** (Document Reference

5.2.11.1) and benthic surveys, as presented in **Appendix 9.1 Benthic Characterisation Survey** (Document Reference 5.2.9.1).

10.2 Consultation

10.7 Consultation with regards to fish and shellfish ecology has been undertaken in line with the general process described in **Chapter 6 EIA Methodology**. The key consultation elements to date have included scoping (Scoping Opinion from the Planning Inspectorate (PINS), received on 2nd August 2022), comments received on the Preliminary Environmental Information Report (PEIR), which was published for statutory consultation in April 2023, and the Evidence Plan Process (EPP) via the Marine Ecology Expert Topic Group (ETG) meetings.

10.8 As part of the EPP, a Marine Ecology Method Statement was submitted to the Marine Ecology ETG in May 2022. This consultation was used to inform the data requirements and the methodology for the assessment of the potential Project effects set out in the EIA Scoping Report submitted to PINS in June 2022 (Morecambe Offshore Windfarm Ltd, 2022).

10.9 ETG meetings were held in June 2022, September 2022, November 2022, June 2023, October 2023 and January 2024, with attendees at some or all of the meetings, including the following:

- Environment Agency
- Natural England (NE)
- Marine Management Organisation (MMO)
- North West Inshore Fisheries and Conservation Authorities (NW IFCA)
- Centre for Environment Fisheries and Aquaculture Science (Cefas)
- North West Wildlife Trust
- Isle of Man Government
- Manx Wildlife Trust
- Merseyside Environmental Advisory Service (MEAS)

10.10 Consultation in relation to commercial fisheries (as presented in **Chapter 13 Commercial Fisheries**) has also been used to inform this chapter.

10.11 The feedback received throughout the EPP, the Scoping Opinion published by PINS and stakeholder comments on the PEIR, have been considered in preparing the ES. The key comments pertinent to this chapter are shown in **Table 10.1**, alongside details of how the Project team has had regard to the comments received and how they have been addressed within this chapter.

10.12 The consultation process is described further in **Chapter 6 EIA Methodology**. Full details of the consultation undertaken throughout the EIA process is presented in the Consultation Report (Document Reference 4.1), which is submitted as part of the DCO Application.

Table 10.1 Consultation responses relative to fish and shellfish ecology and how these have been addressed in the ES

Consultee	Date	Comment	Response/where addressed in the ES
Scoping Opinion responses			
PINS (ref. 2.1.7)	2nd August 2022	Unexploded ordnance (UXO) removal: It is noted that consent for UXO removal will be sought in a future Marine Licence application, which would be supported by a more detailed assessment. The Inspectorate advises that the ES should still include a high level assessment based on a likely worst-case scenario (any assumptions used in the definition of the worst-case scenario should be explained in the ES). The ES should address any cumulative effects from the construction of the Proposed Development with the likely effects from the UXO clearance. If any preliminary works, such as UXO surveys, would be permitted under the DCO, then the effects of these should also be included in the ES.	Impact ranges for noise associated with UXO clearance are included in the noise modelling report (**Appendix 11.1**). As discussed in the ETG meeting on the 9th June 2022, UXO impacts for the Project would be assessed in full in a separate Marine Licence application for UXO clearance works post-consent, and UXO noise modelling is included here for information purposes only for a high-level assessment. UXO clearance is considered as a noise source within the cumulative effects assessment as appropriate.
PINS (ref. 3.4.1)	2nd August 2022	Temporary habitat loss/physical disturbance: It is noted that the ES will consider permanent habitat loss during operation. As such, the Inspectorate is content for this matter to be scoped out of further assessment.	Noted. This comment is in relation to scoping out temporary habitat loss/physical disturbance during operation and maintenance, as permanent habitat loss due to infrastructure has been assessed in operation and maintenance. However, temporary disturbance and habitat loss has been assessed in operation and maintenance (**Section 10.6**), in relation to maintenance activities.

Consultee	Date	Comment	Response/where addressed in the ES
PINS (ref. 3.4.2)	2nd August 2022	Permanent habitat loss: It is noted that the ES will consider permanent habitat loss during operation. The Inspectorate is content that this matter can be scoped out of further assessment	Noted. This comment is in relation to scoping out permanent habitat loss during construction and decommissioning as this is considered within operation and maintenance.
PINS (ref. 3.4.3)	2nd August 2022	EMF: On the basis that the Proposed Development will not be operational and generating EMF during construction and decommissioning, the Inspectorate is content to scope this matter out during construction and decommissioning.	Noted. Electromagnetic fields (EMF) effects are scoped out during construction and decommissioning phase.
PINS (ref. 3.4.4)	2nd August 2022	Introduction of hard substrate: As described in the Scoping Report, this refers to the potential for marine structures to be colonised by benthic invertebrates. The Inspectorate agrees that it is more appropriate for this effect to be considered during operation and, therefore, this matter can be scoped out of the construction stage assessment.	Noted. Introduction of hard substrate is scoped out of the construction phase assessment.
PINS (ref. 3.4.5)	2nd August 2022	Permanent habitat loss and cumulative permanent habitat loss: As noted above, permanent habitat loss will be considered as part of the assessment of operational effects. On the basis that the ES will assess cumulative permanent habitat loss during operation, the Inspectorate agrees that this matter can be scoped out of the construction stage assessment.	Noted. Cumulative permanent habitat loss is scoped out of the construction stage assessment and is considered in the operation and maintenance phase.
PINS (ref. 3.4.6)	2nd August 2022	Remobilisation of contaminated sediments: The Scoping Report notes that if the benthic sampling demonstrates low levels of contamination, then this matter would be scoped out of further assessment through the EPP. As stated above, the Inspectorate agrees that if this approach is agreed through the EPP, then this matter can be scoped out of further assessment. However, the contamination levels recorded through benthic sampling should still be provided as an annex to the ES.	This comment is in relation to scoping out remobilisation of contaminated sediments during construction and operation and maintenance. Benthic sampling across the windfarm site has indicated low levels of contaminants, all below environmental thresholds (Cefas Action level 1 and United States Environmental Protection

Consultee	Date	Comment	Response/where addressed in the ES
			Agency Effects Range - Low). Further detail is provided in **Chapter 8 Marine Sediment and Water Quality** and **Appendix 9.1.** As agreed through the EPP, this impact is scoped out as justified in **Section 10.6.**
PINS (ref. 3.4.7)	2nd August 2022	Transboundary effects: The Scoping Report states that, as the distribution of fish and shellfish species is independent of national geographical boundaries, a specific assessment of transboundary effects is unnecessary, in line with the approach adopted for several other offshore windfarms (East Anglia THREE, East Anglia ONE North, Norfolk Vanguard and Awel y Môr (AyM)). However, the Applicant should be aware that the Inspectorate undertook transboundary consultation with the relevant European Economic Area (EEA) states for these projects, including for their impacts on fish and shellfish. As such, the assessment in the ES must be sufficient to allow any EEA states to determine if a significant effect on their environment is likely. The Inspectorate does not consider that the Scoping Report provides sufficient evidence to allow this matter to be scoped out. Accordingly, the ES should include an assessment of this matter or a justification as to the absence of Likely Significant Effect (LSE).	Noted. The detail of impacts, and impact ranges, are assessed in **Section 10.6**, without limiting the extent of the assessment to geographical boundaries. **Section 10.8** addresses the potential for transboundary LSE.
PINS (ref. 3.4.8)	2nd August 2022	Designated sites: The Scoping Report notes the presence of various designated sites within 30–45km of the windfarm site, but also notes the potential for migratory fish species associated with other designated sites to occur in the windfarm site. The ES should explain how the zone of influence for the Proposed Development has been defined	**Section 10.3.1** and **Section 10.5.10** describe the study area and relevant designated sites. The study area encompasses the maximum potential zone of influence (ZoI) of 15km for indirect effects from suspended

Consultee	Date	Comment	Response/where addressed in the ES
		and how this has led to the identification of designated sites which could be affected.	sediment (encompassing the tidal ellipse). The study area also considers migratory species and designated sites over a wider study area of 100km which encompasses noise impact ranges and considers the coastal orientation, migratory movements and the level of dispersal expected beyond this range. Further information for European sites is within the Report to Inform Appropriate Assessment (RIAA) (Document Reference 4.9) and Marine Conservation Zone Assessment (MCZA) (Document Reference 4.13) supplied with the DCO Application.
PINS (ref. 3.4.9)	2nd August 2022	Data and information sources: Table 8.12 lists existing datasets used to inform the review. Given the age of previous surveys within the area, the distance from the Proposed Development and the lack of information on the survey methods used, there is a risk that the baseline may not be robust. The ES should clearly identify the datasets used to determine the baseline, supported with evidence of agreement with relevant stakeholders, wherever possible. The Applicant's attention is drawn to the comments from the MMO relating to the need to include data on Irish Sea herring larvae which is held by the Agri-Food and Biosciences Institute (AFBI) of Northern Ireland (see Appendix 2 of this Opinion).	**Section 10.4.2** lists the data sources used, which have been discussed with stakeholders throughout the EPP. Agri-food & Biosciences Institute (AFBI) herring larvae survey data has been obtained and used to inform the assessments in this chapter.
PINS (ref. 3.4.10)	2nd August 2022	Project design envelope: The Scoping Report states that the assessment of impacts will be based on a realistic worst-case scenario. The Applicant is reminded that the ES should assess the full range of potential impacts which	The potential impacts on fish and shellfish ecology receptors that could occur as a result of the Project are assessed in this chapter, with the

Consultee	Date	Comment	Response/where addressed in the ES
		could occur as a result of the works which would be permitted by the DCO.	assessment of each impact based on a realistic worst-case scenario.
PINS (ref. 3.4.11)	2nd August 2022	Impacts that span the lifetime of the Project: The Scoping Report states that impacts which span the life of the Proposed Development will be considered as part of the operational phase, rather than the construction phase, to avoid duplication. This implies that the ES may not report the full range of effects for construction. The Inspectorate advises that it would be more appropriate to take the approach outlined in relation to benthic ecology (para 274), where effects likely to arise across the lifetime of the Proposed Development are assessed in the construction phase.	There are two impacts that potentially span the life of the Project: 'Permanent habitat loss' (see **Section 10.6.3.1**); and 'Introduction of hard substrate' (see **Section 10.6.3.6**), as well as cumulative effects in **Section 10.7**. To avoid confusion, it is made clear in these sections that these impacts would also manifest effects (although to a lesser extent) over construction and decommissioning phases but are assessed in the operation and maintenance phase only to avoid duplication.
PINS (ref. 3.4.12)	2nd August 2022	Operational noise: The Scoping Report states that it considers it unlikely that operational noise impacts would cause physical harm to fish or shellfish, but this matter has been scoped in to allow for further justification when full baseline information is available. It is noted that the research cited in the Scoping Report dates from 2011 and 2014. Given the age of the studies, and the increase in the size and capacity of wind turbines since 2014, the Inspectorate considers that this matter should be addressed in the ES.	Noted, operational noise is assessed in **Section 10.6.3.3**, and within a cumulative context in **Section 10.7**.
PINS (ref. 3.4.13)	2nd August 2022	Basking sharks: The Inspectorate notes that the Scoping Report identifies the potential presence of basking shark. The ES should assess the potential for vessel collision on basking shark and any significant effects that are likely to occur.	Basking shark has been identified as a receptor, with collision risk impacts assessed in **Section 10.6.3**, as well as cumulative effects in **Section 10.7**.

Consultee	Date	Comment	Response/where addressed in the ES
PINS (ref. 3.4.14)	2nd August 2022	Fish impact assessment methodology: The Scoping Report gives little information on the methods likely to be used for assessments. The ES should include a clear description of the methods used to assess impacts on fish and shellfish and any assumptions which support the assessment (including whether concurrent piling is expected to occur). Evidence demonstrating that the methodology has been agreed with relevant stakeholders should also be included wherever possible. If agreement with consultees on the approach used is not possible, then the ES should include a justification as to why the methods used in the assessments are appropriate. Unless otherwise agreed with the relevant stakeholders, the ES should: ▪ Base assessments of underwater noise impacts on the assumption that fish, eggs and larvae are stationary, rather than fleeing receptors, for the reasons outlined in the advice from the MMO (see Appendix 2 of this Opinion). ▪ Use particle size analysis to inform the assessment of habitat suitability for herring spawning and sand eel. ▪ Use a 135dB threshold for herring at their spawning ground to model behavioural responses.	Methods used to assess impacts on fish and shellfish are summarised in **Section 10.6.2.4**. Detailed information on noise modelling and effect thresholds is provided in **Appendix 11.1**. All fish, eggs and larvae are treated as stationary receptors in the modelling and the assessment, using the impact thresholds set out in **Table 10.20**. Reported impact ranges in **Table 10.25** are based on stationary receptors. Consideration of site-specific PSA data for herring and sandeel habitat suitability can be found in **Section 10.5.4**. A 135dB SEL_{SS} threshold has been used to assess potential behavioural effects of pile driving noise on spawning herring. See **Figure 10.6**.
PINS (ref. 3.4.15)	2nd August 2022	Mitigation methods: The Applicant should explain how it will control the timing of the proposed construction and/or operational activities to avoid key and sensitive periods to species, such as fish spawning seasons and fish migration periods. Mitigation measures for noise generating activities, such as piling (for example, the use of twin walled piles or bubble curtains) should also be described in the ES. The ES should explain how the delivery of measures has been secured through the DCO.	Mitigation measures embedded in the project design are outlined in **Section 10.3.3**. The assessment has not identified the need for further mitigation measures beyond those embedded within the Project design. However, mitigation options for marine mammals in regards of noise generating activities are further discussed within the draft

Consultee	Date	Comment	Response/where addressed in the ES
			Marine Management Mitigation Protocol (MMMP) (Document Reference 6.5) supplied as part of the DCO Application.
MMO (ref. 3.4.16)	2nd August 2022	Data and information sources: The existing data sets outlined in Table 8.12 are considered appropriate for the characterisation of fisheries and fish ecology for the Project area.	Noted, no further action required.
MMO (ref. 3.4.17)	2nd August 2022	Data and information sources: The MMO recommend that in using and interpreting some of the existing data, the limitations of some of the data sources proposed for use are acknowledged. For example, in terms of the vintage of data, some Environmental Statements are well in excess of 10 years old (e.g., Barrow, Ormonde, Walney, and West of Duddon Sands offshore windfarms). The fishing methods (i.e., gear type) and the (seasonal) timing of past surveys are likely to influence the fish species caught and the size of catches, therefore, data should be interpreted with caution.	Noted – assumptions and limitations are discussed in **Section 10.4.6**.
MMO (ref. 3.4.18)	2nd August 2022	Herring spawning grounds: The MMO notes that, whilst the Project is not situated within a herring spawning ground, there is a spawning ground located 40km to the north west of the project site. With this in mind, for the purpose of the characterisation and the assessment of impacts of noise and vibration from construction activities (e.g., piling); the MMO recommend that the AFBI of Northern Ireland is contacted to request Irish Sea herring larvae survey data. Herring larvae surveys of the northern Irish Sea are conducted around the Isle of Man and eastern coast of Northern Ireland herring spawning grounds by the AFBI.	Herring is considered in the impact ranges for underwater noise modelling (**Section 10.6.2.4**), as well as for cumulative effects in **Section 10.7**, and considering herring larvae data from the ICES Working Group on Surveys on Ichthyoplankton in the North Sea and adjacent Seas (WGSINS) (2020) report (**Section 10.5.4**). Ten years of the AFBI NINEL herring larvae survey data has also been obtained and used to inform

Consultee	Date	Comment	Response/where addressed in the ES
		Please also refer to the International Council for the Exploration of the Sea (ICES) WGSINS (2020) report for further details of this survey.	the assessment, via the production of a herring larvae heatmap.
MMO (ref. 3.4.19)	2nd August 2022	Data and information sources: The approach to defining the baseline looks appropriate. The MMO notes the report details the presence of spawning and nursery grounds in the Project area and has identified species with commercial and/or conservation importance. Importantly, the report has assigned fish according to the hearing groups described by Popper *et al.* (2014) for the purpose of the assessment of underwater noise and vibration.	Noted, no further action required.
MMO (ref. 3.4.6)	2nd August 2022	Data and information sources: The MMO note the report does not propose to undertake any fisheries specific surveys to inform the baseline characterisation. The MMO believe this is acceptable, given the available data and publications for the Project area. However, the MMO note that benthic grab surveys are proposed to be carried out to inform the seabed characterisation, so the MMO recommend that particle size analysis (PSA) is undertaken on the sediment samples collected, as these can be used to determine sandeel habitat suitability when following the methods described by Latto *et al.* (2013) and MarineSpace (2013).	Noted – PSA data collected at the windfarm site is considered for sandeel habitat. See **Section 10.5.4**.
MMO (ref. 3.4.1)	2nd August 2022	Transboundary effects; Underwater noise and vibration generated by piling has the potential to propagate over vast areas, potentially beyond UK jurisdictional waters. With this in mind, the MMO recommend that potential transboundary effects of underwater noise and vibration on fish during the	Fish and shellfish receptors are assessed at the population level, irrespective of national boundaries or jurisdictions. The impact ranges modelled for piling on fish and shellfish receptors (see **Appendix 11.1**) and the

Consultee	Date	Comment	Response/where addressed in the ES
		construction phase are scoped into the assessment. This comment is also applicable to shellfish below.	potential for transboundary effects are discussed in **Section 10.8**.
MMO (ref. 3.4.1)	2nd August 2022	Data and information sources: The existing data sets outlined in Table 8.12, and those shellfish species identified and described in 8.4.3.2, are appropriate and accurate for the characterisation of shellfisheries and shellfish ecology for the Project area. Particularly, the MMO Landings Data will provide an up-to-date overview of commercially important species, which may be lacking in some of the older surveys.	Noted – the most recent (at time of writing) MMO Landings Data is used for baseline characterisation.
MMO	2nd August 2022	Data and information sources: The MMO agree the approach to defining the baseline is appropriate. The report has identified species with commercial value and has acknowledged that some shellfish (king and queen scallops, whelk, crab and lobster) may be prone to direct physical disturbance during the construction phase, from the installation of the windfarm infrastructure.	Noted, no further action required.
MMO	2nd August 2022	Approach to EIA: The MMO believe the approach to EIA described within the Scoping Report is generally appropriate, as are the sources of data and literature proposed for use within the EIA.	Noted, no further action required.
MMO (ref 3.4.1)	2nd August 2022	Temporary habitat loss/physical disturbance: Impacts arising from temporary habitat loss/physical disturbance during the operational phase should also be scoped into the EIA. There is currently no justification as to why this has been scoped out.	Temporary habitat loss/physical disturbance is assessed for operation and maintenance activities (**Section 10.6.3.2**).

Consultee	Date	Comment	Response/where addressed in the ES
MMO (ref 3.4.1)	2nd August 2022	Underwater noise modelling: The MMO note the Applicant has assigned fish according to the hearing groups described by Popper *et al.* (2014) for the purpose of the assessment of underwater noise and vibration. However, there is no further information on how the hearing thresholds will be applied in the underwater noise modelling. Please note that the MMO recommend that all underwater modelling is based on a stationary, rather than a fleeing, receptor for fish, for the reasons outlined below: i. The MMO know that fish will respond to loud noise and vibration, through observed reactions including schooling more closely; moving to the bottom of the water column; swimming away and burying in substrate (Popper *et al.* 2014). However, this is not the same as fleeing, which would require a fish to flee directly away from the source over the distance shown in the modelling. We are not aware of scientific or empirical evidence to support the assumption that fish will flee in this manner. ii. The assumption that a fish will flee from the source of noise is overly simplistic, as it overlooks factors such as fish size and mobility, biological drivers and philopatric behaviour, which may cause an animal to remain/return to the area of impact. This is of particular relevance to herring, as they are benthic spawners, which spawn in a specific location due to its substrate composition. iii. Eggs and larvae have little to no mobility, which makes them vulnerable to barotrauma and developmental effects. Accordingly, they should also be assessed and modelled as a stationary receptor, as per the Popper *et al.* (2014) guidelines.	The Applicant accepts that given the uncertainty around whether a sound sensitive fish would flee from a harmful noise source, and for the three reasons the MMO gives in this comment (for the rationale behind the preference to model fish as a stationary receptor for underwater sound impacts), the assessment has proceeded under the assumption that all fish receptors would remain stationary for the entirety of the modelled duration of piling. Impact ranges for underwater noise, based on stationary fish receptors, are provided in **Section 10.6.2.4**. Eggs and larvae are also treated as stationary receptors in the underwater noise assessment (**Section 10.6.2.4**).

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MMO (ref. 3.4.10)	2nd August 2022	Noise impacts on herring: For the purpose of modelling behavioural responses in herring at their spawning ground, the MMO recommend the inclusion of a 135dB threshold, based on startle responses observed in sprat by Hawkins *et al.* (2014). Sprat is considered a suitable proxy species for herring for the purpose of modelling likely behavioural responses in gravid herring at the spawning ground. It would be useful if the 135dB noise contour was presented in mapped form (i.e. as an additional contour to the 186dB, 203dB and 207dB, as per Popper *et al.*, 2014).	A 135dB noise contour has been considered (**Section 10.6.2.4**). The overlap with potential herring spawning is displayed in **Figure 10.6**.
MMO (ref. 3.4.11)	2nd August 2022	Changes in fishing activity: In relation to commercial fishing activity in the Eastern Irish Sea, this project will impact most significantly on the potting and dredging activity, which is prominent in this area. It may also displace/disrupt fishing activity to other parts of the Irish Sea, potentially putting extra pressure on stocks. It may also, once constructed, provide habitat creation opportunities and nursery/feeding grounds for fish.	Changes in fishing activity are assessed in **Section 10.6.2.6** and in **Chapter 13 Commercial Fisheries**.
MMO (ref. 3.5.1)	2nd August 2022	Data and information sources: The MMO note Section 8.4.3.2 (paragraph 313) gives a clear description of the shellfish important to the area. Lockwood (2005) has been used as a reference for shellfish resources in the Eastern Irish Sea, though it is unclear if the applicant has considered more recent data, which may be more representative of current shellfish population dynamics.	Noted – the most recent (at time of writing) MMO Landings Data (2022) is also used for baseline characterisation, and the ICES Working Group for the Celtic Seas Ecoregion (WGCSE) report 2022. Bangor University's Fisheries and Conservation Science Group scientific stock assessments for Wales and the Isle of Man have also been considered.

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MMO (ref. 3.5.2)	2nd August 2022	Data and information sources: The MMO acknowledge that the Northern Ireland Ground Fish Survey (NIGFS) has been used to support Lockwood's findings, though this might provide an indication of species presence/absence at best, given many shellfish are usually caught by traps (inshore cuttlefish, crabs, lobsters, whelks). The MMO requests that the date of the NIGFS data is provided.	Noted – the publication date of the NIGFS data is provided and additional data sources to support findings have been added – see **Section 10.1.1.**
MMO (ref. 3.5.3)	2nd August 2022	Data and information sources: The MMO note that our own landings data have been analysed and is satisfied that key shellfish species have been identified. Specifically, paragraph 530 details that "Landings of shellfish species account for approximately 95% of total landings values across the 2016 to 2020 period. Landings data indicate that queen scallops *Aequipecten opercularis* and king scallops Pecten maximus are primarily landed by Scottish-registered dredgers of over 10m length; whelks *Buccinum undatum*, brown crab *Cancer pagurus* and lobster *Homarus gammarus* by primarily English-registered vessels deploying pots and traps; and prawns *Nephrops norvegicus* by Northern Irish and English-registered otter trawlers; and brown shrimp *Crangon crangon* by English beam trawlers. Non-shellfish, primarily demersal species, are primarily landed by vessels registered in England using a variety of gear types, including fixed nets, trawls and gears using hooks."	Noted, no further action required.
MMO (ref. 3.5.4)	2nd August 2022	Impact scoping and noise modelling: The MMO is satisfied that all relevant impacts have been scoped in. The MMO notes Section 8.4.5 that states it is envisioned that the impact assessment will use existing and additional noise	Noted. Site specific noise modelling has been undertaken (see **Appendix 11.1**) and noise survey data available from literature has been used.

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		survey data to assess the level of potential noise impacts upon shellfish, and that site specific underwater noise modelling will be undertaken for all potential noise sources that could impact shellfish species.	
MMO (ref. 3.5.5)	2nd August 2022	Impact scoping: The MMO welcome the inclusion of Table 8.13 that summarises the potential impacts which have been scoped in or out. For the construction phase, permanent habitat loss, electromagnet fields, introduction/removal of hard structure, cumulative permanent habitat loss and transboundary impacts have been scoped out. For the operation and maintenance phase, temporary habitat loss/physical disturbance and transboundary impacts have been scoped out. For the decommissioning phase, permanent habitat loss, electromagnetic fields (EMF) and transboundary impacts have been scoped out. The MMO consider that these decisions are justified.	Noted, no further action required.
MMO (ref. 3.5.6)	2nd August 2022	Embedded mitigation: The applicant has provided example mitigation measures that may be appropriate for the Morecambe Offshore Windfarm development and further measures may be proposed in response to the outcome of the impact assessment and following stakeholder engagement, such as with the commercial fishing industry. The measures adopted as part of the project are detailed in paragraph 568. The MMO believe these measures to be appropriate, though their effectiveness will be determined at a later stage.	Noted. Embedded mitigation is presented in **Section 10.3.3**.

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MMO (ref. 3.6.1)	2nd August 2022	Underwater noise: The MMO note that in the fish and shellfish ecology section of the Scoping Report, underwater noise and vibration has been appropriately identified as a potential impact during the construction, operation and maintenance phases.	Noted, no further action required.
MMO (ref. 3.6.2)	2nd August 2022	Underwater noise: As per para 338: "underwater noise generated by pile driving 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". The MMO advises that underwater noise may also have the potential to injure fish species.	Noted. The potential for noise-induced injury is assessed in **Section 10.6.2.4**, and cumulatively in **Section 10.7.3.2**
MMO (ref. 3.6.3)	2nd August 2022	Barrier effects: The MMO welcome that acoustic barrier effects (noting the potential presence of Annex II migratory species) which may also arise as a result of underwater noise during construction, will be included as part of the underwater noise assessment (para 339).	Noted, no further action required.
MMO (ref. 3.6.10)	2nd August 2022	Underwater noise: Para 329 (of the Scoping Report) states the following: *"It is envisioned that the impact assessment will use existing and additional noise survey data (ambient noise) combined with appropriate guidance such as Popper et al. (2014); and the Environment Agency Informed Approach (Navitus Bay, 2014). This approach uses a combination of Popper et al. (2014), Hawkins & Popper (2014), and Hawkins (2014), to assess the level of potential noise impacts upon fish, including migratory fish and shellfish....site specific underwater noise modelling will be undertaken for all potential noise sources that could impact*	The specified 'Environment Agency Informed Approach' (Navitus Bay, 2014), referred to a noise impact assessment approach for migratory salmon, whereby the swimming speed of salmon was taken into account. Since submission of the Scoping Report, and through further consultation via the EPP process, a more conservative approach of assuming that fish receptors are stationary, with respect to the noise source, has been adopted. The Popper *et al*. (2014) criteria are used to

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		fish and shellfish species". The Popper *et al*. (2014) criteria are the most current, peer-reviewed criteria for fish. The MMO advises the Applicant provide further information/context on the specified 'Environment Agency Informed Approach' (Navitus Bay, 2014).	determine impact thresholds, except in the case of spawning herring, where a 135dB SEL_{ss} threshold for behavioural disturbance is used (Hawkins *et al*. 2014).
ETG responses			
Natural England	10th June 2022	Basking sharks: Additional information on basking shark sightings may be available from the citizen science projects run by MarineLife www.marinelife.org.	The National Biodiversity Network collates a wide range of citizen science projects and has been used to inform the basking shark baseline in **Section 10.5.7**.
Natural England	10th June 2022	Designated sites: Liverpool Bay/Bae Lerpwl Special Protection Area (SPA) should be scoped in here, due to fish and shellfish species that may be affected by the project being prey species of the designated bird species protected in this site.	Liverpool Bay SPA is considered in the baseline in **Section 10.5.10** and assessed in **Section 10.6** and **Section 10.7**.
Natural England	10th June 2022	Introduction of hard substrate: The presence of hard structures represents a modification of the existing habitat. The fish aggregation effect of such structures may not always benefit the existing communities and species. Natural England advises that this is given consideration in the EIA.	The fish aggregation assessment encompasses beneficial and adverse effects and is assessed in **Section 10.6.3**.
Statutory consultation feedback on the PEIR			
MMO	30th May 2023	The MMO recommend that the herring spawning habitat suitability assessment use the method described by MarineSpace (2013). The MMO also recommend acquiring Northern Irish Herring Larvae Survey (NIHLS) data to	As agreed in the ETG on 11th October 2023, herring spawning habitat heatmapping, using NIHLS data from the

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		inform the assessment, which would be applied in lieu of the International Herring Larvae Survey (IHLS) data used in MarineSpace (2013).	previous 10 years has been undertaken and is presented in **Section 10.5.4**. The most recent 10-years of Northern Irish Herring Larvae Survey data has been provided by AFBI and these have been used to produce a heatmap of herring larvae distribution in the northern Irish Sea using kernel density interpolation in GIS, as agreed in the Marine Ecology ETG on 11th October. This recent data shows that the likely present day extent of the Isle of Man herring spawning ground maps closely onto the historical spawning ground extent defined by Coull *et al*., (1998) (**Figure 10.6**). Given this appraisal of recent data, there is no reason to consider that the location and extent of the known herring spawning ground at the Isle of Man has meaningfully shifted in recent years.
MMO	30th May 2023	The 'heatmapping' approach used in MarineSpace (2013) has not been followed, therefore no 'confidence scores' have been assigned to the various data layers. For a development of this nature and scale, and given noise-generating activities proposed, the report should present a minimum of 10 years of NIHLS data, as per the MarineSpace (2013) method, and used this, alongside British Geological Survey (BGS) and historic spawning ground data to present a proper heatmap, which would	As agreed in the ETG on 11th October 2023, herring spawning habitat heatmapping, using NIHLS data from the previous 10 years, has been undertaken and is presented in **Section 10.5.4**. This is presented alongside BGS and historic spawning ground data to indicate the likely present-day extent of the IoM herring spawning ground. Given this appraisal of recent data, there is no

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		better indicate the full extent and intensity of spawning activity around the Isle of Man.	reason to consider that the location and extent of the known herring spawning ground at the IoM has meaningfully shifted in recent years.
MMO	30th May 2023	The MMO advise that the final report should include an appropriate heatmap for the Isle of Man herring spawning ground. Once this has been done, the mapped noise contours from appropriate underwater noise modelling can be overlaid. The modelled noise contours presented should include thresholds for mortality and potential mortal injury, recoverable injury and temporary threshold shift (TTS), as per the pile driving threshold guidelines described by Popper *et al*. (2014).	As agreed in the ETG on 11th October 2023, herring spawning habitat heatmapping, using NIHLS data from the previous 10 years, has been undertaken and is presented in **Section 10.5.4**. The heatmap is overlaid with noise contours in **Figure 10.6.** Given this appraisal of recent data, there is no reason to consider that the location and extent of the known herring spawning ground at the IoM has meaningfully shifted in recent years.
MMO	30th May 2023	In Section 10.6.2.4 the modelled noise impacts overlap 4% of the herring spawning ground. The MMO do not recommend the use of calculated total available herring spawning habitat, as this would assume that the population will spawn in the same area every year and will successfully spawn in a reduced area – which is inaccurate. Herring will return to a broad area to spawn annually, but the exact locations change year on year, therefore the impacts to herring spawning ground is not something that can be easily defined by proportion or percentages.	Noise impact contours for this ES chapter are displayed visually, alongside the herring spawning heatmap and historical spawning ground extent, in **Figure 10.6**. Due to the refinement in windfarm site since PEIR (removal of the western portion of the Agreement for Lease (AfL) area), the 4% overlap mentioned by the MMO no longer occurs, due to greater distance of the monopiles from the Isle of Man spawning ground. However, as recommended by the MMO, quantified levels of overlap

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			are no longer mentioned in **Section 10.6.2.4** and the assessments considers the limitations of the boundaries of spawning grounds.
MMO	30th May 2023	The MMO recommend a detailed assessment for the impacts of underwater noise from piling is undertaken, using the most recent evidence for Atlantic cod, and including the potential impacts to eggs and larvae. Eggs/larvae can be damaged by noise at levels exceeding 207 decibels (dB) (Popper *et al*., 2014). The MMO recommend modelling for the peak sound pressure level (SPLpeak) of 207dB for eggs and larvae, following a worst-case scenario.	Noise impact modelling for eggs and larvae, based on the SPLpeak reported by Popper *et al*. (2014), is now included in **Section 10.6.2.4**. A literature search for noise impact information for Atlantic cod has been undertaken and no new noise impact thresholds have been established beyond those set out by Popper *et al*. (2014). However, new information suggests that pile driving at a distance of 2.3 – 7.1km causes cod to move closer to the hard substrate they are associating with during and after piling (Van der Knaap *et al.*, 2022). The consequences of the modest change in movement patterns in the study are unclear, but are surpassed in magnitude by the potential impacts considered by Popper *et al.* (2014). Treating Atlantic cod as stationary receptors in the modelling ensures that impact ranges are sufficiently conservative.
MMO	30th May 2023	Section 10.6.3.4 discusses the impacts of electromagnetic field (EMF) to fish receptors from the proposed works. This section should include new and additional peer reviewed	Literature has been reviewed and Hutchison *et al*., (2020; 2021) has been used to inform the assessment of EMF

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		studies specific to EMF impacts from OWFs. For example, studies such as Hutchison *et al*., (2020; 2021) should inform the assessment of EMF impacts to electro-receptive species.	impacts in **Section 10.6.3.4**. However, it should be noted that some new peer reviewed studies, such as Hutchinson *et al*. (2020), focus on DC currents, which have limited relevance to the AC cables assessed for this Project.
MMO	30th May 2023	The MMO note that the Isle of Man OWF being developed by Orsted has not been scoped into the cumulative impact assessment. The Isle of Man OWF is being developed and is in the concept/early planning stage. The Isle of Man OWF will likely show potential cumulative impacts from noise disturbance to a number of fish species. The Isle of Man OWF should, therefore, be included in the assessment, to ensure all cumulative impacts are appropriately assessed in relation to herring spawning.	The Isle of Man offshore windfarm project (Mooir Vannin) has been considered in the cumulative impact assessment screening (**Table 10.38**) and assessed using the publicly available information at the time of writing, as set out in the cumulative effects assessment (**Section 10.7**).
MMO	30th May 2023	Section 10.189 (Chapter 10) refers to fish as a fleeing receptor, however, the MMO considers fish should be assessed as a stationary animal. When considering a stationary animal, the impact ranges are increased as a result of sequential piling.	On a precautionary basis, all fish have been treated as stationary receptors for the underwater noise impact assessment, including for sequential piling (**Section 10.6.2.4**).
MMO	30th May 2023	Table 10.25 (Chapter 10) the maximum impact range for monopile (hammer energy 5,000 kilojoules (kJ) has been modelled as 47.2km. The MMO note that it should be clarified if this metric has been modelled from the northwest location of the windfarm. Clarification on this is important, because in Section 10.5.2.4 the modelling is used to discuss the impacts to the Isle of Man herring spawning ground. The northwest location of the site will likely be the nearest point to the	Due to A) Changes in the potential hammer models to be used for the Project; and B) Refinements of the windfarm site, updated noise modelling has been undertaken for a maximum hammer energy of 6,600kJ. Updated cumulative sound exposure level (SEL_{cum}) impact ranges are found in **Table 10.25**, and these are based on the

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		herring spawning ground and, thus, is the recommended point to model for an appropriate worst-case scenario assessment.	worst-case (deepest) modelling location, which is the southwest location. The deepest modelling location (southwest) has consistently produced the largest SEL_{cum} impact ranges in previous modelling iterations for the Project. The worst-case Popper *et al.* (2014) derived SEL_{cum} impact ranges from the southwest location are precautionarily applied across the site. However, the greatest impact range considered for herring is the conservative 135dB SEL_{SS} threshold, applied specifically to temporary behavioural changes for spawning herring. This is the most relevant worst-case range for spawning herring and is displayed in **Figure 10.6** for all modelling locations. The position of the 135dB SEL_{SS} contours in relation to IoM spawning grounds (as defined by Coull *et al*., 1998) and a heatmap of herring larvae produced with recent NINEL herring larvae data, gives a more complete picture of the potential for behavioural impacts on spawning herring. Based on **Figure 10.6**, there is no overlap with the historical spawning grounds from the Project-alone impacts.

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MMO	30th May 2023	The MMO note in Table 4-6 of the Underwater Noise Assessment (Appendix 11.1 B) that a maximum impact range of 49km is predicted from the northwest location of the OWF. The MMO note the report must clarify which of the maximum impact ranges (47.2km or 49km) is correct for herring as a stationary receptor, for the monopile worst-case scenario. There seems to be some discrepancies in the report and an accurate prediction is essential for assessing the potential impacts to Isle of Man herring.	Due to A) Changes in the potential hammer models to be used for the Project; and B) Refinements of the windfarm site, updated noise modelling has been undertaken for a maximum hammer energy of 6,600kJ. For clarity, the worst-case impact range for spawning herring arises from the 135dB SEL_{SS} behavioural disturbance threshold. This is an instantaneous effect, so remains the same, regardless of assumptions around stationary or fleeing receptors. This impact range is displayed for all modelling locations in relation to Isle of Man spawning grounds (as defined by Coull *et al.*, 1998) and a heatmap of herring larvae produced with recent NINEL herring larvae data in **Figure 10.6**. This gives a more complete picture of the potential for behavioural impacts on spawning herring. Based on **Figure 10.6** there is no overlap with the historical spawning grounds (Coull *et al.*, 1998) from the Project-alone, but there may be potential for the Project to contribute to a behavioural effect on spawning herring if other projects in the Irish Sea pile

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			simultaneously, as discussed in **Section 10.7**.
MMO	30th May 2023	In Table 10.16 the conservation status of Atlantic salmon is listed as 'Least Concern', based on the International Union for Conservation of Nature (IUCN) red list. However, the IUCN's most recent assessment for Atlantic salmon in European waters classifies the species as 'Vulnerable'. Please can this be updated in accordance with the most recent IUCN red list.	Acknowledged. **Table 10.16** has been updated. This is not considered to affect the outcome of the assessment.
MMO	30th May 2023	Section 10.5.4 states that "herring larvae are pelagic" and drift in ocean currents. The MMO do not consider this entirely correct. Newly hatched herring larvae are dependent on reserves in the yolk sac and, as a result, stay on the seabed for a period between 3 and 20 days, until the yolk is absorbed. The yolk sac absorption rate is dependent on sea temperature (Russell, 1976). Once the yolk sac is absorbed, the larvae then become pelagic.	Acknowledged. Text in **Section 10.5.4** has been amended, but this is not considered to affect the outcome of the assessment.
MMO	30th May 2023	In Section 10.5.4 it states that "no sandeel were recorded in any of the 50 grab sample locations across the windfarm site". It should be noted that a sediment grab is not a suitable method of catching sandeels. As such, an absence of sandeels in grab samples does not mean that the species is absent from the area.	Acknowledged. Text in **Section 10.5.4** has been amended, and site-specific PSA data has been used to characterise sandeel habitat suitability.
MMO	30th May 2023	Section 10.5.4 refers to data from the annual Northern Irish Ground Fish Trawl Surveys to highlight that surveys "carried out between 2000 and 2017 contained just 311 records of sandeel spp. in the Irish sea and St George's Channel". Trawl surveys aren't an appropriate method to	The client acknowledges the MMO's position on the use of Ground Fish Trawl Surveys, and this is no longer referred to in **Section 10.5.4**. The baseline environment section for sandeel (**Section 10.5.4**) now relies on recent site-specific PSA data collected for the Project, together with BGS data to

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		target sandeels, as they only target demersal species that live or feed on or near the bottom of the seabed. Trawl methods, such as otter and beam trawls, don't penetrate deep enough into the sediment to target burrowing sandeels. Additionally, the mesh size used in these surveys is often larger than the size of sandeels, meaning its likely many sandeels wouldn't reach the end of the net. A sandeel dredge would be required, to provide appropriate abundance data.	inform the sandeel habitat suitability baseline.
MMO	30th May 2023	There are some inaccuracies in the referencing and referring of different sections and tables throughout the report. For example, in point 10.103 of Chapter 10 – Fish and Shellfish Ecology, the report refers to Section 10.5.6 (Pelagic Fish), in relation to Annex II species that pass-through rivers and estuaries, when in fact they should have referred to Section 10.5.6 (Diadromous Fish).	Acknowledged. Text in **Paragraph 10.112** has been amended to correctly refer to **Section 10.5.8** (Diadromous Fish)**.**
MMO	30th May 2023	The MMO note that the report does not include the River Ehen SAC and River Eden SAC in Section 10.5.10. The rationale for this is due to both sites being located to the north of the project area, and that fish receptors are "recorded as travelling north when moving from rivers into the sea". At present, this statement is unsupported within the HRA report and the potential effects to diadromous fish travelling from the south has not been considered. Statements on the directional movements of migratory fish must be supported with data or references to determine which receptors are screened in/out of further assessment.	To clarify, it is only Atlantic salmon smolt that are recorded as travelling northwards in the Irish Sea as they leave river systems from both Northern Irish and English Rivers, as outlined in Barry *et al*., (2020) and Green *et al*., (2022). This is consistent with the fact that UK salmon are known to migrate to Norwegian feeding grounds (Malcolm *et al*., 2010). Since PEIR, more recent evidence shows a strong preference for Irish Sea smolts to migrate in a north westerly direction, out of the Irish Sea to

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		This is particularly important as the River Ehen SAC is designated for Atlantic salmon (Salmo salar), which have medium-sensitivity to underwater noise (Popper *et al.*, 2014). Similarly, the River Eden SAC is designated for brook lamprey (Lampetra planeri), river lamprey (Lampetra fluviatilis) and sea lamprey (Petromyzon marinus), which are benthic spawners and known to construct nests along riverbeds. As such, these receptors are vulnerable to underwater noise and vibration associated with pile driving activities. The MMO considers that the River Ehen SAC and River Eden SAC should not be scoped out of the HRA.	the North East Atlantic, after exiting their natal rivers (Lilly *et al.*, 2023). This evidence is presented in **Section 10.5.8** of this ES. The River Eden SAC is located more than 50km away from the Project (straight line distance) and over 100km via sea to the estuary (through the Solway Firth) and is therefore beyond the ZoI for worst-case noise impacts to interfere with spawning lamprey species, which spawn on the riverbed, as noted by the MMO. The Applicant therefore considers there to be no potential for noise to impact lamprey during spawning at the River Eden. Lamprey species (outside of designated sites) are assessed in this ES as a receptor (see **Section 10.5.8**) and impact assessments on diadromous fish thereafter. On a precautionary basis the River Ehen and River Eden are considered in this EIA chapter and within the RIAA provided with the DCO Application.
MMO	30th May 2023	The report has appropriately assessed the impacts of EMF on shellfish. The MMO notes the report states it is unclear what impact EMF will have on brown crab. The MMO recommend applying the paper published by Scott *et al.*	Noted. Scott *et al*. (2021) is now considered in **Section 10.6.3.4**, to further inform the assessment for edible crab (also known as brown crab).

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		(2021) on the effects of EMF exposure on Edible crab (Cancer pagarus).	
MMO	30th May 2023	There is a high value and quantity of queen scallop (Aequipecten opercularis) in the wider area. Annual assessments of queen scallops are undertaken in territorial waters by the Isle of Man Government and AFBI, with occasional work undertaken by Bangor university for Welsh waters. The MMO considers further data analysis necessary, outlining their coverage, abundance and any potential impacts.	The high quantity of queen scallop in the study area is reflected in **Paragraphs 10.67**, **10.68** and in **Table 10.11**, which shows queen scallop to be an abundant and valuable commercial shellfish species in the study area. The latest Isle of Man (Bloor *et al*., 2022) and Welsh (Delargy *et al*., 2019) queen scallop stock assessments have been consulted to bolster the baseline in **Section 10.5.2**. Local landings data for the Study Area provides the most relevant data for the Project. Impacts on queen scallops, along with other bivalves, are assessed in relevant 'Mollusc' sections throughout **Section 10.6**, and cumulatively in **Section 10.7.3.2**.
NWWT	22nd May 2023	We are disappointed that fishing has been considered as part of the baseline and has not been included in the CEA for fish and shellfish ecology. Fishing is a licensable activity that has the potential to have an adverse impact on the marine environment, including fish and shellfish.	Fishing activity is noted as part of the future baseline on the assumption that fishing will continue at a comparable intensity/rate (and in the absence of any evidence which supports the position of what future trends in fishing activity will look like across the wider region). If fishing activity changes substantially at a future date, due to e.g. change in

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			distribution of prey species, it would be the responsibility of the competent authority (e.g. MMO, IFCA) to review this in fishing licensing plans. Management plans are considered within the commercial fisheries cumulative assessment as relevant in **Chapter 13 Commercial Fisheries**.
NWWT	22nd May 2023	We welcome that the herring spawning grounds potential cumulative impact will be assessed further in the ES. Herring spawning grounds are an important area utilised by adult herring, who spawn directly onto the seabed. Displacement, due to noise during wind farm construction/decommissioning, could have potentially serious population implications. Herring return to the same spawning site every year and expend a significant amount of energy reaching their destination. If noise restricts their access to these areas, they may have no energy remaining to locate an alternative site and may 'abort' their eggs. This would have a substantial impact on the herring population and, potentially, an indirect effect on a wide range of other species, as herring are an essential component of many food chains. We would recommend considering further mitigation measures to be put in place.	As agreed in the ETG on 11th October 2023, herring spawning habitat heatmapping, using NIHLS data from the previous 10 years, has been undertaken and is presented in **Section 10.5.4**. The heatmap is overlaid with noise contours in **Figure 10.6**. This shows that there is no direct overlap in the worst-case temporary behavioural impact range derived from Hawkins *et al*., (2014), with either the historical or likely present day spawning ground at the Isle of Man. However, an assessment on herring spawning is made, noting the proximity and limitations of the definition of spawning ground in **Section 10.6.2.4**.
NWWT	22nd May 2023	Both species of shad have been omitted from the HRA despite presence in the region.	Response outlined as below.

Consultee	Date	Comment	Response/where addressed in the ES
Natural England (ref. C13, C14)	2nd June 2023	Both shad species (Alosa alosa and Alosa fallax) are omitted from the diadromous fish receptor group, despite being present in the region (non-spawning). Given the species is present in the region, either shad should be included within all assessments of impacts on diadromous fish, particularly underwater noise, or a justification for its exclusion provided.	Whilst shad are present in the region, there is no SAC designated for shad within 100km of the Project, thereby ruling out direct effects on these sites. All worst-case noise impact ranges for fish species are contained within 50km, so there is no pathway for direct impact on SACs designated for shad species. . Whilst adult non-spawning shad may be present at the site, there is no way to apportion individuals to any one SAC river population (or non-designated population). However, shad species are now considered in this ES and the RIAA as part of the diadromous fish assemblage (**Section 10.5.8**).
Natural England (ref. C13, C14)	2nd June 2023	Both shad species (Alosa alosa and Alosa fallax) are omitted from the diadromous fish receptor group, despite being present in the region (non-spawning). Include shad within all assessments of impacts on diadromous fish, particularly underwater noise, or provide a justification for excluding them. The species is regionally present. https://sac.jncc.gov.uk/species/S1103/	
Natural England (ref. C11)	2nd June 2023	Several designated sites from the region are not included in the assessment. However, all the omitted fish designated features have coincidentally been assessed due to their presence within other designated sites which were assessed. Recommendation: Incorporate the following designated site features into the appropriate assessments: ▪ Solway Firth MCZ (Smelt) ▪ Solway Firth SAC (Sea lamprey, River lamprey). ▪ River Ehen SAC (Atlantic Salmon)	The River Ehen (Atlantic Salmon) and River Derwent and Bassenthwaite Lake SAC (Atlantic Salmon, Sea lamprey, River lamprey) are included, and listed in **Section 10.5.10**. Designated sites beyond 100km are not listed, but an assessment of the species listed as part of the Solway Firth MCZ (Smelt), Solway Firth SAC (Sea lamprey, River lamprey) are considered in the fish assemblages within this Chapter and at designated sites in closer proximity to the Project.

Consultee	Date	Comment	Response/where addressed in the ES
		- River Derwent and Bassenthwaite Lake SAC (Atlantic Salmon, Sea lamprey, River lamprey).	All sites are also discussed within the MCZA and RIAA provided as part of the DCO Application.
Natural England (ref. C3)	2nd June 2023	It is unclear why UXO removal is not considered within Table 10.2. It could legitimately be included under existing pressure "Impact 4b: underwater noise and vibration impacts to hearing sensitive species due to other activities". Recommendation: Clarify here how the UXO removal is addressed within the PEIR and include within the WCS either as Impact 4b or as a new Impact 4c. Wider sections of the PEIR suggest that the pressure "UXO removal" is part of a separate project and so considered cumulatively, but we recommend including it in the underwater noise assessment for completeness.	As discussed through the EPP, underwater noise modelling results for UXO impact ranges are included for information only. Once quantities and likely charge weights of potential UXO are known, a more detailed assessment of UXO clearance would be undertaken, which would accompany a separate Marine Licence application post-consent.
Natural England (ref. C5)	2nd June 2023	Suitable data sources were used. Text suggests that stakeholders have agreed that a robust assessment was possible with the available data, and therefore no specific fish sampling surveys were required. The limitations of the survey data were largely acknowledged. However, NE note that there is only a single reference, which may contain data that is both reasonably recent and is also site specific (the AyM) Offshore Windfarm ES), but it is unclear whether any new data was collected under this project. Recommendation: NE recognise that the data sources used broadly represent the best available evidence for key fish habitats on a	It is noted that NE is broadly content with the data sources used. Site specific benthic survey data was collected for the Project by Ocean Ecology Limited (OEL) in May/June 2022. The PSA data generated has been used to inform the baseline habitat suitability for sandeel and spawning herring (**Section 10.5.4**). The caveat "Data sources such as Ellis *et al*., (2012) are over 10 years old and

Consultee	Date	Comment	Response/where addressed in the ES
		national scale. Most data listed in Table 10.5 are over 10 years old and are necessarily coarse in scale. These factors introduce uncertainty when applied to site-specific assessments, which is largely recognised in the text. Nevertheless, the submitted ES would benefit from presenting relevant caveats, such as "Data sources such as Ellis *et al* (2012) are over 10 years old and so may not reflect true species composition and abundance". Due to this uncertainty, NE broadly recommend that individual OWF projects generate site-specific data on fish community composition, to verify the conclusions within environmental assessments. However, fish populations are highly mobile and complex. Data gathered by individual projects are, therefore, likely to have limited use, apart from confirming the conclusions presented within the ES. Therefore, we highlight that this undertaking would be greatly beneficial to the ES, but is not a pre-requisite for a successful assessment. Additional, dedicated surveys, for protected species (such as diadromous fish) are appropriate where potential risks to local populations are identified. Depending on the risk to protected fish and migratory corridors, this additional data may be crucial to a successful impact assessment.	so may not reflect true species composition and abundance" suggested by NE has been stated where Coull *et al*., (1998) and Ellis *et al*., (2012) are used and considered within assessments. No significant impacts have been identified for fish populations or diadromous fish species, and there is no proposal to undertake pre or post construction monitoring. These assessments have been based on recent datasets, such as heatmaps produced from the AFBI NINEL herring larvae survey (**Figure 10.6**), recent landings data (**Section 10.5.2**), site-specific benthic survey data for sediment type (**Section 10.5.4**) and Project specific (and precautionary) underwater noise modelling (**Appendix 11.1**). This has allowed both broadscale and local effects to be considered.
Natural England (ref. C6)	2nd June 2023	This section contains a reference to fish being a "fleeing" receptor, also present throughout document relating to underwater noise modelling. Natural England advise that there is very little evidence to support any assertion that fish flee consistently and coherently away from noise sources.	On a precautionary basis, all fish have been treated as stationary receptors for the underwater noise impact assessment, including for sequential piling (**Section 10.6.2.4**).

Consultee	Date	Comment	Response/where addressed in the ES
		Agree with MMO comment (ref 3.4.1) dated 13th July 2022 – 2nd August 2022. Recommendation: Ensure consistency across the text that fish are considered a stationary receptor within the underwater noise assessment.	
Natural England (ref. C6)	2nd June 2023	In some cases, we noticed significant overlap with spawning grounds for a number of commercial species, including Cod, Plaice, Sole, Herring, sprat and sandeel. Recommendation: We highlight that whilst these species are not designated features within SAC or MCZ, some are NERC Section 41 species, and/or are of commercial importance and/or provide foraging resources for other receptors. The submitted ES should recognise that the datasets used are relatively old and have a coarse spatial scale. Updated data may provide more accurate information.	To clarify, there is no direct overlap of the Project, or its worst-case noise impact range, with herring spawning grounds, as defined by Coull *et al*., (1998) or Ellis *et al*., (2012). Heatmapping for herring spawning habitat suitability, using the previous 10 years of NIHLS data, supports this position (**Figure 10.6**). In the case of sandeel, Ellis *et al*., (2012) suggests that the Project overlaps with high intensity sandeel spawning ground. However, recent site-specific PSA data collected for the Project, together with BGS data, shows that the Project is located in an area that is unsuitable (overly high mud content) sandeel habitat (**Figure 10.5**). In this case, the recent site-specific data takes precedence.
Natural England (ref. C8)	2nd June 2023	See above comment addressing Table 10.5/ sections 10.33 & 10.56. Recommendation: See above comment relating to table 10.5/ sections 10.33 & 10.56.	

Consultee	Date	Comment	Response/where addressed in the ES
			For other species, such as cod, plaice, sole and sprat, it is acknowledged that the Project overlaps with spawning grounds, as defined by Coull *et al*., (1998) or Ellis *et al*., (2012). However, the Applicant maintains the position that the ZoI for serious and permanent effects is temporary and minor, in the context of the wider spawning grounds throughout the Irish and Celtic Seas, which the high intensity spawning maps tend to encompass. There is a range of 8.2km for potential mortal injury assuming a fish stationary receptor subjected to noise from three sequential monopiles with a swim bladder involved in hearing (**Table 10.25**). The conservation importance of the species mentioned by NE is set out in **Table 10.14** and **Table 10.15.** The caveat "Data sources such as Ellis *et al* (2012) are over 10 years old and so may not reflect true species composition and abundance" suggested by NE has been used where Coull *et al*., (1998) and Ellis *et al*., (2012) is used and considered within assessments. This includes **Table 10.5** and **Section 10.4.6**.

Consultee	Date	Comment	Response/where addressed in the ES
Natural England (ref. C9)	2nd June 2023	See comment C6 above addressing both section 10.189 & section 10.346. Recommendation: See comment C6 above addressing both section 10.189 & section 10.346	On a precautionary basis, all fish have been treated as stationary receptors for the underwater noise impact assessment, including for sequential piling (**Section 10.6.2.4**) and for the cumulative noise assessment (**Section 10.7.3**), the sections referenced by NE that referred to fleeing receptors have been amended.
Natural England (ref. C10)	2nd June 2023	See comment C5 on Baseline characterisation above.	It is noted that NE is broadly content with the data sources used. Site specific benthic survey data was collected for the Project by Ocean Ecology Limited (OEL) in May/June 2022. The PSA data generated has been used to inform the baseline habitat suitability for sandeel and spawning herring (**Section 10.5.4**).
Natural England (ref. C12)	2nd June 2023	Please note that NE defer to CEFAS on the suitability of the underwater noise modelling parameters and methods.	Noted, no further action required.
IoM Government	2nd June 2023	MMO 3.4.1 – The report appears to separate spawning and nursery grounds, but doesn't acknowledge transboundary effects. There is limited purpose in protecting spawning, only to kill them during the nursery phase, or vice versa. While the species may be assessed at the population level, are they assessed at lifecycle level? (e.g. Section 10.52 –	The MMO recommend modelling for the peak sound pressure level (SPLpeak) of 207dB for eggs and larvae following a worst-case scenario. This modelling has been undertaken and impact ranges are reported in **Table 10.26**.

Consultee	Date	Comment	Response/where addressed in the ES
		distributions of fish and shellfish is independent of national boundaries – as are their lifecycle stages)). Other work has indicated connectivity's between life cycle stages, spawning grounds and nursery grounds, or fishing grounds – thereby requiring a linked assessment, i.e., can't consider the life stages in isolation and so the assessment must look at each stage and consider where the highest risk arises. For example, Neil *et al* 2008 (http://sustainable-fisheries-iom.bangor.ac.uk/documents/government-reports/scallop/2008/BangorFisheriesReport_No3.pdf) showed connectivity between south and north areas within the Eastern Irish sea spawning connections with nursery areas. How has connectivity across the area, with respect to life cycle stages and impacts been assessed?	It is acknowledged that within the worst-case instantaneous noise impact range of 320m during maximum hammer energy (6,600kJ) monopiling, pelagic larvae and eggs may be subject to mortality. However, taking a life cycle approach, the viability of the Isle of Man herring population (and all other fish populations considered) is not considered to be at risk from impacts on larvae and eggs of this scale. Planktonic larvae are numerous (10,000 – 60,000 eggs per female in the case of herring) and dispersed across a wider area by the time some larvae drift to the windfarm site. Also, given the seasonality of spawning, only some larvae from some species would be present within the windfarm site or within noise impact ranges at any one time.
IoM Government	2nd June 2023	As per MMO advice (pg. 19 Table – MMO ref – 3.4.18) – recommends contacting AFBI – has this been done? It indicates that the data obtained, but given their expertise, has the project and conclusions been discussed with them? There are only 6 references to AFBI, and none specific to expert advice.	The MMO recommended that the AFBI be contacted to discuss use of their NIHLS data, to better inform the baseline for herring spawning. AFBI have been contacted to discuss the use of NIHLS data. AFBI provided the previous 10 years of data, which have been used to generate a herring larvae heatmap (**Figure 10.6**) to provide present-day context to the extent of the Isle of Man

Consultee	Date	Comment	Response/where addressed in the ES
			herring spawning ground, as discussed and agreed with ETG members.
IoM Government	2nd June 2023	Pg . 55 – 10.55 – notes that no transboundary effects expected for noise affecting Isle of Man waters, which is the approach adopted for other developments. However, none of them are in the vicinity and they are older projects. How does that rationale enable progression of data and improved understanding of impacts?	The windfarm site has been refined since PEIR and worst-case impact ranges (and therefore ZoI for the Project) can be more confidently applied, allowing for a Project-specific rationale for the assessment of transboundary effects to be set out (**Section 10.8**).
IoM Government	2nd June 2023	10.4.2.2 Do you need to include, or acknowledge, the relevant Isle of Man policy and legislation, given the acknowledgement of potential transboundary effects on species which are protected/managed in Manx waters, including the existence of designated conservation areas? (see also comment on MCZ Assessment Report).	See above comment for explanation on the refinement of the windfarm site and updated worst-case impacts ranges which supports the assessment of transboundary effects set out (**Section 10.8**).
IoM Government	2nd June 2023	Pg.48 Table 10.5: noting that Manx Basking Shark Watch has now transferred its public sightings database responsibilities to the Manx Whale and Dolphin watch: https://www.mwdw.net/ https://www.mwdw.net/history-of-manx-basking-shark-watch/ And also that the Isle of Man has its own NBN Atlas website: https://isleofman.nbnatlas.org/. This should be linked to the main NBN Atlas, and therefore should be the same, however, it may be worth checking, and noting.	Noted. The Isle of Man NBN atlas is consistent with the main NBN atlas with regard to basking shark at the time of writing.

Consultee	Date	Comment	Response/where addressed in the ES
IoM Government	2nd June 2023	10.37, as noted above – spawning and nursery grounds are both assessed; are they considered linked or separately? Could this make a difference in the eventual impact on the species, either in the short or long term?	If significant effects are found on either spawning or nursery grounds (or any aspect of any receptor), then population level effects may occur for the receptor, which includes the ability of the population to survive and reproduce into the future, with life cycle effects included in this. Any impact is considered in terms of its effect at the population level.
IoM Government	2nd June 2023	10.54 sound effect on herring (spawning aggregations) up to 47 km away, but what effect does it have on larvae or eggs already spawned? The assessment seems to consider only the adults as the receptors, but the impact may be on the eggs and larvae.	The MMO recommend modelling for the peak sound pressure level (SPLpeak) of 207dB for eggs and larvae following a worst-case scenario. This modelling has been undertaken and impact ranges are reported in **Table 10.26**. The modelling suggests that, within the worst-case instantaneous noise impact range of 320m around the monopile during maximum hammer energy (6,600kJ) piling, pelagic larvae and eggs may be subject to mortality. This impact range is not assessed as sufficient to cause significant effects on fish populations within the region.
IoM Government	2nd June 2023	10.55, it is not clear how examples from the North Sea are relevant as to whether or not transboundary effects in relation to the Isle of Man should be included. Surely the regional circumstances of each windfarm determines this, not how previous developments have treated it? That is,	North Sea examples are used as a precedent for EIA methodology and rationale around transboundary effects under the English system that this EIA must ultimately be determined under and

Consultee	Date	Comment	Response/where addressed in the ES
		these examples are not valid justifications for specific assessment, or otherwise, of transboundary effects for Morecambe proposal and the Isle of Man. The decision should be based upon consideration of evidence, assessment and consultation.	competent authorities may wish to adopt a consistent approach in their determinations, despite regional differences. It is acknowledged, however, that the biogeographic regions are not comparable and that different stakeholders are of relevance for the Project compared to North Sea projects. The windfarm site has been refined since PEIR and worst-case impact ranges (and therefore ZoI for the Project) can be more confidently applied, allowing for a Project-specific rationale for transboundary effects to be set out (**Section 10.8**).
	2nd June 2023	10.63 and 10.68 - It's not clear why herring nursery grounds are not mentioned in relation to the array site – Figure 10.3c clearly shown the site covers an area of high intensity herring nursery ground. There is acknowledgement of the spawning grounds further away in Manx waters, but the connectivity between the two areas appears not to be acknowledged in the assessment. It appears that the emphasis is on the distance away from the site for spawning, but no recognition of the site being on a nursery ground. Can't consider the noise impact on spawning aggregations and spawning in Manx waters, without making the same	The MMO recommend modelling for the peak sound pressure level (SPLpeak) of 207dB for eggs and larvae following a worst-case scenario. This modelling has been undertaken and impact ranges are reported in **Table 10.26**. The modelling suggests that, within the worst-case instantaneous noise impact range of 320m around the monopile during maximum hammer energy (6,600kJ) piling, pelagic larvae and eggs may be subject to mortality. This impact range is not assessed as sufficient to

Consultee	Date	Comment	Response/where addressed in the ES
		assessment of the larvae when they hatch and drift to the NE and SE towards the array area. There's little point in protecting one part of the life cycle somewhere, but kill them later at a different life cycle stage. As above, noting that Table 10.2 acknowledges the nursery ground on site, but not necessarily the connectivity?	cause significant effects on fish populations within the region.
IoM Government	2nd June 2023	10.5.4 Again, there is no sense of connectivity between the spawning and nursery grounds for herring in this section. There is reference to the larval distribution, and also acknowledgement of the array site being a high intensity nursery ground - so what's the connection between larval distribution and the nursery ground – they must originate as larvae and end up on the nursery ground. It feels like there is a disconnect. Suggest specific consultation with AFBI in relation to the interaction of herring spawning and nursery grounds in the Eastern Irish Sea, and the validity of the conclusions drawn.	The MMO recommend modelling for the peak sound pressure level (SPLpeak) of 207dB for eggs and larvae following a worst-case scenario. This modelling has been undertaken and impact ranges are reported in **Table 10.26**. The modelling suggests that, within the worst-case instantaneous noise impact range of 320m around the monopile during maximum hammer energy (6,600kJ) piling, pelagic larvae and eggs may be subject to mortality. This impact range is not assessed as sufficient to cause significant effects on fish populations within the region.
IoM Government	2nd June 2023	10.64 and 10.86 Basking shark are also protected under the Wildlife Act 1990 of the Isle of Man. The Isle of Man is also signatory to both CITES and the Bern Convention.	Acknowledgement of the Isle of Man Wildlife Act 1990 has been added to **Section 10.5.7**.

Consultee	Date	Comment	Response/where addressed in the ES
IoM Government	2nd June 2023	Table 10.11 does anyone actually fish Nucella lapillus? It's predominantly a littoral species. Also, should be Homarus gammarus.	Acknowledged. Erroneous inclusion of *Nucella lapillus* in **Table 10.11** removed. Instances of incorrect spelling of *Homarus gammarus* are also resolved.
IoM Government	2nd June 2023	10.5.10 Does not appear to include the Isle of Man designated sites, under the Wildlife Act 1990. Several have relevant designation features to this chapter. See: https://www.gov.im/media/1378920/designation-of-marine-nature-reserves-guidance-note.pdf	IoM designations are noted within **Section 10.8**), as well as relevant species covered in the assessments in **Sections 10.6** and **10.7**.
IoM Government	2nd June 2023	Table 10.17 Please clarify why herring spawning (and larval distributions – as shown on Plate 10.1) – would not be considered as a receptor when they have a specific sensitivity to underwater noise, and sound levels would extend to those areas?	To clarify, herring spawning and nursery grounds are considered as receptors in and of themselves. They are characterised in **Sections 10.5.3** and **10.5.4** and considered in all assessments in **Section 10.6** and **10.7**. The omission of herring spawning and nursery grounds from **Table 10.17** has now been amended to include these receptors.
IoM Government	2nd June 2023	10.121 Herring as a high sensitivity species, and with a high intensity nursery ground on the array site does not seem to justify a negligible impact. Sound energy from the construction phase on a high intensity nursery ground would presumably have a potentially significant impact on the animals on site, and for some distance around – so it's not potentially short term or reversible for the cohort affected by the noise, which has the potential to affect a	To clarify, **paragraph 10.121** in **Section 10.6.2.1** is in relation to the impact of temporary physical disturbance to the seabed within the windfarm site, rather than underwater noise impacts. Temporary physical disturbance is quantified in **Section 10.3.2**. The negligible assessment of magnitude still

Consultee	Date	Comment	Response/where addressed in the ES
		considerable area of the high intensity nursery ground. Has the effect been modelled or is just assumed to be negligible? If not actually estimated, should it not be taken forward for further assessment and specific monitoring in case the data-limited assumption is incorrect? Has AFBI concurred with this conclusion?	stands in relation to herring larvae. AFBI have not given feedback on this conclusion, but the Applicant considers this clarification on the impact considered in **Section 10.6.2.1** provides the necessary context as to the assessment conclusion. Underwater noise impacts from piling are assessed in **Section 10.6.2.4**.
IoM Government	2nd June 2023	10.204 - 10.211 Given the amount of uncertainty associated with this receptor, why not undertake some empirical monitoring, rather than assuming effects and excluding from EIA? Negligible/minor adverse and no monitoring – how will the assumptions be verified?	The Applicant is proposing to undertake monitoring of publicly available commercial fisheries data. Further, noise monitoring of the first four piles, whilst primarily a monitoring measure for marine mammals, would also determine that the maximum underwater noise levels as assessed within the ES for fish are not being breached. The Applicant would remain in dialogue with stakeholders, including nearby projects, to discuss any regional or strategic projects that may be in planning and that may assist in verifying EIA conclusions.
IoM Government	2nd June 2023	Table 10.38 and 10.362 Has Ørsted Isle of Man offshore windfarm been considered? Conclusion at this section noted and agreed.	The Isle of Man offshore windfarm (Mooir Vannin) has been considered in the cumulative impact assessment screening (**Table 10.38**), using the latest publicly available information. At this

Consultee	Date	Comment	Response/where addressed in the ES
			stage, no underwater noise modelling has been undertaken (with the published Mooir Vannin scoping report (Ørsted, 2023) using nearby modelling at the Morgan offshore wind Project to define a 50km study area), and timescales (as they are currently planned for Mooir Vannin and the Project) would mean offshore construction would not overlap. Assessments based on this information are provided in **Section 10.7**.
IoM Government	2nd June 2023	10.11 Potential Monitoring Requirements Negligible/minor adverse and no monitoring – how will the assumptions and conclusion be verified? How does this development contribute to the increase in evidence and information in this particular regional and specific set of circumstances?	The Applicant is proposing to undertake monitoring of publicly available commercial fisheries data. Further, noise monitoring of the first four piles, whilst primarily a monitoring measure for marine mammals, would also determine that the maximum underwater noise levels as assessed within the ES for fish are not being breached. The Applicant would remain in dialogue with stakeholders, including nearby projects to discuss any regional or strategic projects that may be in planning that may assist in verifying EIA conclusions.
NFFO	4th June 2023	A general concern within the PEIR is the lack of site-specific data used to characterise the baseline environment for fish and shellfish. The only site-specific data used that is	The data sources used have been broadly agreed through the EPP, with

Consultee	Date	Comment	Response/where addressed in the ES
		not dated (by more than a decade in many cases) were MMO landings statistics and ICES/IBTS surveys, both of which the resolution is too coarse to characterise an accurate baseline. The use of data from other wind farm assessments feeds into the cycle of non-site-specific data being used to characterise a baseline, these data are either dated (one over 20 years old) or from sites some considerable distance from the Morecambe proposed area.	some requested additions, which are outlined below. The Applicant maintains that landings data at the level of ICES rectangle, averaged over 5 years, is sufficient to characterise the key species for the baseline for mobile commercial species in relation to the Project and also reduces the potential for interannual variations to skew the baseline. Highly mobile populations are better understood at a more regional scale and cannot be sufficiently characterised by site-specific survey snapshots. In addition, site specific benthic survey data was collected for this project by Ocean Ecology Limited (OEL) in May/June 2022. The PSA data generated has been used to inform the baseline habitat suitability for sandeel and spawning herring (**Section 10.5.4**). Further data on Basking shark sightings in the area has been included. Finally, the AFBI have provided the previous 10 years of NIHLS data, which have been used to generate a herring larvae heatmap to provide present-day context to the extent of the IoM herring spawning ground, as discussed and

Consultee	Date	Comment	Response/where addressed in the ES
			agreed with ETG members. This is presented in **Section 10.5.4**. The heatmap is overlaid with noise contours in **Figure 10.6**. Therefore, as noted in **Section 10.4.2**, it is considered by the Applicant, and agreed with stakeholders, that sufficient publicly available information is available to undertake a robust assessment.
NFFO	4th June 2023	The reliance of offshore wind impact assessments on Coull *et al*., (1998) and Ellis *et al*., (2012) has been called into question in several of our responses to offshore developments. These data are over a decade old but seem to be used as a 'gold standard' to assess impacts on spawning and nursery grounds. If these data are to be used, Table 10.12 and Figures 10.2a – 10.3b highlight the importance of the Morecambe development area to gadoid, herring, plaice and sole nursery grounds, all of which are shown to occur with high frequency in locations that overlap with the development area. However, the assessments of the impacts for all stressors state that there will be "minor/adverse" at worse, with no monitoring or mitigation suggested. This, in our opinion, calls into question the methodology used in the assessment. If there is an overlap of high intensity spawning/nursery areas, then surely some form of monitoring is needed to ensure there are no adverse effects on the ecology of these commercially important stocks. If such effects are found, mitigation would be needed. Having no form of mitigation for, or monitoring of, these stocks is in contravention of NW-FISH 3 marine	The non-significant impacts assessed with respect to spawning and nursery grounds consider receptor sensitivity and impact magnitude, as required in the EIA Regulations (**Section 10.4.3**) and in line with guidance (**Section 10.4.1)**. The assessment for nursery and spawning grounds takes into account the very broad extent of these mapped grounds in relation to the localised and temporary nature of many of the impacts assessed. Where impacts are likely to be longer term, such as EMF, embedded mitigation, such a cable burial to a target depth of 1.5m, is committed to. Taking into account the mitigation already proposed (**Section 10.3.3**), the sensitivity of receptors and magnitude of impacts, the Applicant maintains the assessed significance of effects.

Consultee	Date	Comment	Response/where addressed in the ES
		plan, that states “adverse impacts on essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes, must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts so they are no longer significant”. We find it difficult to accept that the assessment of the construction, operation and decommissioning of a major energy infrastructure project has not identified a single impact to a receptor above “not significant”.	The Applicant is proposing to undertake monitoring of publicly available commercial fisheries data. Further, noise monitoring of the first four piles, whilst primarily a monitoring measure for marine mammals, would also determine that the maximum underwater noise levels as assessed within the ES for fish are not being breached. The Applicant would remain in dialogue with stakeholders, including nearby projects to discuss any regional or strategic projects that may be in planning that may assist in verifying EIA conclusions.
NFFO	4th June 2023	There is minimal site-specific and contemporary data used that can support the assessments made in this chapter. The use of data that is over a decade old in some cases, or from other developments a considerable distance beyond the assessment area, is not acceptable when characterising a site-specific baseline.	Data is considered suitable upon which to base the assessment. The limitations of data sources used have been noted (**Section 10.4.6**) and additions made which are outlined below: The Applicant maintains that landings data at the level of ICES rectangle averaged over 5 years is sufficient to characterise the key species for the baseline for mobile commercial species in relation to the Project, and also reduces the potential for interannual variations to skew the baseline. Highly

Consultee	Date	Comment	Response/where addressed in the ES
			mobile populations are better understood at a more regional scale and cannot be sufficiently characterised by site-specific survey snapshots. In addition, site specific benthic survey data was collected for the Project by Ocean Ecology Limited (OEL) in May/June 2022. The PSA data generated has been used to inform the baseline habitat suitability for sandeel and spawning herring (**Section 10.5.4**). Further data on basking shark sightings in the area has also been included. Finally, the AFBI have provided the previous 10 years of NIHLS data which have been used to generate a herring larvae heatmap to provide present-day context to the extent of the Isle of Man herring spawning ground, as discussed and agreed with ETG members. This is presented in **Section 10.5.4**. The heatmap is overlaid with noise contours in **Figure 10.6.**
NFFO	4th June 2023	Data was analysed from monitoring projects of other OWF developments, however, the methodology used for these monitoring projects (e.g., otter or beam trawl) is not the correct methodology for sampling receptors that the data have been used to assess (e.g. shellfish). This incorrect use of data, from inappropriate methodologies, should be	Data is considered suitable upon which to base the assessment. The limitations of data sources used have been noted (**Section 10.4.6**) and additions made which are outlined below.

Consultee	Date	Comment	Response/where addressed in the ES
		accounted for when assessing impacts to receptors. Acknowledging the limitations in the data, but ignoring such and using it as concrete evidence, with no precaution used, misinforms the assessment of the impacts. This is done throughout this chapter and questions the validity of the impacts assessed.	In this ES, the primary datasets used for shellfish baseline characterisation are landings data, stock assessments (e.g. Bloor *et al*., 2022) and site-specific Project datasets such as PSA data from a site specific 2022 benthic survey. The baseline for herring spawning grounds and sandeel habitat is based on recent site specific data (**Section 10.5.4**) and the most recent 10 years of AFBI NINEL herring larvae survey data, which has been used to produce a herring larvae heatmap (**Figure 10.6**). The limitations of datasets used are stated in **Section 10.4.6**. And further caveats for older datasets are now included in e.g. **Table 10.5** and **Section 10.4.6**. Monitoring data from other OWF developments is not relied upon in the assessments.
NFFO	4th June 2023	We acknowledge the difficulties with the lack of site-specific, contemporary data, but we would expect to see some element of precaution taken when assessing impacts to fish and shellfish ecology, specifically when advised through inappropriate methodologies.	The limitations of datasets used are stated in **Section 10.4.6**, and further caveats for older datasets are now included in, e.g. **Table 10.5** and **Section 10.4.6**. Data is considered suitable upon which to base the assessment. In this ES, the primary datasets used for baseline characterisation are landings

Consultee	Date	Comment	Response/where addressed in the ES
			data, stock assessments (e.g. Bloor *et al.*, 2022) and site-specific Project datasets such as PSA data from a site specific 2022 benthic survey. In addition, precautionary and Project-specific underwater noise modelling has been undertaken (**Appendix 11.1**), with reference to established sound impact thresholds (Popper *et al.*, 2004), and in the case of herring, a precautionary 135dB SEL_{SS} threshold for behavioural disturbance (Hawkins *et al.*, 2004). All fish, larvae, and eggs have precautionarily been treated as stationary receptors in this modelling. The baseline for herring spawning grounds and sandeel habitat is based on recent site specific data (**Section 10.5.4**) and the most recent 10 years of AFBI NINEL herring larvae survey data, which has been used to produce a herring larvae heatmap (**Figure 10.6**).
Natural Resources Wales (NRW)	21st May 2023	NRW (A) agree with the conclusions of the PEIR but advise that the potential for cumulative effects to Atlantic cod need to be considered further in the full Environmental Statement.	It is noted that NRW agree with the conclusions of the PEIR. Cumulative impacts on cod are considered in **Section 10.7.3.2**.
NRW	21st May 2023	Overall, NRW (A) agree with the conclusion of no significant impact to site integrity for diadromous fish features of the following sites: Dee Estuary/ Aber Dyfrwy SAC, River Dee	It is noted that NRW agree with the conclusions for the diadromous fish assessment for the SACs mentioned.

Consultee	Date	Comment	Response/where addressed in the ES
		and Bala Lake/ Afon Dyfrwy a Llyn Tegid SAC, Afon Gwyrfai a Llyn Cwellyn SAC and Afon Eden – Cors Goch Trawsfynydd SAC.	
NRW	21st May 2023	The following comments are with reference to the assessment of marine fish found outside of Welsh waters and, therefore, are provided only for information. With reference to Chapter 10, Fish and Shellfish Ecology, Section 10.362, NRW (A) note the conclusion of the PEIR and that cumulative impacts to herring from underwater noise will be further assessed in the full ES.	Herring spawning habitat heatmapping, using AFBI NINEL herring larvae survey data from the previous 10 years has been undertaken and is presented in **Section 10.5.4**. The heatmap is overlaid with precautionary 135dB SEL_{SS} noise contours in **Figure 10.6**. This shows that there is no direct overlap in the worst-case temporary behavioural impact range derived from Hawkins *et al*., (2014) with either the historical or likely present day spawning ground at the Isle of Man. However, an assessment on herring spawning is made noting the proximity and limitations of the definition of spawning ground in **Section 10.6.2.4**.
NRW	21st May 2023	Atlantic cod have high intensity spawning and nursery grounds overlapping with the array site and are a group 3 hearing fish, which are sensitive to noise. It is unclear from the assessment whether cod have been assessed only as a fleeing receptor. NRW (A) note the consultation advice from PINS and MMO that all receptors are modelled as stationary.	To clarify, taking a precautionary approach and with the recommendation of the MMO, all fish have been treated as stationary receptors for the underwater noise impact assessment, including for sequential piling (**Section 10.6.2.4**) and for the cumulative noise assessment (**Section 10.7.3**).

Consultee	Date	Comment	Response/where addressed in the ES
NRW	21st May 2023	Atlantic cod are listed as Vulnerable (VU) on the IUCN Red List and ICES advice for 2023 for the Eastern Irish sea stock (division VIIa) is that there should be zero catch (Working Group for the Celtic Seas Ecoregion (WGCSE)). As there is potential for underwater noise to cause disturbance, or sub-lethal injury, to cod, in the same manner as for herring, NRW (A) advise that best practice would be to consider the potential for cumulative effects to Atlantic cod in the full ES.	In acknowledgement of the IUCN listing and ICES advice on cod take in the Irish Sea, the cumulative impacts on cod are considered in **Section 10.7.2.2**.

10.3 Scope

10.3.1 Study area

10.13 The windfarm site (encompassing all Project infrastructure) is located in the Eastern Irish Sea and encompasses a seabed area of 87km^2. The nearest point from the windfarm site to shore (coast of northwest England) is approximately 30km from the Lancashire coast.

10.14 The windfarm site is located wholly within International Council for the Exploration of the Sea (ICES) rectangle 36E6 (which lies within the wider ICES area of VIIa). Fishing stocks are managed by ICES division and quotas are allocated per rectangle. Both commercial fisheries data and data gathered from various national and international fish surveys are recorded, collated, analysed and reported at the level of ICES rectangles. Given the availability of broad scale data sets for both fish and shellfish receptors at the level of ICES rectangles, they are a useful and appropriate means of delineating the study area for fish and shellfish. ICES rectangle 36E6 therefore defines the 'study area' for fish and shellfish ecology and is the primary focus of this assessment **Figure 10.1**.

10.15 The study area encompasses a 15km Zone of Influence (ZoI) for direct and indirect effects (namely increased suspended sediment concentrations (SSCs) and subsequent deposition) on fish and shellfish ecology and provides a regional context on baseline fish and shellfish populations.

10.16 In the case of noise and migratory species of conservation importance, such as diadromous fish and basking shark *Cetorhinus maximus*, consideration of an additional 'wider study area' is appropriate. The 'wider study area' encompasses a circular area with 100km radius around the windfarm site (noting noise impacts are encompassed with a 50km ZoI based on site specific modelling). This is to allow for the maximum noise impact ranges and the fact that migratory species could pass through the windfarm site. Considering maximum noise impact ranges and the level of dispersion of migratory species over larger distances, detectable effects beyond 100km are not expected.

10.3.2 Realistic worst-case scenario

10.17 The final design of the Project would be confirmed through detailed engineering design studies, that would be undertaken post-consent, to enable the commencement of construction. To provide a precautionary, but robust, impact assessment at this stage of the development process, realistic worst-case scenarios have been defined. The realistic worst-case scenario (having the most impact) for each individual impact is derived from the Project Design Envelope (PDE), to ensure that all other design scenarios would have less or the same impact. Further details are provided in **Chapter 6 EIA Methodology**.

This approach is common practice for developments of this nature, as set out in Planning Inspectorate Advice Note Nine: Rochdale Envelope (PINS, 2018).

10.18 The realistic worst-case scenarios for the assessment for fish and shellfish ecology are summarised **Table 10.2.** These are based on the PDE described in **Chapter 5 Project Description** (Document Reference 5.1.5), which provides further details regarding specific activities and their durations. The envelope presented has been refined as much as possible between PEIR and ES, presenting a project description with design flexibility only where it is needed.

Table 10.2 Realistic worst-case scenarios for fish and shellfish ecology

Impact	Worst-case scenario	Notes and rationale
Construction phase		
Impact 1: Temporary habitat loss/physical disturbance	**WTG & OSP foundations:** ▪ 35 x WTGs with Gravity Based Structures (GBS) foundations (including jack-up footprint) = 303,625m^2 ▪ Two x OSPs with GBS foundations (including jack-up footprint) = 17,350m^2 ▪ Anchoring for 35 WTGs and two OSPs = 26,640m^2 Total = **347,615m^2**	Given the seabed preparation is the same per foundation for smaller and larger WTGs, the worst-case assumes 35 x smaller WTGs with GBS foundations. GBS foundations are assumed to have a diameter of 65m + 10m disturbance either side. The worst-case scenario is for two jack-up visits per WTG/OSP foundation in different positions over the construction period (each jack-up with 6 legs, each with a 250m^2 footprint). This equates to a total footprint of 1,500m^2 per jack-up vessel visit and 3,000m^2 over the construction period per WTG/OSP foundation. The worst-case scenario is for two anchor positions per foundation (including resetting), with up to 12 anchors per location. Each anchor width is estimated to be 6m, with an approximate seabed footprint of 30m^2 per anchor. Scour protection is encompassed within the seabed preparation area and therefore is not presented.
	Inter-array and platform link cables: ▪ Inter-array cables = 1,750,000m^2 ▪ Platform link cables = 250,000m^2 Total = **2,000,000m^2**	The worst-case scenario for seabed preparation for cables is based on a maximum length of 70km of inter-array cables and 10km of platform link cables with a 25m wide installation corridor in which cable preparation activities may take place (this encompasses pre-lay activities (e.g. boulder removal), trenching and spoil width).

Impact	Worst-case scenario	Notes and rationale
		This combination causes the largest area of seabed disturbance.
	Cumulative area of seabed disturbance: 2,347,615m^2 (approximately 2.4km^2)	
Impact 2: Increased SSCs and sediment re-deposition	**Sediment displaced during seabed preparation (sandwave levelling) for WTGs and OSPs foundations:** ▪ 35 x WTGs with GBS foundations = 455,438m^3 ▪ Two x OSPs with GBS foundations = 26,025m^3 Total = **481,463m^3**	The seabed preparation area parameters are outlined in Impact 1 above. The seabed preparation area would be dredged to a depth of up to 1.5m. Seabed preparation (e.g. excavation using a trailing suction hopper dredger (TSHD) or other specialist bed leveller/trencher such as mass flow excavation) may be required. This is a volume of sediment that is disturbed prior to installation of WTG/OSP foundation and involves the removal of sediment from the seabed. The worst-case scenario assumes that sediment would be removed and returned to the water column at the sea surface (e.g. during disposal from a dredger vessel[3]) for WTGs and OSPs. Drill arisings from drive-drill-drive installation methodology would result in a lower volume of sediment being disturbed (55,865m^3 – based on monopile foundations).

[3] It is possible that seabed preparation would be undertaken by plough and sediment would therefore not be released at the surface, however disposal at the surface has been retained for the worst-case scenario.

Impact	Worst-case scenario	Notes and rationale
	Sediment displaced during sandwave levelling for cables: ▪ Inter-array cables = 70,000m³ ▪ Platform link cables = 10,000m³ Total = **80,000m³** **Sediment displaced during cable installation:** ▪ Inter-array cables = 472,500m³ ▪ Platform link cables = 67,500m³ Total = **540,000m³**	The worst-case length of inter-array cables is 70km and platform link cables is 10km. The worst-case assumes that 10% of the length of inter-array and platform link cables would require sandwave clearance/levelling. A clearance width of 10m and height of 1m is used. The worst case assumes sediment would be released at the water surface. The worst-case assumes that 50% of inter-array and platform link cables are buried at 3m and 50% length is buried at 1.5m by jetting in a box-shaped trench.
	Cumulative volume of sediment disturbed: 1,101,463m³ (approximately 1.1km²)	
Impact 3: Remobilisation of existing contaminated sediments if present	As per construction Impact 2	As per construction Impact 2.
Impact 4a: Underwater noise and vibration impacts to hearing sensitive species during foundation piling	**Largest hammer energy** ▪ Diameter of monopiles: 12.0m ▪ Maximum monopile penetration depth: 56m ▪ Maximum hammer driving energy: 6,600kJ **Longest duration** ▪ Number of pin pile foundations: 148 (each WTG/OSP foundation with 4 pin piles) ▪ Maximum hammer driving energy: 2,500kJ	Larger WTGs require a greater pile diameter than smaller WTGs and therefore would generate more noise for a given hammer driving energy. This assessment assumes the largest pile diameter (12m) for WTGs and OSPs and is therefore precautionary. Pin piles are the worst-case scenario in terms of the length of time likely to be taken for installation. See **Appendix 11.1** for underwater noise modelling parameters and scenarios.

Impact	Worst-case scenario	Notes and rationale
	▪ Duration: 1 pile = 4 hours 30 minutes duration. 4 pin piles = 18 hours duration (per foundation). Total duration is 666 hours for all WTGs & OSPs **Highest strike rate** ▪ Fastest strike rate: 100 blows per minute. ▪ Maximum hammer energy: 6,600kJ ▪ Duration: 1 monopile = 3 hours 48 minutes duration; 1 pin pile = 3 hours 13 minutes. 4 pin piles = 12 hours 54 minutes.	Cumulative sound exposure levels have been modelled for each piling event under consideration: single monopiles, single pin piles, and four pin piles piled sequentially. Four sequential pin piles provides the worst-case in terms of cumulative sound exposure levels at this stage. Two scenarios for cumulative sound exposure have been modelled reflecting both the longest duration (with a lower strike rate) and a shorter duration (with a higher strike rate).
Impact 4b: Underwater noise and vibration impacts to hearing sensitive species due to other activities (seabed preparation, cable installation etc.)	**Seabed clearance** Methods could include: Pre-lay grapnel run, boulder grab, plough, sandwave levelling (pre-sweeping) and dredging. **Inter-array and platform link 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: 70km	Example source levels from literature have been used to assess continuous noise sources. Underwater noise modelling undertaken for dredging, trenching, cable laying and rock placement is considered the worst-case in terms of underwater noise for construction activities other than piling (see **Appendix 11.1**).

Impact	Worst-case scenario	Notes and rationale
	▪ Platform link cables: 10km **Vessels** ▪ Maximum number of vessels on site at any one time: **37**	
Impact 5: Barrier effects	As Construction Impact 2, Impact 4a and Impact 4b.	Impacts such as noise, EMF or hard substrate may act as a barrier to the movement of species. The worst-case has been generated from the most extreme design parameters considered in the PDE.
Impact 6: Changes in fishing activity	The worst-case scenarios are set out in **Chapter 13 Commercial Fisheries.**	The worst-case has been generated from the most extreme design parameters considered in the PDE. The implications of fishing displacement for fish and shellfish populations (rather than commercial interests as in **Chapter 13 Commercial Fisheries**) are considered in this chapter.
Impact 7: Collision risk	Maximum number of WTGs/OSPs = **35 WTGs** and **2 OSPs** Maximum number of vessels on site at any one time: **37**	Maximum vessel traffic and infrastructure.
Operation and maintenance phase		
Impact 1: Permanent habitat loss	**Seabed footprint of WTG/OSP foundations:** ▪ 35 x GBS WTGs with scour protection = 248,080m^2 ▪ Two GBS OSPs with scour protection = 14,176m^2 Total = **262,256m^2**	The worst-case scenario assumes 35 x WTGs and two x OSPs (each with a 65m diameter conical GBS foundation, plus scour protection extending 15m from foundations in all directions). This combination causes the largest area of lost seabed habitat.

Impact	Worst-case scenario	Notes and rationale
	Seabed footprint of cable protection: ▪ Inter-array cables = 91,000m² ▪ Platform link cables = 13,000m² ▪ Entry to WTGs and OSPs = 45,500m² Total = **149,500m²**	The worst-case is based on 70km of inter-array cables and 10km of platform link cables. Assumes 10% of cable length is unburied due to ground conditions with a 13m cable protection width at the base and 2m height. The worst-case for cable protection for the entry to WTGs and OSPs assumes 70 points of entry, each with a length of cable protection of 50m, width at the base of 13m. The seabed footprint of cable protection per entry point is 650m².
	Footprint of crossings: ▪ Inter-array cable crossings (9) = 40,050m² ▪ Platform link cable crossings (6) = 26,700m² Total = **66,750m²**	The worst-case for cable/pipeline crossings is based on nine cable/pipeline crossings across inter-array cables and six cable/pipeline crossings across platform link cables. Assumes each crossing footprint is 4,450m² (17.8m width at the base, 250m length and 2.8m in height).
	Replacement scour protection material and cable protection: ▪ Scour protection = 13,950m² ▪ Cable protection including crossings and entries to WTGs/OSPs = 21,625m² Total = **35,575m²**	It is assumed that up to 10% of the total scour protection and cable protection material installed during construction would be required to be replaced or replenished during the operation and maintenance phase. It is assumed that all replacement scour protection and cable protection material would be placed within the same footprint as outlined above.
	Cumulative seabed footprint: 514,081m² (approximately 0.51km²)	
Impact 2: Temporary habitat loss/disturbance and	**Jack-up deployments:** ▪ Jack-up vessel footprint every other year = 1,500m²	The worst-case scenario for jack-up deployments assumes the use of one jack-up vessel with a

Impact	Worst-case scenario	Notes and rationale
increased SSCs (and subsequent deposition)	**Cable repair/replacement:** ▪ Average cable repair/replacement footprint per year = 2,000m^2 ▪ Average cable reburial footprint per year = 1,000m^2 **Anchoring:** ▪ Average temporary anchor footprint per year = 720m^2 Total per year (noting jack-ups are only assumed every other year) = **5,220m^2** Total over operational period = **155,700m^2** **Sediment displaced during cable repair/replacement and reburial per year:** ▪ Average cable repair or replacement sediment volume = 6,000m^3 ▪ Average cable reburial sediment volume = 3,000m^3 Total disturbed per year (on average) = **9,000m^3** Total over operational period = **315,000m^3**	seabed footprint of 1,500m^2 (up to six legs, each with a footprint of up to 250m^2) every other year. 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. The worst-case for anchoring is anticipated to be on average one anchoring event per year. Temporary increases in SSCs would result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities. The worst-case sediment volume assumes that both inter-array and platform link cable repair/replacements would have a 10m disturbance width and 3m maximum depth for a box-shaped trench. The volume of sediment that could be suspended due to the presence of jack-up vessels has not been calculated but would be a much smaller proportion compared to the quantity generated by construction and decommissioning activities. Disturbance is shown on average per year; however, operational and maintenance activities could vary across years during the operation and maintenance phase and therefore an approximate total disturbance is shown for the operational lifetime, which is expected to be 35 years.

Impact	Worst-case scenario	Notes and rationale
Impact 3: Underwater noise and vibration	The following impacts are relevant to the worst-case scenario for fish and shellfish ecology **Underwater noise from operational turbines:** ▪ WTG parameters (e.g. size and number) as outlined above and underwater noise parameters described in **Appendix 11.1**. ▪ Operational life of windfarm = 35 years **Underwater noise from maintenance activities (cable repair, replacement and reburial and cable protection works):** ▪ Average length of cable repair/replacement every year = up to 200m ▪ Average length of cable reburial every year = up to 100m **Underwater noise from vessels:** ▪ Types of vessels: cable laying and burial, rock placement, support vessels, crew transfer vessels, jack-up barges ▪ Maximum number of vessels on site at any one time = up to 3 vessels during a standard year and up to 10 vessels on a 'heavy maintenance' year (every 5 years)	Underwater noise modelling undertaken for operational turbines, dredging, trenching, cable laying and rock placement is found in **Appendix 11.1.** Vessel assessments based on worst-case scenario for maximum number of vessels on site at any one-time and maximum number of return vessel trips during operation and maintenance, and construction period. Operation and maintenance port(s) are still to be determined.

Impact	Worst-case scenario	Notes and rationale
	- Maximum annual number of Operation and Maintenance vessel return trips to port = 384 during a standard year and up to 832 vessels on a 'heavy maintenance' year.	
Impact 4: Interactions of EMF	**Platform link and inter-array cables** - Burial range 0.5-3.0m with a target burial depth of 1.5m - Inter-array cable operating voltage of up to 132kV AC and 275kV for a platform link cable - 70km of inter-array and 10km of platform link cables	The maximum length of cables would result in the greatest potential for EMF-related effects. It should be noted that where cables are unable to be buried, they would instead be protected which would afford a degree of attenuation of EMF.
Impact 5: Barrier effects	As Operation Impact 2, 3 and 4	As Operation Impact 2, 3 and 4
Impact 6: Introduction of hard substrate	As Operation Impact 1	As Operation Impact 1
Impact 7: Changes in fishing activity	The worst-case scenarios are set out in Table 13.2 in **Chapter 13 Commercial Fisheries**.	Changes in fish stocks of commercial importance as a result of changes in fishing activity.

<table>
<tr><th>Impact</th><th>Worst-case scenario</th><th>Notes and rationale</th></tr>
<tr><td colspan="3">Decommissioning phase</td></tr>
<tr><td>Impact 1: Temporary habitat loss/physical disturbance</td><td rowspan="7">The decommissioning policy for the Project infrastructure is not yet defined however it is anticipated that structures above the seabed would be removed.
The following infrastructure is likely be removed reused, or recycled where practicable:
WTG’s and foundations
OSPs including topsides and foundations.
The following infrastructure is likely to be decommissioned and could be left in-situ depending on available information at the time of decommissioning:
Inter-array and platform link cables
Scour protection
Crossings and cable protection
Part of the foundations (e.g. some foundation material below the seabed may be left in situ)</td><td rowspan="7">The detail and scope of the decommissioning works would be determined by the relevant legislation and guidance at the time.
Decommissioning arrangements would be detailed in a Decommissioning Programme, which would be drawn up and agreed with the relevant authority, prior to decommissioning.
For the purposes of the worst-case scenario, it is anticipated that the impacts would be comparable to those identified for the construction phase.</td></tr>
<tr><td>Impact 2: Increases in SSCs and sediment re-deposition</td></tr>
<tr><td>Impact 3: Remobilisation of contaminated sediments</td></tr>
<tr><td>Impact 4: Underwater noise and vibration</td></tr>
<tr><td>Impact 5: Barrier effects</td></tr>
<tr><td>Impact 6: Changes in fishing activity</td></tr>
<tr><td>Impact 7: Removal of hard substrate</td></tr>
</table>

10.3.3 Summary of mitigation embedded in the design

10.19 This section outlines the embedded mitigation relevant to the fish and shellfish ecology assessment, which has been incorporated into the design of the Project (**Table 10.3**). Where additional mitigation measures are proposed, these are detailed in the impact assessment (**Section 10.6** and **Section 10.7**).

Table 10.3 Embedded mitigation measures related to fish and shellfish ecology

Parameter	Mitigation measures embedded into the design of the Project
Cables	The cable burial range is between 0.5m and 3.0m below the seabed (with a target depth of 1.5m, where ground conditions allow (recognised industry good practice, which would reduce effects of EMF)). A Cable Burial Risk Assessment (CBRA) would also be required to confirm the extent to which cable burial can be achieved. Where it is not reasonably practicable to achieve cable burial, additional cable protection may be required. Cables would be specified to reduce EMF emissions, as per industry standards and best practice, such as the relevant IEC (International Electrotechnical Commission) specifications. To minimise the extent of any unnecessary habitat disturbance, material displaced as a result of cable burial activities would be back filled, where necessary, in order to promote recovery.
Foundation installation	The selection of appropriate foundation designs and sizes at each WTG and OSP location would be made following pre-construction surveys within the windfarm site. A soft start and ramp up protocol for pile driving (if piled foundations are selected) may also allow mobile species to move away from the area before the maximum hammer energy with the greatest noise impact area is reached. Any further mitigation beneficial to marine mammals (as outlined in **Chapter 11 Marine Mammals**) could also potentially reduce impacts on fish and shellfish ecology.
Construction	During construction, overnight working practices would be employed offshore, so that construction activities could be 24 hours, thus reducing the overall period for potential impacts to fish communities in proximity to the windfarm site. Vessels would avoid deliberate approaching when basking sharks are sighted. Further, vessel management protocols for marine mammals are outlined in **Chapter 11 Marine Mammals**.
Decommissioning	An Offshore Decommissioning Programme would be developed post-consent and implemented at the time of decommissioning.

10.4 Impact assessment methodology

10.4.1 Policy, legislation and guidance

10.4.1.1 National Policy Statements

10.20 The assessment of potential impacts on fish and shellfish ecology has been made with specific reference to the relevant NPS. These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Project are:

- Overarching National Policy Statement for Energy (EN-1) (DESNZ, 2023a)
- NPS for Renewable Energy Infrastructure (EN-3) (DESNZ, 2023b)

10.21 The specific assessment requirements for fish and shellfish ecology, as detailed in the NPS, are summarised in **Table 10.4**, together with an indication of the section of the ES chapter where each is addressed.

Table 10.4 NPS assessment requirements for fish and shellfish ecology

NPS requirement	NPS reference	ES reference
NPS for Renewable Energy Infrastructure (EN-1)		
The applicant should show how the project has taken advantage of opportunities to conserve and enhance biodiversity and geological conservation interests.	Paragraph 5.4.19	An Environmental Benefit and Net Gain Statement (Document Reference 4.4) has been submitted as part of the DCO Application.
The design process should embed opportunities for nature inclusive design. Energy infrastructure projects have the potential to deliver significant benefits and enhancements beyond Biodiversity Net Gain, which result in wider environmental gains (see Section 4.6 on Environmental and Biodiversity Net Gain). The scope of potential gains will be dependent on the type, scale, and location of each project.	Paragraph 5.4.21	
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.	Section 5.4.22	Fish and shellfish species which may be likely receptors of impacts are identified in **Section 10.5** and are assessed in **Section 10.6** and **Section 10.7**.
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	Paragraph 5.4.35	Embedded mitigation measures are set out in **Section 10.3.3**. Where applicable, other mitigation measures required to reduce the risk of significant adverse effects on fish and shellfish ecology are detailed in the corresponding subsections in **Section 10.6** and **Section 10.7**. An Environmental Benefit and Net Gain Statement has also been submitted as part of the DCO Application.

NPS requirement	NPS reference	ES reference
▪ 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.		
NPS for Renewable Energy Infrastructure (EN-3)		
Fish in the context of this NPS also includes elasmobranchs (sharks and rays) and shellfish (e.g., crabs).	Section 2.8.147	Elasmobranchs and shellfish are considered in this chapter, **see Section 10.5.7**and **10.1.1**.
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.	Section 2.8.148	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 **Section 10.6** and **Section 10.7**.
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	Section 2.8.149	Underwater noise and EMF are assessed in **Section 10.6.**

NPS requirement	NPS reference	ES reference
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)	Section 2.8.150	Fish and shellfish species which may be likely receptors of impacts are identified in **Section 10.5**.
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.	Section 2.8.151	Underwater noise and EMF are assessed in **Section 10.6**. Underwater noise modelling has included 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.
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.	Section 2.8.245	EMF in terms of electric and magnetic fields are considered within this assessment, see **Section 10.6.3.4**.
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.	Section 2.8.246	EMF in terms of electric and magnetic fields are considered within this assessment, see **Section 10.6.3.4**.
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.	Section 2.8.247	Given the proposed target burial depth of 1.5m, and the findings of the EMF assessment (**Section 10.6.3.4**), 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.

NPS requirement	NPS reference	ES reference
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.	Section 2.8.249	Embedded mitigations that may reduce noise impacts on fish receptors are set out in **Section 10.3.3**.

10.4.1.2 Additional relevant policy and guidance

10.22 UK legislation concerning marine habitats and species includes the following:

- The Conservation of Habitats and Species Regulations 2017 (as amended)[4]
- The Conservation of Offshore Marine Habitats and Species Regulations 2017
- The Marine and Coastal Access Act 2009 (MCAA)

10.23 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 Legislation** (Document Reference 5.1.3). Under the Habitats Regulations, marine European sites are designated under the European Habitats Directive[5] 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 namely 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 riverine, rather than marine, and the potential for effect on these SACs arises from effects on migratory fish features travelling to and from these fluvial sites.

10.24 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). MCZ Assessment is a necessary component of marine development wherein there may be adverse effects on the status of qualifying features that consequently jeopardise MCZ conservation objectives.

10.25 In line with the above, this Chapter is supplemented by a RIAA and a MCZ Assessment Report.

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

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

10.26 In addition, there are a number of pieces of 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
  - Our oceans support viable populations of representative, rare, vulnerable, and valued species
- The North West Inshore and Offshore Marine Plan (HM Government, 2021) has the following objectives that are relevant to this chapter:
  - Objective 11: "Biodiversity is protected, conserved and, where appropriate, recovered, and loss has been halted"
  - Objective 12: "Healthy marine and coastal habitats occur across their natural range and are able to support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems"
  - Objective 13: "Our oceans support viable populations of representative, rare, vulnerable, and valued species"

10.27 Several policies within the North West Marine Plans (HM Government, 2021) are of particular relevance to fish and shellfish ecology and have been considered within this assessment:

- NW-FISH 1: Proposals that support a sustainable fishing industry, including the industry's diversification, should be supported
- NW-FISH 2: Proposals that enhance access for fishing activities should be supported. Proposals that may have significant adverse impacts on access for fishing activities must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts so they are no longer significant. If it is not possible to mitigate significant adverse impacts, proposals should state the case for proceeding
- NW-FISH 3: Proposals that enhance essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes, should be supported. Proposals that may have significant adverse impacts on essential fish habitat, including spawning, nursery and feeding grounds,

and migratory routes, must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate – adverse impacts so they are no longer significant

10.28 In addition to the above, the following documents have been used to inform the assessment of potential impacts of the Project on fish and shellfish ecology. These include:

- Cefas, Marine Consents and Environment Unit, Department for Environment, Food and Rural Affairs (DEFRA) and Department of Trade and Industry (2004) OWFs – Guidance note for Environmental Impact Assessment In respect of the Food and Environmental Protection Act (FEPA) and CPA requirements, Version 2
- Blyth-Skyrme, R.E. (2010) Options and opportunities for marine fisheries mitigation associated with wind farms. Final report for Collaborative Offshore Wind Research into the Environment contract FISHMITIG09. COWRIE Limited, London
- Strategic Review of Offshore Windfarm Monitoring Data Associated with FEPA Licence Conditions (Cefas, 2010)
- Cefas (2011) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Contract report: ME5403, September 2011
- Renewable UK (2013) Cumulative Effect Assessment guidelines, guiding principles for cumulative impacts assessments in offshore windfarms (OWFs)
- Monitoring Guidance for Underwater Noise in European Seas, Part II Monitoring Guidance Specifications. JRC Scientific and Policy Report EUR 26555 EN. (Dekeling *et al*, 2014)
- Review of post-consent OWF monitoring data associated with licence conditions (MMO, 2014)
- Sound Exposure Guidelines for Fishes and Sea Turtles Monitoring (Popper *et al*., 2014)
- Energy transmission infrastructure and EU nature legislation (2018)
- Guidelines for Ecological Impact Assessment in the UK and Ireland (Chartered Institute of Ecology and Environmental Management , 2018)
- Guidance document on wind energy developments and EU nature legislation (2020)
- Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards (Natural England, 2022)

- Planning Inspectorate Scoping Opinion (Planning Inspectorate, 2022) which included scoping responses from statutory consultees

10.29 Further detail is provided in **Chapter 3 Policy and Legislation**.

10.4.2 Data and information sources

10.30 To provide site specific and up to date information on which to base the impact assessment, the data sources listed in **Table 10.5** were used. Given that fish are highly mobile, both temporally and spatially, a site-specific survey only provides coverage of the species present in a particular area at a particular time. This has the potential to skew the baseline. Other datasets, as outlined in **Table 10.5**, with large-scale coverage, are relevant for characterising the natural fish and shellfish resource.

10.31 Fisheries landings datasets, in combination with other datasets, provide sufficient information, detail, and coverage to characterise and describe the fish and shellfish resource within the fish and shellfish ecology study area.

10.32 Considering the datasets available, it was discussed through the EPP that sufficient publicly available information is available to undertake a robust assessment (with any limitations clearly stated and considered where relevant – see **Table 10.1** and **Section 10.1**) and, as a result, site specific baseline fish sampling surveys were not considered necessary.

10.33 Given the interconnected nature of the Project and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, the environmental information for the Transmission Assets PEIR has also been used to inform this chapter (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023a).

Table 10.5 Existing data sources used in this chapter

Data source	Date	Data contents
AFBI NINEL Irish Sea Herring larvae Survey	2012-2021	Annual Irish Sea survey of herring larvae distribution.
Irish Sea Annual Egg Production Method (AEPM) Plankton Survey	2000	Irish Sea.
Cefas (2019) Young Fish Survey	1981 – 2010	North Sea, North East Atlantic, Irish and Celtic Sea and Channel.
Distribution of Spawning and Nursery Grounds as defined in Coull *et al.* (1998) and in Ellis *et al.* (2012)*	1998 & 2010	North Sea, North East Atlantic, Irish and Celtic Sea and Channel.

Data source	Date	Data contents
Updating Fisheries Sensitivity Maps in British Waters	2014	Modelled probability of presence of various species of juvenile fish.
Manx Marine Environmental Assessment	2012	Baseline environmental information in Manx territorial waters.
North West Groundfish Survey (Cefas, 2013)	2013	Data coverage of the Irish Sea.
Northern Ireland Ground Fish Survey (ICES)	2005 – 2018	Data coverage across the northern Irish Sea region.
International Trawl Survey (IBTS) Working Group	1965 – 2021	Irish Sea.
ICES Working Group for the Celtic Seas Ecoregion (WGCSE) report 2022	2022	Commercial species stock assessments for the Celtic Seas Ecoregion, including the east Irish Sea.
MMO Landings Data (weight and value) by species	2009 – 2021	Irish Sea – Landings from ICES rectangles 36E6, 37E6 and 37E7.
Bangor University's Fisheries and Conservation Science Group	2007 – 2021	Bangor University provide fisheries support to the Isle of Man.
Basking Shark Watch database (Shark Trust)	1987 – 2022	Data/information on relative abundance, distribution, and behaviour of basking sharks in UK water.
Manx Basking Shark Watch	1987 – 2022	Data/information on relative abundance, distribution and behaviour of basking sharks in Manx territorial waters.
Available spatial data available from basking shark sightings by citizen science projects included in the National Biodiversity Network Atlas (NBN, 2022)	As available	Data coverage across the northern Irish Sea region.
Barrow Offshore Windfarm Environmental Statement and associated technical supporting documents	2002	There have been many fish and shellfish surveys and desk studies undertaken for existing/planned offshore windfarms which overlap with the fish and shellfish ecology study area. As appropriate the fish and shellfish information
Ormonde Offshore Windfarm Environmental Statement and associated technical supporting documents	2005	

Data source	Date	Data contents
West of Duddon Sands Offshore Windfarm Environmental Statement and associated technical supporting documents	2006	and data related to the other offshore windfarms has been used to inform the Project's EIA alongside other data sources. This also includes available post-consent monitoring.
Rhiannon Offshore Windfarm Preliminary Environmental Information Report	2012	
Walney Extension Offshore Windfarm Environmental Statement and associated technical supporting documents	2013	
AyM Offshore Windfarm Environmental Statement and associated technical supporting documents	2022	
Morgan and Morecambe Transmission Assets PEIR (Morgan and Morecambe Offshore Wind Farms: Transmission Assets, 2023)	2023	Baseline information.
Mona and Morgan OWF PEIR (Mona Offshore Wind Limited, 2023 and Morgan Offshore Wind Limited, 2023)	2023	
Irish Sea Atlantic salmon tracking studies. Green *et al*., (2022) Barry *et al*., (2020) Lilly *et al*., (2023)	2020,2022, 2023	Smolt tracking studies for Atlantic salmon smolts exiting river systems in northwest England and the northeast coast of Northern Ireland.
Population studies in support of the conservation of the European sea bass (C-Bass) (Cefas, 2020)	2013-2020	Movements of individually tagged European sea bass in UK waters.

* Data sources such as Ellis et al (2012) are over 10 years old and so may not reflect up to date species composition and abundance. They are therefore supplemented with more recent and relevant data where warranted.

10.34 Other data and information available to inform the EIA include:

- Predictive European Nature Information System (EUNIS) seabed habitats, European Marine Observation and Data Network (EMODnet) (2021)
- Database containing information on the predicted seabed habitats present across Europe, mapped in accordance with the EUNIS habitat

classification system, 2009 – 2013, 2013 – 2016, 2017 – 2019, and 2022 update (European Environment Agency, 2022)

- North West Marine Plan documents (HM Government, 2022)

10.4.3 Impact assessment methodology

10.35 **Chapter 6 EIA Methodology** provides a summary of the general impact assessment methodology applied to the Project. The following sections outline the methodology used to assess the potential impacts on fish and shellfish ecology.

10.36 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 environment being exposed to the Impact (i.e. water quality)
- **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 existing environment with negative implications for the affected receptor
- **Beneficial effect** – an alteration of the existing environment with positive implications for the affected receptor

10.37 The potentially relevant impacts of offshore wind projects on fish and shellfish are specified in the Natural England Best Practice Guidelines (Phase III) for offshore wind applications (Natural England, 2022). As outlined in the Scoping Report and agreed with PINS through its Scoping Opinion (see **Section 10.6**), the following aspects are taken forward for assessment:

- Spawning grounds (identified as a receptor)
- Nursery grounds (identified as a receptor)
- Migration routes (diadromous fish identified as a receptor)
- Conservation importance (designated sites identified as receptors)
- Importance in the food web (sandeel identified as a receptor)
- Commercial importance (shellfish identified as a receptor)

10.38 Assessment of the impacts on the above have been separately applied to the construction, operation and maintenance and decommissioning phases.

10.39 Cumulative impacts relevant to fish and shellfish ecology arising from other marine developments are discussed in **Section 10.7** and inter-relationships, transboundary and interactions with other receptor groups are described in **Section 10.9**, **Section 10.8** and **Section 10.10** respectively.

10.4.3.1 Definitions of sensitivity, value and magnitude

Sensitivity

10.40 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 10.6**, **Table 10.7** and **Table 10.8**.

10.41 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)
- 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)

10.42 Throughout the assessment, receptor sensitivities have been informed through review of the available peer-reviewed scientific literature, and assessments available on the Marine Life Information Network (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 10.6.**

10.43 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).

Table 10.6 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.
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.

Value

10.44 In some instances, the ecological value of the receptor may also be taken into account, using expert judgment, within the assessment of impacts. For example, a receptor with low sensitivity, but high conservation value, may be given a value/sensitivity of medium. In these instances, 'value' refers to the importance of the receptor in the area in terms of conservation status, role in the ecosystem, and geographic frame of reference. Note that for stocks of species which support significant fisheries, commercial value is also taken into consideration. Value definitions are provided in **Table 10.7.**

Table 10.7 Definitions of value for fish and shellfish receptor

Value	Definition
High	▪ Internationally or nationally important ▪ Internationally protected species that are listed as a qualifying interest feature of an internationally protected site (i.e., Annex II protected species designated feature of a designated site) and protected species (including European Protected Species (EPS)) that are not qualifying features of a designated site
Medium	▪ Regionally important or internationally rare ▪ Protected species that are not qualifying features of a designated site, but are listed as a Biodiversity Action Plan (BAP) priority species, either alone or under a grouped action plan, and are listed on the local action plan relating to the fish and shellfish study area
Low	▪ Locally important or nationally rare ▪ Protected species that are not qualifying features of a designated site and are occasionally recorded within the study area in low numbers, compared to other regions
Negligible	▪ Not considered to be particularly important or rare

Value	Definition
	▪ Species that are not qualifying features of a designated site and are never or infrequently recorded within the study area in very low numbers, compared to other regions

Magnitude

10.45 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 10.8**.

Table 10.8 Definition of impact 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* change, 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

Effect significance

10.46 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 EIA Methodology** for further details). A matrix is used (**Table 10.9**) as a framework to determine the significance of an effect. Definitions of each level of significance are provided in **Table 10.10**. Impacts and effects may be deemed as being either positive (beneficial) or negative (adverse).

10.47 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.

10.48 Potential effects are described, followed by a statement of whether the effect is significant in terms of the EIA regulations. Potential effects identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. 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.

10.49 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.

Table 10.9 Effect significance matrix

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

Table 10.10 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.

10.4.4 Cumulative effect assessment methodology

10.50 The CEA considers other plans, projects and activities that may impact cumulatively with the Project. As part of this process, the assessment considers which of the residual impacts assessed for the Project on its own have the potential to contribute to a cumulative effect. **Chapter 6 EIA Methodology** provides further details of the general framework and approach to the CEA.

10.51 As described in **Chapter 1 Introduction**, the transmission assets associated with the Project are undergoing a separate consent process as part of the

Morgan and Morecambe Offshore Wind Farms: Transmission Assets project. To enable impacts from the Project and the Transmission Assets to be considered together, a ‘combined’ assessment is made within the cumulative assessment to identify any key interactions and additive effects (**Section 10.7.3.1**).

10.4.5 Transboundary effects assessment methodology

10.52 **Chapter 6 EIA Methodology** provides details of the general framework and approach to the assessment of transboundary effects.

10.53 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.

10.54 Consideration of suspended sediment transportation dynamics in **Chapter 7 Marine Geology, Oceanography and Physical Processes, Chapter 8 Marine Sediment and Water Quality** and **Chapter 9 Benthic Ecology** (Document Reference 5.1.9) identifies a ZoI for suspended sediment produced by Project activities of less than 15km, and therefore transboundary effects resulting from suspension of sediment cannot occur for this Project.

10.55 There is a potential for underwater noise from piling during construction to travel into the territorial waters of the Isle of Man (noting the IoM is not an EEA state but a self-governing British Crown Dependency). The impact ranges for construction piling on fish receptors, as determined by a dedicated modelling study (**Appendix 11.1**), are discussed in **Section 10.6.2.4** and further considered in relation to transboundary effects in **Section 10.8**. Impacts to designated sites around the IoM are also considered in **Section 10.8**.

10.56 Beyond the effects of noise on receptors within Isle of Man waters, it is considered that a specific assessment of transboundary effects is unnecessary given the fact that receptors are assessed irrespective of national jurisdictions and relevant species across the study area are assessed.

10.4.6 Assumptions and limitations

10.57 There are numerous datasets on fish and shellfish within the study area, and from other existing offshore windfarms 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 environmental (seasonal), biological (spawning) and anthropogenic factors, the available data has limitations. These include historic site survey data from other wind farms that are over 15 years’ old, and/or where the surveys were temporally and spatially quite limited, whereby it is acknowledged that such datasets only represent a snapshot of the assemblage at the time of survey.

10.58 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 commercially important 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 larvae using the previous 10 years of AFBI NINEL herring larvae survey data (this is the equivalent of the ICES International Herring Larvae Survey, which is not carried out in the area of Irish Sea under consideration).

10.59 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 do 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.

10.60 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 not an exhaustive account of all species.

10.61 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 10.3.2**) and, as set out in **Section 10.4.2**. more recent and regional data sources, such as site-specific benthic survey data, the last 10 years of Irish Sea herring larvae survey data, Irish Sea Atlantic salmon tracking studies and shellfish stock assessments, have been used to supplement the baseline. See **Section 10.4.2** for the data sources used.

10.5 Existing environment

10.62 The characterisation of the existing environment is undertaken using data sources listed in **Table 10.5**, plus other relevant literature.

10.5.1 Overview

10.63 The north Irish Sea (ICES division VIIa) is composed of a deep channel, about 300km long, with shallower bays to the east. The waters to the east of the Isle of Man are generally less than 50m deep. Regional and local data sources have been used to describe the fish and shellfish ecology baseline, with a focus on the local study area defined by ICES rectangle 36E6. Regional data includes MMO landings, used to identify commercially important species; and the International Bottom Trawl Survey (IBTS), which provides information about demersal species present locally that are effectively sampled by beam trawls, including non-commercial species.

10.64 The local fish community includes commercially important species for local fleets such as plaice *Pleuronectes plattessa*, cod *Gadhus morhua* and common sole *Solea solea,* characteristic of inshore, coastal waters (<50m deep); as well as typical smaller demersal species, including whiting *Merlangius merlangus* and sandeels *Ammodytidae sp.*, which are an important prey species for many kinds of fish, birds, and marine mammals (Teal, 2011). Other fish species common to the North Irish Sea include mackerel *Scomber scombrus,* ling *Molva molva,* herring *Clupea Harengus,* and anglerfish *Lophius pisccatorius.*

10.65 There are records of several species of conservation importance in the study area (as described in the below sections). Potential spawning and nursery grounds of sandeel, common sole, plaice, cod, whiting, and mackerel overlap with the study area. The nearest herring spawning grounds are located approximately 40km northwest of the Project (Coull *et al*. 1998 and AFBI NINEL[6]).

10.66 The Irish Sea area also supports populations of elasmobranchs (sharks, skates and rays). Of particular note for conservation importance are basking sharks *Cetorhinus maximus*, which are protected under Appendix III of the Bern Convention and the Wildlife and Countryside Act (1981). Basking shark are also listed under the Convention on International Trade in Endangered Species (CITES). Thornback ray *Raja clavata,* which are of national significance, are also present in the Irish Sea. There are estimated to be

[6] The most recent 10 years (2012-2021) of the Irish Sea Herring larvae survey (NINEL) run by the Agri-food and Biosciences Institute (AFBI)

around 23 species of elasmobranchs commonly found in the Irish Sea (Niels, 2005).

10.67 The wider fish and shellfish ecology study area is commercially important for Norway lobster *Nephrops norvegicus* (hereafter referred to as *Nephrops*), queen scallops *Aequipecten opercularis,* king scallops *Pecten maximus*, common whelks *Buccinum undatum*, European lobster *Homarus gammarus* and brown crab *Cancer pagurus*. Lockwood (2005) shows two shellfish resources within the Irish Sea. These comprise a large scallop ground, across the whole Eastern Irish Sea, and a *Nephrops* resource, located to the north of Liverpool Bay, between the Isle of Man and the Cumbrian coast (this finding is supported by similar findings by the Northern Ireland Ground Fish Survey (NIGFS)).

10.5.2 Commercial species

10.68 Commercial fisheries data can provide a useful additional insight into the species found in the vicinity of the study area. **Table 10.11** highlights the annual average landings over 0.5 tonnes (2018-2022) by species, in terms of quantity (landed weight) and value, for ICES rectangle 36E6. Catches within this rectangle were dominated by shellfish, with queen scallops representing 37.9% of all landings, whelks 37.5% and king scallops 19.2%. The top two fish species by landed weight were thornback ray, representing 1.7% of all landings, and common sole, representing 1.2%.

Table 10.11 Mean annual fisheries landings data between 2018 – 2022 by species (over 0.5 tonne) in ICES rectangle 36E6 (National Statistics, 2023)

Species	Quantity (tonnes)	Percentage of total
Fish		
Thornback ray *Raja clavata*	23.4	1.7%
Common sole *Solea solea*	17.2	1.2%
Plaice *Pleuronectes platessa*	9.9	0.7%
Sea bass *Dicentrarchus labrax*	7.8	0.5%
Lesser spotted dogfish *Scyliorhinus canicula*	2.5	0.2%
Flounder *Platicthys flesus*	2.3	0.2%
Brill *Scophthalmus rhombus*	1.0	0.1%
Unidentified dogfish	0.6	<0.05%
Shellfish		
Queen scallops *Aequipecten opercularis*	533.7	37.9%

Species	Quantity (tonnes)	Percentage of total
Whelks *B. undatum*	528.4	37.5%
King Scallops *Pecten maximus*	270.0	19.2%
European lobster *Homarus Gammarus*	3.2	0.2%
Brown crab *Cancer pagurus*	3.0	0.2%
Norway lobster *Nephrops norvegicus*	1.9	0.1%
Brown shrimp *Crangon crangon*	0.93	0.1%

10.5.3 Spawning and nursery grounds

10.69 Spawning and nursery grounds, defined by Coull *et al*. (1998), Ellis *et al*. (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.*, 2014). 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. Modelling based on collated survey data in the Isle of Man territorial waters (Campanella and van der Kooij, 2021) provides evidence to support the distribution of the previously identified spawning and nursery grounds for a range of foraging species, with any slight changes in mapped species distribution likely being due to natural interannual variation. Broadly, these studies all describe the same patterns of spawning and nursery habitat within the fish and shellfish ecology study area, and thus the maps available from Coull *et al.* (1998) and Ellis *et al.* (2012) data can be considered reliable.

10.70 In addition, site specific data and recent herring larvae data have been used to further inform the baseline for sandeel and herring (see Section 10.5.4), showing low herring larvae counts in the study area.

10.71 The windfarm site overlaps, or is in close proximity to, a number of fish spawning and nursery grounds, including sandeel, common sole, plaice, cod, whiting and mackerel (see **Figures 10.2 a-c** and **10.3 a-d** and **Table 10.12**). **Table 10.12** highlights the hearing group of each species (as defined by

Popper *et al*. (2014)), with an overlapping spawning or nursery ground (as defined by Coull *et al*. (1998) and Ellis *et al*. (2012)). It is also noted that herring spawning grounds, whilst not overlapping the windfarm site, are found approximately 44km to the northwest of the windfarm site (Coull *et al*. 1998) and have been considered further, due to their particular sensitivity to noise impacts (Popper *et al*., 2014).

10.72 Spawning grounds for elasmobranch species, such as thornback ray, and spurdog, are not defined by Coull *et al*. (1998) or Ellis *et al*., (2012). However, it has been reported that adult thornback rays occur in shallow inshore waters during summer months, potentially for spawning and mating (Walker *et al*, 1997; HOW03, 2018), before returning to deeper offshore waters, leaving juveniles in the shallows. Thornback ray spawning grounds are poorly defined, but are thought to generally coincide with nursery areas (Ellis *et al*., 2012).

Table 10.12 Spawning and nursery areas

Species	Hearing group[1]	Areas overlapping the windfarm site[2]		Conservation designation
		Spawning	Nursery	
Sandeel spp.	Group 1: Fish with no swim bladder or other gas chamber	Y (high intensity)	Y (low intensity)	The lesser sandeel *Ammodytes tobianus* 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	Y (high intensity)	Y (high intensity)	International Union for Conservation of Nature (IUCN): data deficient
Plaice *Pleuronectes platessa*	Group 1: Fish with no swim bladder or other gas chamber	Y (high intensity)	Y (low intensity)	IUCN (least concern)
Mackerel *Scomber scombrus*	Group 1: Fish with no swim bladder or other gas chamber	Y (low intensity)	Y (low intensity)	Species of Principle Importance in England (SPII, IUCN (least concern)
Spurdog *Squalus acanthias*	Group 1: Fish with no swim bladder or other gas chamber	N	Y (high intensity)	SPII, OSPAR, IUCN (vulnerable)
Anglerfish *Lophius pisccatorius*	Group 1: Fish with no swim bladder or other gas chamber	N	Y (low intensity)	SPII

Species	Hearing group[1]	Areas overlapping the windfarm site[2]		Conservation designation
		Spawning	Nursery	
Tope shark *Galeorhinus galeus*	Group 1: Fish with no swim bladder or other gas chamber	N	Y (low intensity)	SPII, IUCN (vulnerable)
Thornback ray *Raja clavata*	Group 1: Fish with no swim bladder or other gas chamber	N	Y (low intensity)	OSPAR, IUCN (near threatened)
Spotted ray *Raja montagui*	Group 1: Fish with no swim bladder or other gas chamber	N	Y (low intensity)	SPII, IUCN (least concern)
Cod *Gadhus morhua*	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Y (high intensity)	Y (high intensity)	IUCN Status Global: VU (Vulnerable) Europe: LC (Least Concern)
Whiting *Merlangius merlangus*	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Y (low intensity)	Y (high intensity)	SPII, IUCN (least concern)
Ling *Molva molva*	Group 3: Fish in which hearing involves a swim bladder or other gas volume	Y (low intensity)	N	SPII
Herring *Clupea harengus*	Group 4: Fish that have special structures mechanically linking the swim bladder to the ear	N	Y (high intensity)	SPII, IUCN (least concern)

[1] As defined by Popper et al. (2014); [2]As defined by Coull et al., (1998) and Ellis et al., (2010)

10.73 **Table 10.13** shows the fish and shellfish species with spawning and nursery grounds that overlap with the windfarm site, and the intensity and annual timings of these activities.

Table 10.13 Species with spawning and/or nursery grounds in the windfarm site (Coull et al., 1998; Ellis et al., 2012)

Orange = spawning/nursery ground, ● = peak spawning, Hatched = unknown/lack of data *For these species there is no known spawning ground overlap,

Species	Spawning season in the windfarm site												Nursery grounds
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Study area
Plaice	●	●											
Common sole				●									
Cod		●	●										
Anglerfish													
Whiting													
Mackerel					●	●	●						
Ling													
Sandeel sp.													
Sprat					●	●							N/A
Herring*													
Thornback ray				●	●	●	●	●					
Spotted ray													
Spurdog	Gravid females present year round												
Tope	Gravid females present year round												

however, they are within proximity (<40km) to the windfarm site.

10.5.4 Sandeel and herring spawning habitat

10.74 Various desk-based benthic characterisation surveys for the Project have been utilised, as well as site-specific surveys, to provide particle size analysis (PSA) of the existing sediment in the windfarm site. This data has been used to assess the suitability of the seabed for demersal spawning species sandeel spp and Atlantic herring *Clupea harengus* . Both species are thought to be particularly sensitive to disturbance, due to highly specific sandy substrate requirements.

10.5.4.1 Sandeel

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

10.76 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 Irish Sea is the lesser sandeel *Ammodytes tobianus*. There are 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.*, 2013). 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).

10.77 Due to high substrate specificity and limited larval exchange between sandeel populations, sandeel are particularly vulnerable to overfishing and other pressures. Whilst no large-scale fisheries exist for sandeel in the Irish Sea, they are an important trophic link in the region's food chain, between zooplankton and sandeel predators, including piscivorous fish, seabirds and mammals. 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.

10.78 No sandeel were recorded in any of the 50 grab sample stations across the survey area (**Appendix 9.1**), although it should be noted that grab samples are not an optimal sampling method for sandeel.

10.79 Based on the Folk 1954 sediment classifications, the study area was predicted to comprise of a mixture of sand, and sandy mud (DigSBS250, British Geological Survey (BGS) 2015), shown in **Figure 10.4**. However, site-specific PSA surveys found that the predominant sediment type across the survey area (reflecting the Agreement for Lease Area (AfL)) is fine sand (see **Chapter**

7 Marine Geology, Oceanography and Physical Processes and **Appendix 9.1**). The distribution of Project benthic grab samples, their analysed suitability for sandeel habitat, and the broader BGS sediment map showing coarse modelled sandeel habitat suitability, is shown in **Figure 10.5**. This shows the broad lack of suitable sandeel habitat within the windfarm site (largely to due to sediment mud content that is higher than preferred by the species), with a small area of potential suitable habitat in the southwest portion of the windfarm site.

10.80 Average mud (particle size <0.63μm) content across all samples in the survey area is 18.5% (and therefore too high, on average, to support significant sandeel assemblages (Holland *et al*., 2005, Wright *et al*., 2000)), and mud content is less than 30% in 76% of samples and less than 10% in 30% of samples. Only nine of the 50 sample stations within the survey area had sediment with less than 4% mud content, again suggesting that the area is generally unsuitable for sandeel (Holland *et al*., 2005, Wright *et al*., 2000). Given that sandeel rarely occur in sediments where the mud content (particle size <0.63μm) is greater than 4%, this data suggests that the majority of the windfarm site is unlikely to represent significant suitable habitat for sandeel.

10.81 A review of larvae data collected in UK waters from the Continuous Plankton Recorder was compared to dedicated larval samples collected by ICES in 2004 and 2009. Findings suggest that the sandeel spp. abundance in the wider study area is relatively low, ranging from <0.1 to a maximum of <0.2 individuals per m^3 (Lynam *et al.,* 2013).

10.5.4.2 Herring

10.82 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 10-80m deep, in areas of gravel, or similar coarse habitats (e.g., coarse sand, shell and maerl), with well oxygenated waters (Ellis *et al.*, 2012; Bowers, 1980; de Groot, 1980; Rakine, 1986, Aneer, 1989; Stratoudakis *et al.*, 1998).

10.83 Based on the Folk 1954 sediment classifications, the study area was predicted to comprise of a mixture of sand, and sandy mud (DigSBS250, British Geological Survey (BGS) 2015), shown in **Figure 10.4**. However, the predominant sediment type across the survey area (reflecting the Agreement for Lease Area (AfL)) is fine sand. Site-specific PSA surveys found that average gravel content is 0.1% across 98% of samples in the survey area, with only one station comprising a higher gravel content (20.6%) (see **Chapter 7 Marine Geology, Oceanography and Physical Processes** and **Appendix 9.1**), meaning that the windfarm site is generally unsuitable for herring spawning (Stratoudakis *et al.* 1998). For context, sediment is considered unsuitable for herring spawning if it has >5% mud content and <10% gravel content (Reach *et al.*, 2013). As mentioned for sandeel, average mud (particle size <0.63µm) content across all samples in the survey area is 18.5% (and therefore too high, on average, to support herring spawning (Reach *et al.*, 2013), and mud content is less than 30% in 76% of samples and less than 10% in 30% of samples. Only nine of the 50 sample stations within the survey area had sediment with less than 4% mud content, again suggesting that the area is generally unsuitable for herring spawning (Reach *et al.* 2013).Herring do not spawn in areas without gravel, so this data suggests that the windfarm site is unlikely to represent significant suitable habitat for spawning herring.

10.84 Atlantic herring is widespread in UK and Irish waters and is an important stock commercially and as a forage species. Herring are benthic spawners, normally preferring gravel, stones and/or rock, on which to lay their eggs (O'Sullivan *et. al,*. 2013).

10.85 The main spawning grounds for Irish Sea herring stock are shown to be close to the east coast of the Isle of Man, 44km away from the Project (**Figure 10.6,** Marine Scotland 2022, Coull *et al.* 1998). There are also spawning grounds off the east coast of Northern Ireland at Mourne (Dickey-Collas *et al.*, 2001). This data, combined with recent PSA analysis (**Figures 10.5** and **10.7**), demonstrates that there is a low likelihood of suitable habitat for herring spawning existing within the windfarm site itself. Herring fecundity (ability to produce offspring) ranges from 10,000 – 60,000 eggs per spawning. Newly hatched herring larvae are dependent on reserves in the yolk sac and, as a result, stay on the seabed for a period between 3 and 20 days, until the yolk is absorbed. The yolk sac absorption rate is dependent on sea temperature (Russell, 1976). Once the yolk sac is absorbed, the larvae then become pelagic, drifting with ocean currents. The Northern Irish Herring Larvae Survey (NINEL) has been carried out annually in November, since 1993, with the latest ICES published results being from 2020 (ICES, 2022), demonstrating that the vast majority of larvae are found in the vicinity of the Douglas bank spawning ground, and to the north of the Isle of Man, diminishing significantly closer to the windfarm site (**Plate 10.1**).

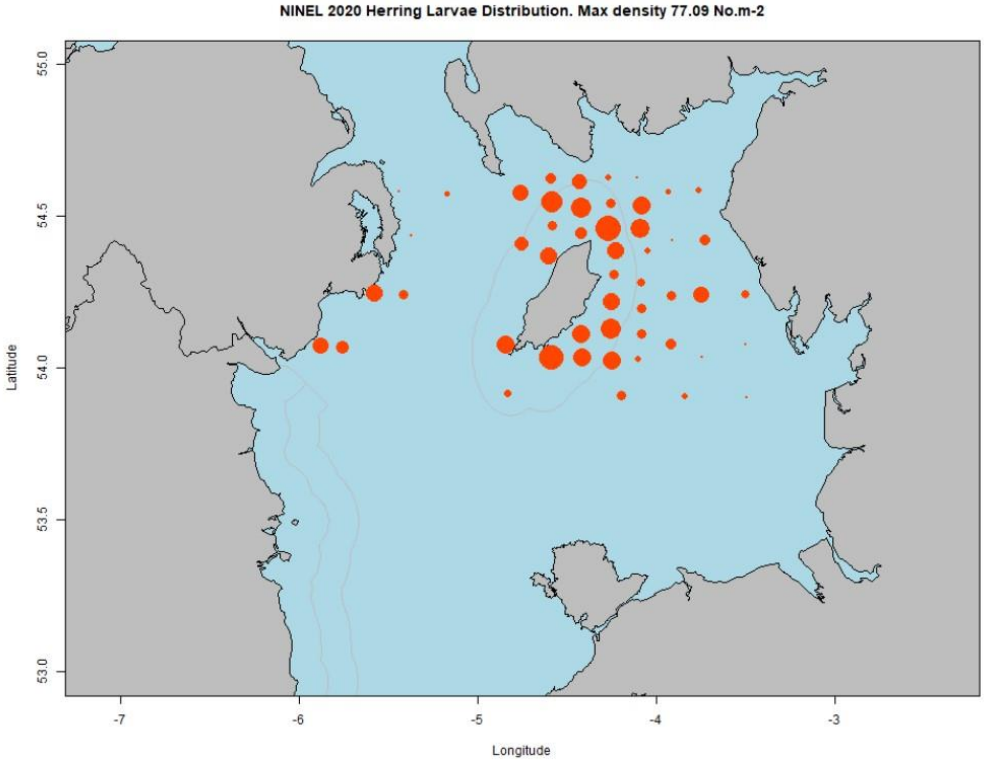

Plate 10.1 Distribution of herring larvae captured during 2020 north Irish Sea herring larvae survey (ICES, 2022)

10.86 The most recent 10-years of Northern Irish Herring Larvae Survey data has been provided by AFBI and these have been used to produce a heatmap of herring larvae distribution in the northern Irish Sea using kernel density interpolation in GIS, as agreed at the Marine Ecology ETG on 11th October 2023. This recent data shows that the likely present day extent of the IoM herring spawning ground maps onto the historical spawning ground extent defined by Coull *et al*., (1998) well (**Figure 10.6**). Given this appraisal of recent data, there is no reason to consider that the location and extent of the known herring spawning ground at the IoM, located 44km away from the Project, has meaningfully shifted in recent years.

10.5.5 Demersal fish

10.87 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 Atlantic cod (referred to as 'cod' hereafter), 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.

10.88 Based on landings data, the key (>1% of total landings from ICES rectangle 36E6) demersal species found in the vicinity of the study area are plaice, common sole, European bass, and flounder (National Statistics, 2023).

10.89 **Table 10.14** shows the demersal fish species likely to occur in the study area as part of the wider fish assemblage.

Table 10.14 Summary of demersal species likely to be present in the study area

Species	Northern Irish Priority List	OSPAR Annex V[1]	IUCN[2] Red List	SPII[3]
Anglerfish/sea monkfish *(Lophius piscatorius)*	✓		LC	
Atlantic cod *(Gadus morhua)*	✓	✓	VU	✓
Common sole *(Solea solea)*	✓			✓
European hake *(Merluccius merluccius)*	✓		LC	✓
European plaice *(Pleuronectes platessa)*			LC	✓
Haddock *(Melanogrammus aeglefinus)*			VU	
Lemon sole *(Microstomus kitt)*	✓		LC	
Ling *(Molva molva)*	✓			✓
Sandeel *(Ammodytes spp)*	✓			✓
European bass (*Dicentrarchus labrax*)			LC	
Whiting *(Merlangius merlangus)*	✓		LC	✓

VU = vulnerable, LC = least concern

[1] OSPAR – Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic – Threatened or declining species

[2] IUCN – International Union for the Conservation of Nature – Red-listed species

[3] SPII – Species of Principle Importance in England

10.90 The Cefas-run C-BASS tracking project, tracked the movements of adult European bass in UK waters using electronic tags[7] over the period 2013-2020 (Cefas, 2020). Results of recaptured tagged fish suggest that bass make extensive migrations through UK waters, including movements of some individuals from the Celtic Sea during winter, up to Morecambe Bay through the spring/summer, then moving back down the coast towards the Celtic Sea

[7] https://marinescience.blog.gov.uk/2016/01/18/c-bass-on-the-move/

once again into the autumn/winter months (Cefas, 2020). Individuals appeared to associate with coastal migratory routes, moving into the Irish sea in Q1, and leaving to the deeper waters of the Celtic Sea in Q4. They may pass through the ZoI of the Project in relation to longer distance noise effects as they move through the Irish Sea (Cefas, 2020; de Pontual *et al.,* 2023).

10.5.6 Pelagic fish

10.91 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. The pelagic fish species set out in **Table 10.15** are likely to occur in the study area (National Statistics, 2021; Coull *et al.*, 1998; Ellis *et al.*, 2012).

Table 10.15 Summary of pelagic fish with the potential to utilise the study area

Species	Northern Irish Priority List	NERC 2006[1]	IUCN Red List	SPII
Atlantic herring	✓	✓	LC	✓
Atlantic mackerel	✓	✓	LC	✓
European sprat		✓	LC	

LC = Least Concern

[1] NERC – Natural Environment Research Council

10.5.7 Elasmobranchs

10.92 There are over 71 different elasmobranch species (sharks, skates, and rays) that have been recorded in the Irish Sea, about half the number that live in European waters, with habitats supporting taxa ranging from sedentary to highly migratory (Clarke *et al*., 2016). The most common elasmobranch species found in the Irish Sea are rays, including thornback ray *Raja clavata*, blonde ray *Raja brachyuran*, cuckoo ray *Leucoraja naevus* and spotted ray *Raja montagui,* with common shark species including spurdog (*Squalus sp*.), dogfish (*Scyliorhinus sp.)* and tope *Galeorhinus galeus*. Since 2005, many species of skates and rays have exhibited long-term declines, however, there are signs of recovery and increased biomass in recent years that may be attributed to reduced fishing effort, and effort changes in the region (from whitefish to *Nephrops* fishing) (ICES 2019).

10.93 Thornback rays are abundant in the Irish Sea and have the potential to be present in the fish and shellfish ecology study area. These are listed as near threatened under the IUCN Red List of Threatened Species, owing to declines caused by fishing and exacerbated by their life history parameters (late maturation and low fecundity).

10.94 Basking shark *Cetorhinus maximus* may be present within the fish and shellfish ecology study area. Basking sharks, subject to a targeted fishing effort until 2007, are now protected under Appendix III of the Bern Convention, the Wildlife and Countryside Act (1981), and the Wildlife Act of the Isle of Man (1990). They are also listed under the CITES. They are known to be highly migratory, with tagged individuals moving between southern Morocco and the northwest of Scotland within a year, and most likely to be found in the Irish Sea during summer months (Doherty *et al.* 2017, Austin *et al.* 2019). It should be noted that a Project site-specific digital aerial survey campaign, undertaken over the period March 2021 to February 2023, identified no basking shark in the study area.

10.95 Data records provide data for basking shark sightings between 1987 to 2021 (with a hotspot occurring off the coast of the Isle of Man). Sightings were recorded year-round, but the majority occurred between the months of May to August (Ocean Biodiversity Information System 2021, Marine Conservation Society, NBN Atlas, 2022). Sightings peaked in 2006 (2,162 sightings), then dropped off significantly in 2014 (103 sightings) and have remained at a lower level since then.

10.5.8 Diadromous fish

10.96 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.

10.97 A number of migratory fish species, such as Atlantic salmon *Salmo salar*, sea trout *Salmo trutta,* smelt *Osmerus eperlanus* and European eel *Anguilla anguilla*, 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 10.16**).

10.98 Atlantic salmon smolts along the west coast of England have been shown to use a northward migratory route through the Irish Sea to reach feeding grounds (Barry *et al.* 2020, Green *et al.* 2022). Similarly, Atlantic salmon smolts from the east coast of Ireland migrate northwards out of the Irish Sea after leaving their natal rivers (COMPASS, 2022). In 2021, 1,008 wild and 60 ranched Atlantic salmon smolts were tagged with acoustic transmitters in 12 rivers in England, Scotland, Northern Ireland and Ireland. The tracking showed a strong preference for Irish Sea smolts to migrate in a north westerly direction out of the Irish Sea to the North East Atlantic after exiting their natal rivers (Lilly *et al*., 2023). Adult Atlantic salmon are observed to commence entry into the Leven, Kent, Lune, and Wyre rivers during early spring, whilst sea trout commence entry in June (through until the autumn), although the upstream migration of sea trout is not considered as extensive (Environment Agency, 2023).

10.99 Other diadromous species recorded from rivers and estuaries (Eden, Dee, Morecambe Bay, Conwy and Solway Firth) in the Eastern Irish Sea include allis shad *Alosa alosa*, twaite shad *Alosa fallax*, sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluivatilis* (Biological Records Centre, 2022). These species are unlikely to be encountered in the windfarm site, as (except in the case of sea lamprey) they remain in close association with estuarine environments during the marine phase of their life cycle (Barnes, 2008a; Barnes, 2008b; Barnes, 2008c; Maitland and Hatton-Ellis, 2003; Reeve, 2005). They are likely, however, to pass through the study area during migratory periods.

10.100 Little is known about the distribution of sea lamprey during the marine phase of their lifecycle, as reports are varied, suggesting a wide range and use of habitats (Maitland, 2004).

10.101 The current understanding is that European eels spawn in the Sargasso Sea, but there are potentially other, more distant, spawning grounds, 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 1-17m (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 15 – 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 Morecambe Bay in spring (English Nature, 2000).

10.102 The marine distribution and migration routes of the river lamprey, sea lamprey or European eel remains largely unknown, however, these species are known to utilise rivers on the western coast of England for spawning and foraging or, in the case of European eel, foraging only (Malcolm *et al.*, 2010). It is therefore likely that these species may be present within the wider study area during marine migration or residency. Brook lamprey, whilst present in some SACs considered in **Section 10.5.10**, remain resident in freshwater rivers for their entire lifecycle, so are not diadromous fish and there is no pathway for impact on this species. **Table 10.16** lists the diadromous species with the potential to interact with the study area during the marine migration period in their life cycles.

Table 10.16 Diadromous fish species of conservation interest that may be present in the study area

Species	Conservation status								
	SPII	OSPAR[8]	NASCO[9]	NERC 2006[10]	ICUN Red List[11]	Bern Convention	CITES	W&C 1981[12]	Habitats Directive
European eel	✓	✓	-	✓	Critically Endangered	-	✓	-	-
Allis shad	✓	✓	-	✓	Least Concern	✓	-	✓	✓
Twaite shad	✓	✓	-	✓	Least Concern	✓	-	✓	✓
Sea lamprey	✓	✓	-	✓	Least Concern	✓	-	-	✓
River lamprey	✓	✓	-	✓	Least Concern	✓	-	-	✓
Sea trout	✓	✓	-	✓	Least Concern	-	-	-	-
Atlantic salmon	✓	✓	✓	✓	Vulnerable	✓	-	-	✓
Smelt	✓	✓	-	✓	Least Concern	-	-	-	-

[8] OSPAR - Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic – Threatened or declining species
[9] NASCO - North Atlantic Salmon Conservation Organization, established by the UN Convention for the Conservation of Salmon in the North Atlantic Ocean
[10] NERC Act 2006
[11] IUCN - International Union for the Conservation of Nature – Red-listed species
[12] Wildlife and Countryside Act 1981

10.5.9 Shellfish (crustaceans and molluscs)

10.103 The wider fish and shellfish ecology study area is important for a number of commercially exploited shellfish, specifically benthic crustaceans and bivalve/gastropod molluscs; taxa that play a key role in the ecological food web, have commercial value, and conservation interest. For the purposes of this assessment, these have been grouped into:

- Crustaceans: arthropod taxon, including decapods and isopods. Typically, mobile species with segmented exoskeleton
- Molluscs: Large marine phylum, containing bivalves, gastropods and cephalopods

10.104 The commercial species found in the study area include queen scallops, whelks, king scallops, brown crab, European lobster, *Nephrops*, and brown shrimp.

10.105 Lockwood (2005) showed two broadscale shellfish resources within the Irish Sea. This includes a large scallop ground across the whole Eastern Irish Sea that overlaps with the windfarm site, and a *Nephrops* resource, located to the north of Liverpool Bay, between the Isle of Man and the Cumbrian coast. This finding is supported by commercial landings data (see **Section 10.5.2**), and the ICES Working Group for the Celtic Seas Ecoregion (WGCSE) Report in 2018, which highlights the main fishing grounds for *Nephrops* being concentrated to the north of the Project (**Plate 10.2**).

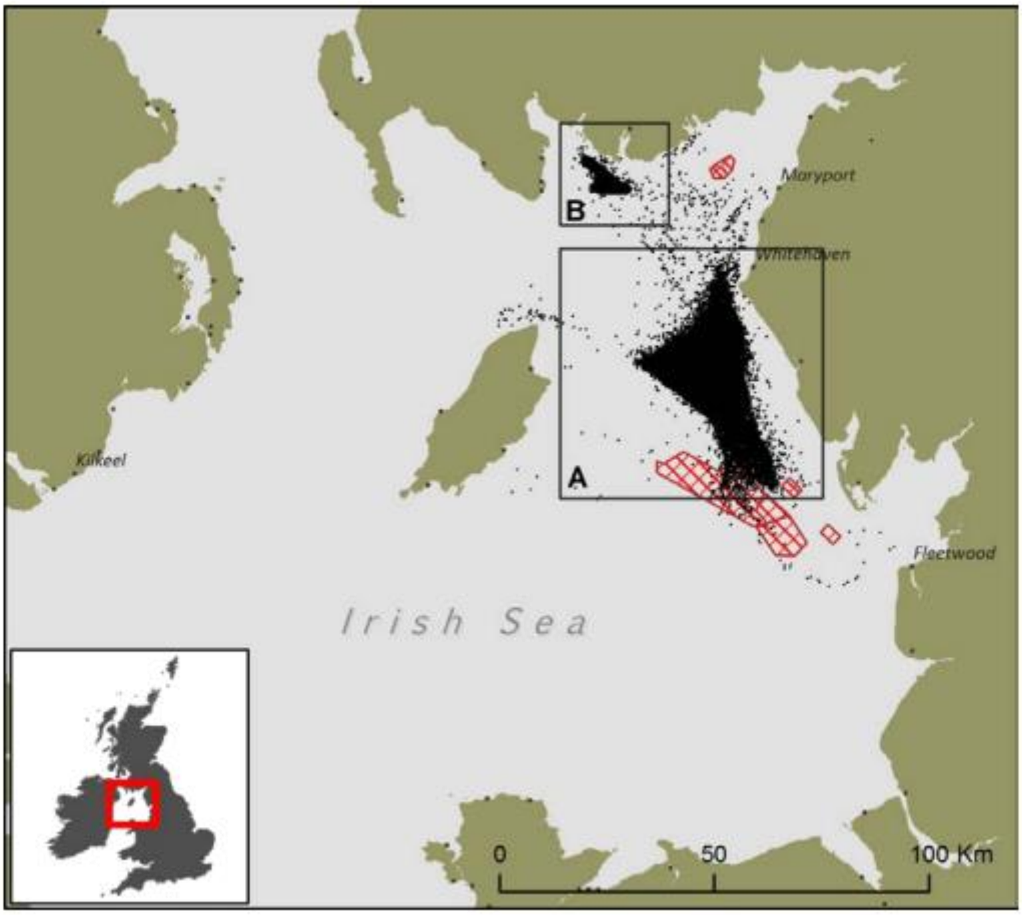

Plate 10.2 East Irish Sea Nephrops fishing grounds: A= Main fishing ground; B= Wigtown bay area. Existing windfarms represented by red polygons (Source: ICES, 2015)

10.106 Reported landings of shellfish within ICES rectangle 36E6 between 2018 and 2022 also includes brown shrimp, cuttlefish sp., velvet crab *Necora puber*, squid sp. and octopus sp. By weight, queen scallops and whelks constituted the highest landings, with lobster and crab species considerably lower (MMO, 2023). Queen scallops are highly abundant in the Study Area (**Table 10.11**) and form important fisheries in the wider study area in the territorial waters of the Isle of Man (Bloor *et al*., 2022) and Wales (Delargy *et al*., 2019).

10.107 Evidence suggests that adult brown crab undertake wide-ranging migrations over considerable distances to offshore overwintering grounds where eggs are hatched, moving back to coastal areas around May (Edwards, 1979; Bennett, 1995; Tonk and Rozemeijer, 2019). The findings of tagging studies suggest that mature females undertake long-distance migrations with preference for direction of travel, whilst the movements of males and immature females is in more random directions, and constrained within local areas (Edwards, 1979; Bennett, 1995).

10.108 Brown crab mating occurs in spring and summer with activity peaking between July and September, after females have moulted. Females are 'berried' (carrying eggs under the abdomen) for 6-9 months after copulation. They do not feed, remaining in pits dug in the sediment or under rocks over the winter period and are unlikely to be caught in a baited pot (Thompson *et al*., 1995; Fahy *et al.,* 2008). Data is lacking for the northwest English coast to suggest the extent and direction of local female brown crab migration, although it is likely that any female migrations will occur in a counter-current direction (Hunter *et al.*, 2013), which would result in a migration of Irish Sea crab in a more coast-parallel direction, rather than a coast-perpendicular direction directly offshore and towards the windfarm site (Hunter *et al.*, 2013).

10.109 Other non-commercial shellfish species to note include:

- Ocean quahog *Arctica islandica* – found on sublittoral firm sediments in sand and muddy sand, distributed all around British and Irish coasts and offshore (Tyler-Walters and Sabatini, 2017). Currently listed as OSPAR Annex V and a Feature of Conservation Importance (England and Wales)
- Freshwater pearl mussel (FWPM) *Margaritifera margaritifera* – widely distributed in Europe and found in fast flowing rivers and streams, the mussel spends its larval stage attached to the gills of salmonid fish as they migrate upstream (this is a key component of the FWPM life cycle). Therefore, impacts upon migratory salmon at sea, can indirectly impact FWPM populations. Currently listed as 'Vulnerable' by IUCN, the species is declining in both range and total population in the UK. It should be noted that there is no direct pathway for impacts of offshore activities on FWPM, only indirectly via impacts on salmonids. Therefore, significant effects on FWPM may only be found if significant effects on Atlantic salmon or sea trout are found.

10.5.10 Designated sites

10.110 The below review has been undertaken to identify designated sites in proximity to the fish and shellfish ecology study area, which are either designated for fish and shellfish interest, or habitats/species which are dependent on, or associated with, fish or shellfish. It should be noted that European Sites and MCZs are also subject to assessment, as part of the HRA and MCZA processes for the Project.

10.111 The Project does not directly overlap with any designated sites. Within 50km (encompassing any potential noise or suspended sediment impacts) are the following relevant sites for fish and shellfish:

- Morecambe Bay SAC, designated for sandbanks, which may represent spawning habitats for sandeel

- Shell Flat and Lune Deep SAC, designated for sandbanks, which may represent spawning habitats for sandeel
- Fylde MCZ, designated for subtidal sand and subtidal mud, which represents productive areas for crustacean, mollusc and flatfish species
- Wyre Lune MCZ, designated for smelt
- Ribble Estuary MCZ, designated for smelt
- West of Walney MCZ, which is designated for subtidal sand and subtidal mud, which represent highly productive areas for crustacean, mollusc and flatfish species
- West of Copeland MCZ, which supports an array of species, including crabs, sea mats and bivalve molluscs (such as venus clams *Chamelea gallina* and razor clams *Ensis ensis*)
- North Anglesey Marine SAC, the primary reason for this site's designation is harbour porpoise *Phocoena phocoena*, of which herring and sandeel are key prey species
- Y Fenai a Bae Conwy/Menai Strait and Conwy Bay is designated for sandbanks, which may represent spawning habitats for sandeel
- Liverpool Bay SPA abuts the eastern boundary of the windfarm site. This site is principally designed for the protection of marine/coastal ornithological features (further information on which is provided in **Chapter 12 Offshore Ornithology**) but habitats also support fish and shellfish species which are prey species

10.112 As noted in **Section 10.5.8**, there is potential for Annex II species to pass through the fish and shellfish ecology study area from various rivers associated with SACs. Within the wider study area are the following:

- Dee Estuary/Aber Dyfrdwy SAC - Sea lamprey and river lamprey present as qualifying features
- River Ehen SAC - FWPM as a primary reason for selection of the site and Atlantic salmon as a qualifying feature
- River Dee and Bala Lake/Afon Dyfrdwy a Llyn Tegid SAC – Atlantic salmon as a primary reason for selection of the site and sea lamprey, river lamprey and brook lamprey present as qualifying features
- Afon Gwyrfai a Llyn Cwellyn SAC – Atlantic salmon as a primary reason for selection of the site
- Afon Eden – Cors Goch Trawsfynydd SAC – FWPM as a primary reason for selection of the site and Atlantic salmon as a qualifying feature
- River Eden SAC – Atlantic salmon, sea lamprey, brook lamprey and river lamprey as primary reasons for selection of the site

- River Derwent and Bassenthwaite Lake SAC (Atlantic Salmon, Sea lamprey, River lamprey)
- Solway Firth Solway Firth SAC (Sea lamprey, River lamprey).

10.113 Further detail on relevant SACs (and SPAs), and assessments of potential effects on site integrity, is provided within the accompanying RIAA. Similarly, effects on MCZs are assessed fully in the accompanying MCZA Report.

10.5.11 Climate change and future trends

10.114 The existing baseline conditions within the fish and shellfish study area described above are considered to be relatively stable. The fish and shellfish baseline environment of the Irish Sea is primarily influenced by global environmental factors and by commercial fishing activity.

10.115 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.

10.5.12 Species taken forward to assessment

10.116 Key species identified, and the rationale for their inclusion within the fish and shellfish ecology assessment, are provided in **Table 10.17** of **Section 10.6.** Note that, for some impacts, species are not considered on an individual basis, but by functional group (e.g., fin fish, shellfish, elasmobranchs or migratory fish), unless there is a specific sensitivity for a specific species (e.g., herring and underwater noise) for assessment.

10.6 Assessment of effects

10.6.1 Impact receptors

10.117 The principal receptors with respect to fish and shellfish ecology are spawning and nursery grounds, diadromous fish, pelagic fish, demersal fish, elasmobranchs, shellfish (crustaceans and molluscs), and designated sites.

10.118 The specific features defined within these receptors as requiring further assessment are listed in **Table 10.17**.

Table 10.17 Fish and shellfish receptors relevant to the Project

Receptor group	Receptor	Relevant designated features	Closest distance from Project windfarm site
Spawning grounds	▪ Sandeel ▪ Common sole ▪ Plaice ▪ Cod ▪ Whiting ▪ Mackerel ▪ Ling ▪ Atlantic herring	▪ Northern Irish Priority List ▪ NERC 2006 ▪ IUCN Red List ▪ SPII ▪ NERC 2006 ▪ Priority Marine Feature (PMF)	Overlapping with the Project windfarm site, or 44km away in the case of Atlantic herring
Nursery grounds	▪ Sandeel ▪ Common sole ▪ Plaice ▪ Cod ▪ Whiting ▪ Mackerel ▪ Herring ▪ Spurdog ▪ Anglerfish ▪ Tope ▪ Thornback ray ▪ Spotted ray ▪ Atlantic herring	▪ Northern Irish Priority List ▪ NERC 2006 ▪ IUCN Red List ▪ SPII ▪ NERC 2006 ▪ PMF	Overlapping with the Project windfarm site
Diadromous fish	▪ European eel ▪ Sea lamprey ▪ River lamprey ▪ Sea trout ▪ Atlantic salmon	▪ SPII ▪ OSPAR Annex V ▪ NERC 2006 ▪ IUCN Red List ▪ Bern Convention ▪ CITES ▪ Habitats Directive ▪ PMF	Potentially overlapping with the Project windfarm site
Pelagic fish	▪ Atlantic herring ▪ Atlantic mackerel ▪ European sprat	▪ Northern Irish Priority List ▪ NERC 2006 ▪ IUCN Red List ▪ SPII ▪ PMF	Overlapping with the Project windfarm site

Receptor group	Receptor	Relevant designated features	Closest distance from Project windfarm site
Demersal Fish	▪ Sandeel ▪ Common sole ▪ Plaice ▪ Cod ▪ Whiting ▪ Ling ▪ European bass	▪ OSPAR Annex V ▪ SPII ▪ IUCN Red List	Potentially overlapping with the Project windfarm site
Molluscs	▪ Queen scallops ▪ King scallops ▪ Whelks ▪ Ocean quahog ▪ FWPM (due to indirect impacts on host fish)	▪ OSPAR Annex V ▪ Feature of Conservation Importance ▪ IUCN Red List ▪ PMF	Overlapping with the Project windfarm site
Crustaceans	▪ Norway lobster ▪ Brown crab ▪ European Lobster ▪ Brown shrimp ▪ Velvet crab	NA	Overlapping with the Project windfarm site
Elasmobranchs	▪ Basking shark ▪ Thornback ray ▪ Spurdog ▪ Dogfish sp. ▪ Tope	▪ IUCN Red List ▪ SPII ▪ CITES ▪ PMF ▪ Bern Convention	Overlapping with the Project windfarm site
Designated sites (those with a * are considered as part of the overall assessment of fish and shellfish, as they are either not designated directly for fish or shellfish	Liverpool Bay SPA*	Designed for the protection of marine/coastal ornithological features, with supporting habitat features of subtidal sand and mud which support fish and shellfish	Adjacent
	Fylde MCZ	Subtidal sand and subtidal mud – areas for crustacean,	8km

Receptor group	Receptor	Relevant designated features	Closest distance from Project windfarm site
species, or are outwith the ZoI for noise or suspended sediment impacts)		mollusc and flatfish species	
	Shell Flat and Lune Deep SAC	Sandbanks (spawning habitat for sandeel)	10km
	West of Walney MCZ*	Subtidal sand and subtidal mud – areas for crustacean, mollusc and flatfish species. Sea-pen and burrowing megafauna communities,	13km
	West of Copeland MCZ*	Subtidal sand, subtidal coarse sediment and subtidal mixed sediment – area for crabs, sea mats and molluscs	27km
	Morecambe Bay SAC*	▪ Sandbanks (spawning habitat for sandeel)	30km
	Wyre Lune MCZ	▪ Smelt	31km
	Ribble Estuary MCZ	▪ Smelt	34km
	Dee Estuary/ Aber Dyfrdwy SAC*	▪ Sea lamprey ▪ River lamprey	42km
	Y Fenai a Bae Conwy SAC*	Sandbanks (spawning habitat for sandeel)	43km
	North Anglesey SAC*	Harbour porpoise (herring & sandeel key prey species)	45km
	River Dee and Bala Lake/ Afon Dyfrdwy a Llyn Tegid*	▪ Atlantic salmon ▪ Sea lamprey ▪ River lamprey ▪ Brook lamprey	65km

Receptor group	Receptor	Relevant designated features	Closest distance from Project windfarm site
	Afon Gwyrfai a Llyn Cwellyn SAC*	Atlantic salmon	82km
	Afon Eden – Cors Goch Trawsfynydd SAC*	Atlantic salmon	98km (over 200km via sea to non-designated river mouth)
	River Ehen SAC*	Atlantic salmon	75km to designated upper river (65km via sea to non-designated river mouth)
	River Derwent and Bassenthwaite Lake SAC*	▪ Atlantic salmon ▪ Sea lamprey ▪ River lamprey	74km (over 95km via sea to river mouth)
	River Eden SAC*	▪ Sea lamprey ▪ River lamprey ▪ Brook lamprey	85km (over 148km via sea to river mouth)

10.6.2 Potential effects during construction

10.6.2.1 Impact 1: Temporary habitat loss/physical disturbance

10.119 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.

10.120 As detailed in **Section 10.3.2**, a maximum area of approximately 2.8% of seabed habitat within the windfarm site would be temporarily disturbed or lost during the construction phase.

10.121 The disturbance at the windfarm site would be temporally and spatially limited during construction activity, with disturbance occurring during installation of foundations and inter-array and platform link cables within the windfarm site (see **Chapter 5 Project Description** for full details of Project infrastructure).

Spawning grounds

10.122 The windfarm site encompasses potential spawning grounds of sensitive demersal spawning species (sandeel), less sensitive pelagic spawners of high intensity (cod, plaice, common sole & lemon sole, whiting, sprat and *Nephrops*), and low intensity spawning grounds of mackerel (also a pelagic spawner and therefore less sensitive to localised disturbance) (Coull *et al.*, 1998; Ellis *et al.*, 2012). However, it should be noted that PSA analysis for sampling stations within the windfarm site indicate that the majority of sediment has a mud content that is too high to support sandeel populations, and a gravel content too low to support herring spawning (see **Section 10.5.4**).

10.123 With approximately 2.4km^2 of seabed disturbed in the windfarm site due to seabed preparation and foundation, inter-array cable and platform link cable installation, the disturbance is minimal, in comparison to the size of the spawning grounds, which cover large areas across the region beyond the study area (see **Figure 10.2a** to **10.3d**) and, therefore, spawning potential of the wider population would not be impacted.

10.124 The species with the most sensitive spawning grounds spawn are from August to September (herring) and November to February (sandeel) (see **Table 10.13**). Whilst some construction activities may occur during the spawning period, these activities are limited in their duration, thus potential effects are predicted to be minimal. As previously stated, based on site specific PSA analysis, the windfarm site is generally unsuitable for both herring and sandeel spawning (see **Section 10.5.4**). Based on heatmapping of herring larvae data (see **Figure 10.6**) there is no overlap of disturbance activities with historical mapped herring spawning grounds (Coull *et al.,* 1998), and the most recent 10 years of NINEL herring larvae data map closely onto the historical (Coull *et al.*, 1998) spawning ground (located 44km away from the windfarm site), suggesting there has been no meaningful shift in the extent of the spawning ground over recent years. Physical disturbance would be highly localised within the windfarm site and therefore would not overlap with herring spawning.

10.125 The value/sensitivity of sandeel and herring spawning grounds to habitat loss and disturbance has been assessed, as a group, to be **high**, due to the potential for this key life stage to be interrupted, and due to the particular sensitivity of demersal spawners to physical disturbance on the seabed. Spawning and nursery grounds are also considered sensitive by ICES (Egan, *et al*., 2020).

10.126 As discussed in **Section 10.5.4.1** the windfarm site is largely unsuitable habitat for sandeel. A small area of potentially suitable habitat exists in the southwest of the windfarm site (**Figure 10.5**), therefore effects of temporary habitat loss/physical disturbance 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.

10.127 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.

10.128 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.

10.129 Infrastructure installation would not occur simultaneously across the windfarm site 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 **Chapter 9 Benthic Ecology**).

10.130 As discussed in **Section 10.5.4.2,** the windfarm site does not provide suitable herring spawning habitat and there is no overlap with mapped herring spawning grounds.

10.131 There is wide availability of suitable spawning habitat for the less sensitive species, both in the windfarm site and in the wider context of the Irish Sea. Together with the limited spatial extent of disturbance, intermittent and temporary nature of the effect, the magnitude of temporary seabed disturbance and habitat loss, on spawning grounds during construction has been assessed as **negligible**.

10.132 With the magnitude considered as negligible; and the value/sensitivity spawning grounds high, an effect of **minor adverse** significance on spawning grounds would be expected from the direct seabed disturbance and temporary habitat loss associated with the Project construction activities. This is not significant in EIA terms.

Nursery grounds

10.133 The windfarm site overlaps with high intensity nursery grounds for common sole, cod, whiting, herring, spurdog and *Nephrops*. There is also overlap with low, or unknown intensity, nursery grounds for sandeel, plaice, mackerel, anglerfish, tope, thornback ray and spotted ray (see **Figures 10.2a** to **10.3d**). Whilst the nursery grounds of many species overlap with the windfarm site, the areas impacted by construction disturbance are small, relative to the size of the entire main nursery grounds, which extend around much of the north English, Irish, and Scottish coast.

10.134 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. 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 future local fish populations.

10.135 The value/sensitivity of herring, sandeel and other nursery grounds to the construction phase of the Project has been assessed as **high**, due to the potential for this key life stage to be interrupted by disturbance, and due to the sensitivity of some demersal species to physical disturbance on the seabed. Spawning and nursery grounds are considered sensitive by ICES (Egan, *et al*., 2020). However, considering the availability of similar suitable habitat, both in the windfarm site and in the wider context of the Irish Sea, together with the short term and reversible nature of the effect, the magnitude of temporary seabed disturbance and habitat loss on nursery grounds during construction activities for the Project has been assessed as **negligible**.

10.136 With the magnitude considered as negligible; and the sensitivity for herring, sandeel and other fish species as high, an effect of **minor adverse** significance on nursery grounds would be expected from the direct seabed disturbance and temporary habitat loss associated with the Project construction activities. This is not significant in EIA terms.

Pelagic fish, demersal fish, diadromous fish, elasmobranchs

10.137 Species in these receptor groups have high levels of mobility and are, therefore, capable of navigating away from any temporary physical disturbance/habitat loss caused by construction activities (EMU, 2004). The value/sensitivity of pelagic, demersal, diadromous fish and elasmobranch species to disturbance and habitat loss has been assessed to be **low**, due to species' conservation status and commercial value, as well as their mobility and distribution range.

10.138 The magnitude of the impact upon this group of receptors is assessed as **negligible**, given the limited spatial extent of effects (approximately 2.8% of the windfarm site).

10.139 An effect of **negligible adverse** significance on pelagic fish, demersal fish, diadromous fish and elasmobranchs would be expected from the direct seabed disturbance and temporary habitat loss associated with the Project construction activities. This is not significant in EIA terms.

Molluscs

10.140 As the mollusc (gastropods and bivalves) species assessed are generally sessile, or at least slow-moving, then loss of habitats may occur in locations that these species inhabit during foundation installation, cable installation and seabed preparations, or from activities that could cause disturbance or burial of these species present in the vicinity of the works. The value/sensitivity of molluscs has been assessed as **medium**.

10.141 **Chapter 9 Benthic Ecology** determines no significant effects from the loss of habitat on benthic ecology, as the habitats occurring within the windfarm site are widely distributed throughout the wider geographical region. Mollusc species associated with the impacted area are widespread throughout adjacent habitats and would not be affected at a population level. The magnitude of impact on mollusc species has been assessed as **low**.

10.142 An effect of **minor adverse** significance on molluscs would be expected from the direct seabed disturbance and temporary habitat loss associated with the Project construction activities. This is not significant in EIA terms.

10.143 FWPM can only be indirectly impacted via impacts on salmonids, and as shown in **Table 10.18**, the effects of temporary habitat loss on diadromous fish have been assessed as **negligible adverse** and are not significant in EIA terms.

Crustaceans

10.144 The key crustacean species potentially present within the windfarm site 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. However, those that are less mobile (small crabs and shrimp), could be directly impacted and are likely to be most vulnerable. The value/sensitivity of crustaceans to disturbance and habitat loss is considered **medium**.

10.145 Habitat loss from foundation and cable installation and seabed preparations would be limited (2.8% of the windfarm site, see **Section 10.3.2**), and the mobile nature of the crustaceans assessed means that, in general, they would be able to move away from the source of disturbance. Where individuals are directly impacted (e.g., through burial or direct mortality), the limited extent of the area of effect would be quickly recolonised by the surrounding crustacean populations. Given this, the magnitude of impact upon crustaceans has been assessed as **negligible**.

10.146 An effect of **minor adverse** significance on crustaceans would be expected from the direct seabed disturbance and temporary habitat loss associated with the Project construction activities. This is not significant in EIA terms.

Designated sites

10.147 The value/sensitivity of designated sites to the construction phase of the Project is considered **high**, given their protected status. However, given the separation achieved between the windfarm site and designated sites for fish and shellfish species (approximately 30km for sites where fish are designated), there would be no habitat loss or physical disturbance in these sites. There is therefore no direct pathway for effects on sites designated for fish. This means an effect of **no change** on designated sites would be expected from the direct seabed disturbance and temporary habitat loss associated with the Project construction activities.

Summary

Table 10.18 Summary of construction activities impact 1: Physical disturbance and temporary habitat loss

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	High	Negligible	Minor Adverse
Nursery Grounds	High	Negligible	Minor Adverse
Diadromous Fish	Low	Negligible	Negligible Adverse
Elasmobranchs	Low	Negligible	Negligible Adverse
Demersal Fish	Low	Negligible	Negligible Adverse
Pelagic Fish	Low	Negligible	Negligible Adverse
Molluscs	Medium	Low	Minor Adverse
Crustaceans	Medium	Negligible	Minor Adverse
Designated Sites	High	No change	

10.6.2.2 Impact 2: Increased SSCs and sediment deposition

10.148 During construction activities, there may be a temporary increase in SSCs and deposition. 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.

10.149 Sands and silts released during seabed preparation and foundation construction activities would be temporarily deposited on the seabed, but are 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. As discussed in **Chapter 7 Marine Geology, Oceanography and Physical Processes**, the windfarm site is predominantly composed of sand and fine sand. Based on the sediment sizes present, finer suspended sediment is expected to exist as a passive plume, extending to a maximum of one spring tidal ellipse (10km), with other sediments settling quickly in proximity to its release, within a few hundred metres and up to around a kilometre away from the construction activity.

Spawning grounds

10.150 Sediment re-deposition could result in changes to the particle size distribution of the seabed, giving rise to some loss of spawning grounds for substrate specific demersal spawning species, such as herring and sandeel. High levels of suspended sediments could also have the potential to deter spawning adults from entering traditional spawning areas.

10.151 The following fish and shellfish species' spawning grounds may be affected by increases in SSCs and deposition during construction activities, as they have mapped spawning grounds located within the windfarm site, or up to 10km away from the site: sandeel, common sole, lemon sole, plaice, whiting, cod, mackerel, ling and *Nephrops*. Herring spawning grounds are located 44km away from the Project and therefore no impact pathway has been identified.

10.152 Eggs and early larval stages do not have the same capacity to avoid increased SSCs as juvenile or adult fish, as they are either passively drifting in the water column, or present on/attached to benthic substrates. The value/sensitivity of sandeel spawning grounds has been assessed as **high,** due to this key life stage and that spawning is demersal. PSA results suggest habitat is not suitable for sandeel, however, so this value/sensitivity is conservatively applied.

10.153 As detailed in **Chapter 7 Marine Geology, Oceanography and Physical Processes,** increase in SSCs and sediment deposition would only occur for a limited duration at specific locations (e.g. piling location), at any given time. Increases in SSCs and minimal disposal would occur within the 10km tidal excursion. The highest SSCs would cover a much smaller area (around 1km from release). The identified spawning grounds are part of a much wider area in the Irish Sea. Therefore, the magnitude of the effect of increased SSCs and sediment re-deposition during construction has been assessed as **negligible**, and an effect of **minor adverse** significance on sandeel spp. spawning grounds has been concluded. This is not significant in EIA terms.

10.154 All other fish species with pelagic spawning have lower sensitivity to sediment loading for spawning, as these species do not have the same level of spatial dependency on a specific substrate. The value/sensitivity has thus been assessed as **medium** and the magnitude **negligible**. An effect of **minor adverse** significance would be expected on other fish spawning grounds, from increased SSCs and sediment re-deposition associated with the Project construction phase. This is not significant in EIA terms.

Nursery grounds

10.155 The following species' nursery grounds may be affected by increases in SSCs and deposition during construction activities, as they are located within the windfarm site, or up to 10km (one spring tidal ellipse) away from the windfarm site: common sole, cod, whiting, herring, spurdog, *Nephrops,* sandeel spp., plaice, mackerel, anglerfish, tope, thornback ray and spotted ray.

10.156 Juvenile stocks of fish are not thought to be sensitive to increased sediment loading, as they have high levels of adaptability and tolerance to transient stress and disturbance. Their high mobility allows them to avoid any localised increases in SSCs. The value/sensitivity of nursery grounds to the construction phase of the Project has been assessed as **medium**, considering their key importance in fish life cycles.

10.157 Whilst the nursery grounds of many species overlap with the windfarm site or are within the area of one tidal ellipse (where sediments may be distributed), the areas impacted by increases in SSCs and deposition during construction activities are very small, relative to the size of the entire main nursery grounds, which extend around much of the Irish, English and Scottish coasts. Furthermore, based on their extensive occurrence within the wider geographic context, any potential disturbance to these areas, due to construction activities, is not predicted to have a significant impact on future local fish populations. As this increase in SSCs would be temporary (intermittent over the construction period) and affect a very small proportion of the wider nursery ground, the magnitude of the impact has been assessed as **negligible**.

10.158 An effect of **minor adverse** significance would be expected on fish nursery grounds from increased SSCs and sediment re-deposition associated with the Project construction phase. This is not significant in EIA terms.

Diadromous fish

10.159 The value/sensitivity of diadromous fish species to the construction phase of the Project has been assessed as **low**. This considers their conservation status, yet tolerance to high levels of SSCs, given their association with estuarine environments in their life cycle. For example, eels and lamprey tolerate silty, turbid and poor light conditions (Behrmann-Godel and Eckmann, 2003; Hansen *et al*., 2016; Christoffersen *et al*., 2018). As these species are all highly mobile, and active in the water column above the seabed, then there is also no risk of smothering or burial.

10.160 Migrating individuals of these species could feasibly cross the windfarm site (and extended area impacted by increased SSCs), during migration to or from freshwater, during the construction phase. During this time, they would be exposed to an increased water column sediment loading for a limited period of time during construction, associated with each disturbance activity. However, the increased sediment loading would be short-term and localised in nature, occurring sequentially with the location of the installation activity and near the seabed. Impacts would be restricted to a passive plume and minimal disposal within the 10km tidal excursion. The highest SSCs would cover a much smaller area (around 1km from release). Therefore, 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. Therefore, the magnitude of these impacts has been assessed to be **negligible**.

10.161 An effect of **negligible adverse** significance on diadromous fish species would be expected from increased SSCs and sediment re-deposition associated with the Project construction phase. This is not significant in EIA terms.

Demersal fish, pelagic fish and elasmobranchs

10.162 The value/sensitivity of demersal fish, pelagic fish, and elasmobranchs to increases in SSCs is considered, as a group, to be **low**. This considers their value, yet the mobility of these species. As these are highly mobile species, then 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, then there is low risk of smothering or burial, even for demersal individuals.

10.163 As individuals of these species, if present in the windfarm site and surrounding areas, would be foraging, then there is a potential effect upon their feeding success from the increased water column sediment loading (Robertson *et al*., 2006). 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, such as the lesser spotted dogfish, thornback ray and spotted ray, as well as non-elasmobranch demersal fish, such as plaice and common sole.

10.164 These species are distributed across the Irish Sea (as well as the North Sea), where storm events, and the associated increases in turbidity, are a regular occurrence. Since the increased SSCs associated with construction are unlikely to exceed background levels, other than in very localised areas and for short time periods (**Chapter 7 Marine Geology, Oceanography and Physical Processes**), it can be expected that both adult and juvenile fish species are unlikely to be affected by a low-level increase in SSCs from construction activities.

10.165 Fine silt particles associated with increases in SSCs have the potential to adhere to the gills of larvae, which could cause suffocation (De Groot, 1980). However, the extent of the impact is minimal in consideration of the distribution of these species. In addition, larvae may be subject to reduced predation from larger visual planktivores in turbid environments (Bone and Moore, 2008).

10.166 Therefore, the overall magnitude of impact upon demersal fish, pelagic fish and elasmobranchs has been assessed as **negligible**.

10.167 An effect of **negligible adverse** significance would be expected from increased SSCs and sediment re-deposition on demersal fish, pelagic fish and elasmobranchs. This is not significant in EIA terms.

Molluscs

10.168 Some mollusc species (e.g., bivalves, gastropods) 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*., 2014). For example, the Marine Evidence based Sensitivity Assessment (MarESA), review of ocean quahog identifies that an increase in turbidity (suspended sediments) may not adversely affect the species, especially as it can avoid sudden changes by burrowing for several days.

10.169 The value/sensitivity of molluscs to the construction phase of the Project has been assessed as **medium** (given the conservation status of the ocean quahog) and their tolerance to turbidity and sediment remobilisation.

10.170 As the increased sediment loading would be short-term and localised in nature, whilst there is a risk of some effect upon nearby individuals, the risk to the wider population is very limited and, therefore, the magnitude of impact upon molluscs has been assessed as **negligible**.

10.171 There is also potential for indirect effects upon juvenile forms of the FWPM, via the Project’s effect on Atlantic salmon and sea trout. However, no significant effects on diadromous fish have been identified.

10.172 An effect of **minor adverse** significance from increased SSCs and sediment re-deposition has been identified. This is not significant in EIA terms.

Crustaceans

10.173 Crustacean species are less mobile and may not readily move away from areas of increased water column sediment loading, however some species, including *Nephrops*, are particularly tolerant to a degree of smothering (Johnson *et al*., 2013). According to the MarESA, shellfish species, such as brown crab, have a low sensitivity to increased SSCs. The value/sensitivity of crustaceans to SSCs increases and deposition has been assessed, as a group, to be **medium**.

10.174 As the increased sediment loading would be short-term and localised in nature, whilst there is a risk of some effect upon nearby individuals, the risk to the wider population is very limited and, therefore, the magnitude of impact upon crustaceans has been assessed as **negligible**. This means an effect of **negligible adverse** significance on crustacean species would be expected from increased SSCs and sediment re-deposition associated with the Project construction phase. This is not significant in EIA terms.

Designated sites

10.175 The value/sensitivity of designated sites (relevant for fish and shellfish species) to the construction phase of the Project has been assessed as **high**. There are two relevant designated sites (for habitats) within 10km (one spring tidal ellipse) of the Project that may be affected by increased SSCs and deposition: Fylde MCZ, designated for subtidal sand and subtidal mud (c.8km) and Shell Flat and Lune Deep SAC, designated for sandbanks (c.10km). Further, Liverpool Bay SPA (adjacent to the windfarm site) which although is not designated for fish and shellfish or habitats, contains mud and sand habitat that supports fish and shellfish populations which are prey to the designated ornithological features.

10.176 These sites are not designated specifically for fish or shellfish receptors (although their habitats support fish and shellfish), and the impact of increased SSCs on these designating features has been concluded to be not significant (see **Chapter 7 Marine Geology, Oceanography and Physical Processes** and **Chapter 8 Marine Sediment and Water Quality**). SSC increases above background levels would be limited at Fylde MCZ and Shell Flats and Lune Deep SAC given their separation of at least 8km. While Liverpool Bay SPA is adjacent to the eastern edge of the windfarm site, effects would be temporary and the maximum distance that suspended sediments could travel overlaps with only 16% of the SPA (and <1% of the SPA overlaps a 1km buffer from the windfarm site where suspended sediments would be higher). Therefore, the magnitude of increased SSCs and sediment re-deposition on designated sites has been assessed as **negligible**. It is noted that no sites specifically designated for fish and shellfish are within the ZoI of impacts.

10.177 An effect of **minor adverse** significance on designated sites would be expected from increased SSCs and sediment re-deposition associated with the Project construction phase. This is not significant in EIA terms.

Summary

Table 10.19 Summary of construction impact 2: Increased SSCs and sediments re-deposition

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	High/Medium	Negligible	Minor Adverse
Nursery Grounds	Medium	Negligible	Minor Adverse
Diadromous Fish	Low	Negligible	Negligible Adverse
Elasmobranchs	Low	Negligible	Negligible Adverse
Demersal Fish	Low	Negligible	Negligible Adverse
Pelagic Fish	Low	Negligible	Negligible Adverse
Crustaceans	Medium	Negligible	Minor Adverse
Molluscs	Medium	Negligible	Minor Adverse
Designated Sites	High	Negligible	Minor Adverse

10.6.2.3 Impact 3: Remobilisation of existing contaminated sediments if present

10.178 The context of contaminant concentrations within sediment is established through comparison with recognised guidelines and action levels, notably Cefas Action Levels (ALs) and US Environmental Protection Agency's Effects Range – Low (ERL). Cefas ALs are widely used for assessing contamination risk in UK marine development and are available for a range of contaminants. ERLs are quality guidelines used by OSPAR and are defined as the lower tenth percentile of the dataset of concentrations in sediments which were associated with biological effects. If concentrations within the sampled sediment generally do not exceed the lower threshold values (i.e., AL 1 and ERL), then contamination levels are not considered to be of significant concern and are low risk in terms of potential impacts on marine benthic, fish and shellfish communities.

10.179 A comparison of the sediment chemistry data at the windfarm site against guideline action levels has been undertaken within **Chapter 8 Marine Sediment and Water Quality**, Section 8.5.2.2 and is not repeated here. To summarise, however, the comparison demonstrated that no samples exceeded either Cefas AL 1 or ERLs, hence sediment contamination levels across the windfarm site are low and the risk of adverse effect on fish and shellfish arising from disturbance of the sediment is consequently low. As contaminant levels are not found to be present at levels where effects would arise, this impact is therefore scoped out of the assessment.

10.6.2.4 Impact 4: Underwater noise and vibration

10.180 By listening to the sounds around them, fish obtain substantial information about their environment and 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 noise 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.,* 2017).

10.181 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).

10.182 Papers on the effects of underwater noise on fish and shellfish species have highlighted the lack of clear evidence to support setting thresholds for impacts on fish and shellfish receptors (Hawkins and Popper, 2016; Popper *et al.*, 2014). These have highlighted some of the shortcomings of impact assessments, including the use of broad criteria for injury and behavioural effects, based on limited studies. 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.

10.183 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.*, 2014). 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)
- 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)

10.184 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).

Injury criteria

10.185 The injury criteria used in this noise assessment for impulsive piling are given in **Table 10.20**. Physiological effects relating to injury criteria are described below (Popper *et al.*, 2014; Popper and Hawkins, 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

- **Temporary Threshold Shift (TTS)**[13]: 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

10.186 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 10.20** (for impulsive piling),

10.187 **Table 10.21** (for continuous noise sources) and **Table 10.22** (for explosions e.g. UXO clearance).

[13] Permanent Threshold Shift (PTS) thresholds do not form part of Popper *et al*., (2014) guidelines.

Table 10.20 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 ▪ Lamprey ▪ Lemon sole ▪ Anglerfish	Sound exposure level (SEL), dB re 1 μPa^{2}s	>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 μPa^{2}s	210	203	>186
		Peak, dB re 1 μPa	>207	>207	-
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	-

Type of animal	Species included	Parameter	Mortality and potential mortal injury	Recoverable injury	TTS
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 10.21 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 ▪ Lamprey ▪ 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 ▪ Smelt	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (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	(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 10.22 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 ▪ Lamprey ▪ 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 ▪ Smelt	229 –234 dB peak	(Near) High (Intermediate) High (Far) Low	(Near) High (Intermediate) Moderate (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	229 –234 dB peak	(Near) High (Intermediate) High (Far) Low	(Near) High (Intermediate) High (Far) Low

Type of animal	Species included	Mortality and potential mortal injury	Recoverable injury	TTS
Eggs and larvae	▪ All species	> 13 mm/s peak velocity	(Near) High (Intermediate) Low (Far) Low	(Near) High (Intermediate) Low (Far) Low

Particle motion

10.188 The criteria defined in **Table 10.20**,

10.189 **Table** 10.21 and **Table 10.22** 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.

10.190 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 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*., 2016, Popper and Hawkins, 2019).

Underwater noise modelling

10.191 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 **Appendix 11.1**. A summary of this modelling is presented in this section.

Pile driving

10.192 Updated underwater noise modelling since PEIR publication was undertaken to estimate the noise levels likely to arise during piling for an increased hammer energy of 6,600kJ (which corresponds to 120% of the hammer energy rating stated for the IQIP IQ6 hammer[14]) and determine the potential impacts, using the INSPIRE v5.1 (Impulsive Noise Propagation and Impact Estimator) subsea noise propagation model (**Appendix 11.1**). 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 **Appendix 11.1** for further details).

10.193 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:

- Location (deepest water and closest to both the shore and herring spawning grounds)
- Piling hammer energies
- Soft-start, ramp-up profile and strike rate
- Duration of piling
- Receptor swim speeds

10.194 Underwater noise (both sound pressure and particle motion) generated during the installation of the WTG and OSP foundations (pile driving), and by work vessels involved in the installation of cables, WTGs 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).

10.195 Prior to piling, UXO clearance may be required. Various possible types and sizes of UXO were also modelled (see **Appendix 11.1** 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 considered as required in the cumulative assessment **Section 10.7**.

[14] https://iqip.com/introducing-the-iq-series-the-next-generation-of-hydrohammers/

Methodology

10.196 The updated modelling for WTG/OSP foundation impact piling was undertaken at three representative locations, covering the extents, and various water depths, around the Project windfarm site:

- Northwest – situated at the northernmost corner of the windfarm boundary, at 33.5m water depth, showing propagation into the wider Irish Sea
- East – situated in shallower waters of 25.2m depth, closest to the shore at Blackpool
- Southwest – situated in the deepest water of 37.2m depth (therefore producing the greatest impact ranges), inside the boundary, along the south western edge of the site

10.197 This modelling took into account a 6,600kJ maximum hammer energy and all modelled instantaneous effects (SPL_{peak} and SEL_{ss} thresholds) are relevant for this assessment for all locations. Given the water depths, the southwest location produced the worst-case impact ranges.

10.198 Further modelling has also been undertaken to consider possible installation methods and strike rates based on drivability studies at the windfarm site. An additional scenario was modelled to account for the fact that new hammer models on the market with a higher strike rate are becoming available, and it was important that these higher strike rates were modelled as a worst-case, as they would result in higher SEL_{cum} impact ranges. A scenario was modelled with high hammer strike rates for the southwest location, being the deepest location, which had consistently produced the worst-case impact ranges in all previous model runs. This meant the worst-case SEL_{cum} impact results for the southwest location can be appropriately and conservatively applied.

10.199 It should be noted, and taken into account, that the underwater noise modelling and assessment is based on 'worst-case' scenarios and precautionary approaches (see **Table 10.2**), which includes, but is not limited to:

- A fast strike rate monopile with a maximum hammer energy of up to 6,600kJ and maximum starting energy of 550kJ. Whilst a slower strike rate and longer total duration schedule for monopiling was also modelled, this produced lower SEL_{cum} impact ranges and so is not worst-case (**Appendix 11.1**).
- Pin-piles with a maximum hammer energy of up to 2,500kJ and maximum starting hammer energy of 250kJ

10.200 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.

10.201 The worst-case piling schedule used to model SEL_{cum} for monopiles and pin-piles is summarised in **Table 10.23**.

10.202 For instantaneous SPL_{peak} and SEL_{SS} impact ranges, these have been modelled at each modelling location (northwest, southwest, and east) based on a worst-case single strike of a monopile at a maximum hammer energy of 6,600kJ.

10.203 As a worst-case scenario, it is assumed that 120% maximum hammer energy would be required and applied for the remaining duration of the pile installation, as this is a stated capability of the IQIP IQ6 Hydrohammer. However, realistically, 120% of maximum hammer energy is only likely to be required for short periods at a few of the piling installation locations, if at all, and for shorter periods of time (as explained in **Paragraph 10.204**).

Table 10.23 Hammer energy, ramp-up and piling duration

Parameter	Starting hammer energy	Ramp-up					Maximum hammer energy
Monopile							
Monopile hammer energy	550kJ	550kJ	1,375kJ	2,750kJ	4,125kJ	5,225kJ	6,600kJ
Number of strikes	10	1067	1601	710	551	2012	3405
Strikes per minute	0.5	100	86	72	58	44	30
Duration (s)	1200	642	1116	588	570	2742	6810
Total duration	3 hours 48 minutes (9,356 total strikes)						
Pin-pile							
Pin-pile hammer energy	250kJ	250kJ	625kJ	1,250kJ	1,875kJ	2,375kJ	2,500kJ
Number of strikes	10	1067	1601	710	551	500	3405
Strikes per minute	0.5	100	86	72	58	44	30
Duration (minutes)	1200	642	1116	588	570	678	6810
Total duration	3 hours 13 minutes (7,844 total strikes) per pile (12 hours 54 minutes per foundation)						

10.204 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 **Chapter 8 Marine Sediment and Water Quality**), and therefore less energy would be required to drive the pile into the seabed
- The maximum predicted impact ranges are based on the location with the greatest potential noise propagation range, and this was assumed as the worst-case for each piling location
- 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 windfarms, 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 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 3 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)

Sequential piling

10.205 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 three monopiles installed sequentially at the southwest location. The southwest location at the Project resulted in the largest ranges, due to the deeper water surrounding that location. The worst-case impact ranges are provided in **Appendix 11.1**.

10.206 Due to the uncertainty of what a receptor would do between piling operations, it has been assumed that any additional piling would occur immediately after the previous installation, with no pause.

10.207 As a precautionary approach, and as with all other piling assessments, when modelling impact ranges, fish receptors are considered to be stationary for the duration of the sequential piling.

Noise source levels

10.208 Underwater noise modelling requires knowledge of the source level, which is the theoretical noise level at 1m from the noise source. The INSPIRE noise propagation model assumes that the noise acts as a single point source. The source level is estimated based on the pile diameter and the hammer energy imparted on the pile by the hammer. This is then adjusted, depending on the water depth at the modelling location, to allow for the length of pile in contact with the water, which can affect the amount of noise that is transmitted from the pile into its surroundings (further information is provided in **Appendix 11.1**).

10.209 The unweighted peak sound pressure level (SPL_{peak}) and single strike sound exposure level (SEL_{ss}) source levels estimated for this assessment are summarised in **Table 10.24**.

Table 10.24 Unweighted SPLpeak and SELss source levels used in underwater noise modelling for monopiles and pin-piles

Source level	Monopile (6,600kJ)	Pin pile (2,500kJ)
SPL_{peak} source levels (dB re 1 µPa @ 1m)	243.1	241.5
SEL_{ss} source levels (dB re 1 µPa^{2}s @ 1m)	224.3	222.4

Modelling results

10.210 **Table 10.25** 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 three monopiles and four sequential pin piles in 24 hours at the Project (worst-case southwest location reported for each scenario).

Table 10.25 Worst-case sequential piling within a 24-hour period underwater noise modelling results for both a three sequential monopiles and four sequential pin piles with maximum hammer energies scenario, for the worst-case modelling location only (using a stationary animal model). For the full set of modelling results, see ***Appendix 11.1****.*

Fish group	Species included	Impact criteria	Potential impact	Impact areas and ranges: Monopile (maximum hammer energy 6,600kJ) (SEL_{cum} relates to three sequential monopiles within 24 hours)				Pin pile (maximum hammer energy 2,500kJ) (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	0.05km^2	130m	130m	130m	0.03km^2	100m	100m	100m
		>219 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	11km^2	2km	1.9km	1.9km	5.9km^2	1.4km	1.4km	1.4km
		>216 dB unweighted SEL_{cum} [stationary]	Recoverable injury	25km^2	2.9km	2.8km	2.8km	14km^2	2.1km	2.1km	2.1km
		>186 dB unweighted SEL_{cum} [stationary]	TTS	2400km^2	33km	20km	27km	1900km^2	30km	19km	25km

Fish group	Species included	Impact criteria	Potential impact	Impact areas and ranges							
				Monopile (maximum hammer energy 6,600kJ) (SEL_{cum} relates to three sequential monopiles within 24 hours)				Pin pile (maximum hammer energy 2,500kJ) (SEL_{cum} relates to four sequential pin piles within 24 hours)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
Group 2 - Fish: swim bladder is not involved in hearing (particle motion detection)	▪ Atlantic salmon ▪ Sea trout ▪ Smelt	>207 dB unweighted SPL_{peak}	Mortality and potential mortal injury	0.32km^2	320m	320m	320m	0.19km^2	250m	250m	250m
		210 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	100km^2	6km	5.4km	5.6km	60km^2	4.6km	4.2km	4.4km
		203 dB unweighted SEL_{cum} [stationary]	Recoverable injury	360km^2	12km	9.4km	11km	240km^2	9.6km	8.0km	8.8km
		>186 dB unweighted SEL_{cum} [stationary]	TTS	2400km^2	33km	20km	27km	1900km^2	30km	19km	25km

Fish group	Species included	Impact criteria	Potential impact	Impact areas and ranges							
				Monopile (maximum hammer energy 6,600kJ) (SEL_{cum} relates to three sequential monopiles within 24 hours)				Pin pile (maximum hammer energy 2,500kJ) (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	0.32km²	320m	320m	320m	0.19km²	250m	250m	250m
		207 dB SEL_{cum} unweighted [stationary]	Mortality and potential mortal injury	180km²	8.2km	7.0km	7.6km	110km²	6.4km	5.7km	6.1km
		203 dB SEL_{cum} unweighted [stationary]	Recoverable injury	360km²	12km	9.4km	11km	240km²	9.6km	8.0km	8.8km
		>186 dB SEL_{cum} unweighted [stationary]	TTS	2400km²	33km	20km	27km	1900km²	30km	19km	25km

Fish group	Species included	Impact criteria	Potential impact	Impact areas and ranges							
				Monopile (maximum hammer energy 6,600kJ) (SEL_{cum} relates to three sequential monopiles within 24 hours)				Pin pile (maximum hammer energy 2,500kJ) (SEL_{cum} relates to four sequential pin piles within 24 hours)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
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 southwest site	Behavioural disturbance	4500km^2	48km	24km	37km	4000km^2	44km	23km	35km

* 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 10.6** should be referred to, to understand the relationship of the 135dB SEL_{SS} behavioural disturbance contours to the likely extent of the nearest herring spawning ground.

Other noise sources

10.211 Details of the source levels and propagation models used for continuous noise, operational WTG noise and UXO clearance can be found in **Appendix 11.1**. Here, the impact ranges for each noise type with respect to fish receptor thresholds, as defined by Popper *et al.* (2014), are reported in **Table 10.26**, **Table 10.27** and **Table 10.28**. 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.

Table 10.26 Summary of the impact ranges for fish from Popper et al. (2014) for shipping and continuous noise, covering the different construction noise sources

Popper *et al*. (2014) Unweighted SPL_{RMS}	**Cable laying**	**Suction dredging**	**Trenching**	**Rock placement**	**Vessels (large)**	**Vessels (medium)**
Recoverable injury 170 dB (48 hours)	<50m	<50m	<50m	<50m	<50m	<50m
TTS 158 dB (12 hours)	<50m	<50m	<50m	<50m	<50m	<50m

Table 10.27 Summary of the operational WTG noise impact ranges using the continuous noise criteria from Popper et al. (2014) for fish (swim bladder involved in hearing)

Popper *et al*. (2014) Unweighted SPL_{RMS}	**Operational WTG (12 MW)**	**Operational WTG (24 MW)**
Recoverable injury 170 dB (48 hours) Unweighted SPL_{RMS}	<50m	<50m
TTS 158 dB (12 hours) Unweighted SPL_{RMS}	<50m	<50m

Table 10.28 Summary of the impact ranges for UXO detonation using the unweighted SPL_{peak} explosion noise criteria from Popper et al. (2014) for all species of fish

Popper *et al.* (2014) Unweighted SPL_{peak}		**0.5kg**	**5.45kg + donor**	**72.6kg + donor**	**103.2kg + donor**	**176.0kg + donor**	**321.1kg + donor**	**353.6kg + donor**
Mortality & potential mortal injury	234 dB	<50m	110m	250 m	280m	340m	410m	430m
	229 dB	80m	180m	420m	470m	560m	690m	710m

Spawning grounds

10.212 Effects may arise from underwater noise via impacts to eggs and larvae, as well as disturbance to spawning adults.

10.213 Movement of eggs and larvae is determined by currents; they do not have the ability to flee the vicinity of piling activity. However, prolonged exposure could be reduced by any drift of eggs/larvae due to currents, which may reduce the risk of mortality.

10.214 Popper *et al*. (2014) describes the impact criteria for potential mortality/potential mortal injury in eggs and larvae as >210dB SEL_{cum} or >207dB SPL_{peak}. As recommended by the MMO (**Table 10.1**), 207dB SPL_{peak} has been modelled and used as an impact threshold for potential mortal injury or mortality for eggs and larvae. These criteria are based on work by Bolle *et al*. (2012), who reported no damage to larval fish at SEL_{cum} as high as 210dB re 1 μPa 2·s. On the basis of Bolle *et al*. (2012), the levels adopted in Popper *et al*. (2014) are likely to be conservative (see **Table 10.25**).

10.215 The distribution of eggs and larvae, for most species, range over large areas, with the exception of herring eggs, which are deposited in specific areas as described previously (**Sections 10.5.3** and **10.5.4**) (noting the 44km distance from herring spawning sites and unsuitable sedimentary habitat within the windfarm site).

10.216 Taking the above into account, the value/sensitivity of spawning grounds to construction noise has assessed to be **medium**.

10.217 As outlined in **Table 10.25**, the maximum ranges for mortality and potential injury are 320m (>207dB SPLpeak).

10.218 With reference to herring eggs and larvae, the nearest known spawning grounds are 44km from the windfarm site and, therefore, beyond the 2.9km range for mortality and injury.

10.219 Injury or mortality of eggs and larvae in close proximity to piling is possible. However, it should be noted that any mortality associated with piling would be minimal, in comparison to the naturally high mortality rates during these life stages. The potential area affected by mortality and potential injury due to 207 dB SPL_{peak} (320m), as detailed within **Table 10.25** is very small in the context of the wide distribution ranges of the relevant fish species, and the large spatial extent of spawning grounds for most species.

10.220 Impacts associated with TTS could result in reduced fitness of some species. For example, behavioural responses to underwater noise could result in decreased feeding activity, leading to the potential avoidance of spawning grounds. However, the potential area affected by TTS and behavioural impacts detailed within **Table 10.25** is very small in the context of the wide distribution ranges of the relevant fish species, including those relating to spawning/nursery grounds.

10.221 Considering the areas of impact, the magnitude of noise-induced mortality, injury and TTS during construction is considered to be **low**.

Behavioural disturbance of spawning herring

10.222 As recommended through the Project Scoping Opinion and EPP (see **Section 10.6**), a level of 135dB SEL_{SS} for pile driving has been considered as a conservative threshold for behavioural impacts in the special case of spawning herring and has been modelled at North West, South West and East locations of the windfarm site. The relationship of the 135dB contours to the herring spawning ground is shown in **Figure 10.6**. The location of the North West modelling location has changed since PEIR, due to movement of the western boundary of this windfarm site eastwards. This has resulted in slightly lower impact ranges from the new position.

10.223 Considering **Figure 10.6**, there is no potential overlap with the historical Isle of Man herring spawning grounds (autumn spawning season) as defined by Coull *et al.* (1998) (**Figures 10.6**). The boundaries defined by Coull *et al*., 1998 are not definitive, but the herring larvae heatmap based on the latest 10 years of NIHLS data supports the historical extent of the ground.

10.224 The 135dB SEL_{SS} threshold is based on a study by Hawkins *et al.* (2014). This experiment used underwater speakers, submerged 3-5m below the surface, to play a total of 10 low frequency pulses (with 2 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 pile driving strikes (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.

10.225 There is also uncertainty around how spawning herring would respond, compared to non-spawning herring, or non-spawning sprat (the species that the 135dB threshold is derived from). Evidence suggests that the strong biological drivers to engage in spawning once a spawning event commences, reduce the susceptibility of herring to be behaviourally disturbed by passing boats for the duration of spawning (Skaret *et al*., 2005).

10.226 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 herring spawning grounds, which are located at least 44km distance from piling within the windfarm site, 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.

10.227 The exact border of the herring spawning ground may vary intra- or interannually, but given the already conservative 135dB SEL_{SS} threshold used in this case, for a maximum hammer energy of 6,600kJ which is unlikely to be reached in most cases, there is little potential for causing behavioural impacts to the herring spawning grounds from the Project.

10.228 Considering the lack of impact overlap displayed in **Figure 10.6**, and the multiple precautions built into the assessment as explained above, the magnitude of impact on herring spawning behaviour is assessed to be **low**.

10.229 Considering the medium receptor sensitivity and low magnitude of impact, the significance of effect from underwater noise associated with the Project construction on spawning grounds has been assessed as **minor adverse** and not significant in EIA terms.

Nursery grounds

10.230 The sensitivity of nursery grounds to noise produced during the construction phase of the Project has been assessed to be **low** for "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 10.25**) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. They are therefore assessed to be of **low** sensitivity.

10.231 Sandeel are an exception to this because, due to their burrowing behaviour and substrate dependence, they may have limited capacity to flee the area compared to other fish species. They are therefore assessed, by exception for this group, to be of **medium** sensitivity.

10.232 Species within the "fish where swim bladder is involved in hearing" (Groups 3 and 4) category (see **Table 10.25**) are highly mobile and likely to depart the area from the onset of 'soft start' piling. These species are, however, susceptible to barotrauma and detect sound pressure as well as particle motion. Therefore, they are assessed to be of **medium** sensitivity.

10.233 Taking into account the spatial extent of the impact (see **Table 10.25**), only a minority of nursery grounds are within impact ranges. Given the temporary and intermittent nature of piling activity during the construction phase, the magnitude of impact has been assessed to be **low**.

10.234 Considering the low-medium receptor sensitivity and low magnitude of impact, the significance of effect from underwater noise associated with piling has been assessed to be **minor adverse** for nursery grounds. This is not significant in EIA terms.

Diadromous fish species

10.235 The swim bladder of salmon does not play a role in the hearing of the species. Studies by Hawkins and Johnstone (1978) found salmon show low sensitivity to noise. Their ability to respond to noise is regarded as poor, with a narrow frequency span and a limited ability to discriminate between different noises.

10.236 As a close relative of salmon (*Salmo salar*), sea trout (Salmo trutta) were used as a model to determine the possible implications to salmon during piling operations at Southampton Water in 2003. Nedwell *et al*. (2008) presents the results from the study conducted simultaneously to the piling operations. Nedwell *et al*. (2008) found no obvious signs of trauma in any examined fish and no increase in activity, or startle response, was observed at any range from the piling.

10.237 Laboratory work on brown trout has shown that repeated sine sweeps (up to 2kHz), and, more relevant to piling, intermittent 140Hz tones, do not affect swimming behaviour (Jesus *et al*., 2019). Further, high intensity (114dB above the hearing threshold) low frequency sound at 150Hz has no effect on downstream smolt migration (Knudsen *et al*., 2005). At high intensities, very low frequency infrasound of 10Hz does deter smolt movement (Jesus *et al*., 2019), but the vast majority of sound energy in a pile frequency spectrum is contained at frequencies above 20Hz (Gill *et al*., 2012). Overall, the evidence suggests that changes to salmonid swimming behaviour during migration may occur only in extreme proximity to the piles.

10.238 Studies on how underwater noise affects smelt are limited, but it is not considered to use its swim bladder for hearing (Popper *et al*., 2014). This species is largely restricted to coastal and estuarine habitats and is therefore beyond the 27km TTS range based on the 186 dB SEL_{cum} threshold. Further, evidence from a port noise study indicates that smelt are able to habituate to repeated noise impacts with no significant loss of ecological function (Jarv *et al*., 2015).

10.239 Salmon, sea trout and smelt are all considered as “fish where swim bladder is not involved in hearing” (Group 2) (for impact ranges see **Table 10.25**).

10.240 Lamprey lack specialist hearing structures and are considered to have low noise sensitivity (Scottish Government, 2011) (see “fish with no swim bladder” (Group 1) in **Table 10.25** for impact ranges).

10.241 The value/sensitivity of diadromous fish species to noise produced during the construction phase of the Project has been assessed as **medium**, given their low sensitivity to noise, yet high conservation value.

10.242 Given the localised nature of the impact ranges (see **Table 10.25**), it is unlikely that noise levels generated during construction of the Project would affect feeding and migration behaviours of Atlantic salmon, lamprey or smelt species. Combined with the highly limited temporal (intermittent piling activity, per foundation) and spatial extent of piling in the windfarm site, the magnitude of impact upon diadromous fish has been assessed as **negligible**.

10.243 Considering the medium receptor sensitivity and negligible magnitude of impact, an effect of **minor adverse** significance would be expected from underwater noise on diadromous fish. This is not significant in EIA terms.

Elasmobranchs, marine demersal fish species, marine pelagic fish species

10.244 The sensitivity of fish to noise produced during the construction phase of the Project is considered **low** for “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 10.25**) are mobile and would be expected to vacate the area in which the impact could occur with the onset of ‘soft start’ piling. Elasmobranchs, such as thornback ray, 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). This group are therefore considered receptors of **low** sensitivity.

10.245 Sandeel are an exception to this because, due to their burrowing behaviour and substrate dependence, they may have limited capacity to flee the area compared to other fish species. They are therefore considered, by exception for this group, to be of **medium** sensitivity.

10.246 Species within the “fish where swim bladder is involved in hearing” (Groups 3 and 4) category (see **Table 10.25**) are highly mobile and may depart the area from the onset of ‘soft start’ piling. These species are susceptible to barotrauma and detect sound pressure, as well as particle motion. 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). This hearing group contains European seabass which may migrate through the wider area between the Eastern Irish Sea and the Celtic Sea (see **Section 10.5.5**). The worst-case SEL_{cum} impact range, assuming a European seabass remains stationary for 24 hours is 33km for TTS. This is a temporary and reversible effect and is unlikely to be reached in the context of a migrating fish which would not remain stationary for 24 hours. Instant effects such as injury would only occur within 320m of a maximum energy pile, which would require the fish to approach, or remain within 320m of the pile during soft start, ramp up, or full energy piling.

10.247 Given the localised nature of the impact ranges (see **Table 10.25**), combined with the highly limited temporal and spatial extent of piling in the windfarm site, the magnitude of impact upon this group has been assessed as **low**.

10.248 Considering the low-medium receptor sensitivity and low magnitude of impact, an effect of **minor adverse** significance would be expected from underwater noise associated with the Project construction phase for elasmobranchs, marine demersal fish species and marine pelagic fish species. This is not significant in EIA terms.

Crustaceans and molluscs

10.249 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). The sensitivity of invertebrates to noise produced during the construction phase of the Project has been assessed, as a group, to be **low**.

10.250 Given the highly limited temporal and spatial extent of piling in the windfarm site, the magnitude of impact upon this group has been assessed as **negligible**.

10.251 Considering the low receptor sensitivity and negligible magnitude of impact, an effect of **negligible adverse** significance for crustaceans and molluscs would be expected from underwater noise associated with the Project's construction. This is not significant in EIA terms.

Designated sites (for fish and shellfish species)

10.252 The value/sensitivity of designated sites (for fish and shellfish species) to noise produced during the construction phase of the Project has been assessed to be **high** given conservation status.

10.253 There are no designated sites for fish and shellfish within mortality or injury impact ranges. The impact range for TTS is 33km. The only sites close to the range are Wyre Lune MCZ (31km from the windfarm site) and the Ribble Estuary MCZ (34km from the windfarm site). Both are designated for smelt. Behavioural responses at or over 31km are expected to be minimal and, while fish are mobile, smelt is generally an estuarine species, keeping close association with the coast. Further assessment of these two sites is provided in the MCZA, with sites at a greater distance being beyond the range of direct impact.

10.254 Given the separation achieved between the Project windfarm site and designated sites for fish and shellfish species, and a maximum TTS impact range of 31km from the piling source, the magnitude of impact upon designated sites has been assessed as **negligible**.

10.255 Considering the high receptor sensitivity and negligible magnitude of impact, an effect of **minor adverse** significance on designated sites would be expected from underwater noise associated with the Project construction activities. This is not significant in EIA terms.

Summary

10.256 A summary of underwater noise and vibration impacts on fish and shellfish receptors, grouped by general receptor group, with the most conservative value/sensitivity, magnitude and significance for each group stated, is displayed in **Table 10.29**.

Table 10.29 Summary of construction impact 4: Underwater noise and vibration impact assessment

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	Medium	Low	Minor Adverse
Nursery Grounds	Medium	Low	Minor Adverse
Diadromous Fish	Medium	Low	Minor Adverse
Elasmobranchs	Medium	Low	Minor Adverse
Marine Demersal Fish	Medium	Low	Minor Adverse
Marine Pelagic Fish	Medium	Low	Minor Adverse
Crustaceans and Molluscs	Low	Negligible	Negligible Adverse
Designated Sites	High	Negligible	Minor Adverse

10.6.2.5 Impact 5: Barrier effects

10.257 Barrier effects during the construction phase of the Project include acoustic barrier effects (noting the potential presence of Annex II migratory/diadromous species, as well as mobile crustaceans, and pelagic fish), and may arise as a result of underwater noise during construction.

10.258 Laboratory work on brown trout has shown that repeated sine sweeps (up to 2kHz), and, more relevant to piling, intermittent 140Hz tones, do not affect swimming behaviour (Jesus *et al*., 2019). Further, high intensity (114dB above the hearing threshold) low frequency sound, at 150Hz, has no effect on downstream smolt migration (Knudsen *et al*., 2005). At high intensities, very low frequency infrasound of 10Hz does deter smolt movement (Jesus *et al*., 2019), but the vast majority of sound energy in a pile frequency spectrum is contained at frequencies above 20Hz (Gill *et al*., 2012). Overall, the evidence suggests that changes to salmonid swimming behaviour during migration may occur only in extreme proximity to the piles.

10.259 The Cefas-run C-BASS tracking project, tracked the movements of adult European bass in UK waters using electronic tags (Cefas, 2020). Preliminary results of recaptured tagged fish suggest that bass make extensive migrations through UK waters, including movements of some individuals from the Celtic Sea during winter, up to Morecambe Bay in Q1, then moving back down the coast towards the Celtic Sea once again into deeper waters in Q4. Individuals appear to associate with coastal migratory routes, but may pass through the ZoI of the Project in relation to longer distance noise effects as they move through the Irish Sea (Cefas, 2020; de Pontual *et al.,* 2023). Laboratory studies show that European seabass schools may increase swim speed, swim depth, and school cohesion when subjected to loud impulsive sound playbacks of 156–167 dB re 1 μPa^{2}s SEL_{SS}, although effects were more pronounced at night, behaviour returns to normal within 1 hour, and animals habituate to repeat exposures (Neo *et al.* 2018). Habituation of seabass to impulsive noise has also been demonstrated by Radford *et al.,* (2016). So, no direct evidence exists of barrier effects to European seabass in the field, but the presence of migratory individuals in the study area is possible, and temporary behavioural effects due to impulsive noise, such as increased swim speed and swim depth may occur within tens of kilometres of maximum energy monopiling, although as discussed in **Section 10.6.2.4**, the impulsive characteristic of the sound would likely degrade over these ranges. The evidence suggests these effects are temporary and reduce after repeat exposures (e.g., multiple hammer strikes).

10.260 There is no evidence to suggest that sound alters the movements of migrating crustaceans.

10.261 For non-migratory pelagic fish, localised noise is not thought to act as a barrier to access to the wider feeding grounds.

10.262 Other disturbance (physical and SSCs increases), assessed in Impacts 1 and 2, have been shown to have negligible effects to diadromous and pelagic fish, and minor adverse effects to crustaceans and, given the transient and localised effects, are not considered to cause barrier effects.

10.263 The diadromous species identified in the study area are mobile species and can utilise alternative routes in the wider area. Crustaceans are less mobile and have less ability to move between habitat areas, however, whilst studies have noted some impacts on shellfish in relation to noise, it is not yet understood whether noise can result in adverse barrier effects.

10.264 Given the above, the value/sensitivity of all receptor groups to barrier effects has been assessed to be **low**, with the exception of **medium** sensitivity for diadromous fish, European seabass and crustaceans. The localised and short-term nature of any potential barrier effects mean the magnitude of this impact is considered **negligible** for these groups. The impact significance has therefore assessed to be **minor – negligible adverse**, which is not significant in EIA terms.

Summary

Table 10.30 Summary of construction impact 5: Barrier effects

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	Low	Negligible	Negligible Adverse
Nursery Grounds	Low	Negligible	Negligible Adverse
Diadromous Fish	Medium	Negligible	Minor Adverse
Elasmobranchs	Low	Negligible	Negligible Adverse
Marine Demersal Fish	Low	Negligible	Negligible Adverse
European seabass	Medium	Negligible	Minor Adverse
Marine Pelagic Fish	Low	Negligible	Negligible Adverse
Crustaceans	Medium	Negligible	Minor Adverse
Molluscs	Low	Negligible	Negligible Adverse
Designated Sites	Low	Negligible	Negligible Adverse

10.6.2.6 Impact 6: Changes in fishing activity

10.265 As discussed in **Chapter 13 Commercial Fisheries**, there is the potential for commercial fishing activity to be displaced from within the windfarm site, due to presence of work vessels, foundation installation activity, and laying of inter-array and platform link cabling. Construction activities may act as a barrier to deployment of mobile fishing gear and may have safety exclusion zones. This may, in turn, displace fishing to nearby grounds. Overall, this may result in reduced fishing pressure on commercially exploited species within the windfarm site or increase fishing pressure on fish and shellfish species outwith the windfarm site.

10.266 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).

10.267 Roach *et al*. (2018) found that temporary restrictions of fishing areas offers 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*. 2018).

10.268 The windfarm site is not heavily fished compared to surrounding areas, with potting as the predominant fishing type. As described in **Chapter 13 Commercial Fisheries**, 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.

10.269 Considering the above, the sensitivity of commercially targeted fish and shellfish stocks in respect of potential changes in fishing activity as a result of the Project construction phase, has been assessed to be **low**. Given the temporary, short-term, impact of construction, and considering the above, the magnitude of the effect has been assessed as **low**. The significance of effect has therefore been assessed as **minor adverse** (although there may be beneficial effects in the localised areas of reduced fishing) and not significant in EIA terms.

10.270 It is noted that displacement of fishing activity from the windfarm site may increase activity in surrounding areas, including at designated sites. However, no sites designated for fish are found within 30km of the windfarm site and, as such, no significant effects are identified.

Summary

Table 10.31 Summary of construction impact 6: Changes in fishing activity

Receptor group	Value/sensitivity	Magnitude	Significance
Commercially targeted fish and shellfish stocks	Low	Low	Minor adverse

10.6.2.7 Impact 7: Collision risk

10.271 Basking sharks have been reported in the study area, particularly on the west coast of Scotland and around the waters of the Isle of Man. Given they spend a high proportion of time at the surface feeding, and they have a lack of awareness of vessels, they have a **high** sensitivity to collision risk.

10.272 Interaction with the Project is expected to be low, given the distribution of basking sharks and assuming embedded mitigation for vessel operations (as stated in **Section 10.3.3**). As such the magnitude has been assessed as **negligible** and significance of effect as **minor adverse**, which is not significant in EIA terms.

10.273 Collision risk is assessed for the construction phase as a worst-case, given the higher number of vessels onsite at any one time during construction. However, the finding of this assessment also applies during the other phases of the Project, as the same level of effects (considering lower ship passage frequency, but longer duration in operation and maintenance) is anticipated.

10.6.3 Potential effects during operation and maintenance

10.6.3.1 Impact 1: Permanent habitat loss

10.274 As detailed in **Table 10.2**, the worst-case area of total habitat loss due to the windfarm infrastructure (including WTGs, OSP(s), scour protection and inter-array/platform link cable protection) is approximately 0.51km^2. As such, less than 0.6% of seabed habitat of the windfarm site would potentially be lost to the footprint of infrastructure.

10.275 At this stage, it is not known which structures would remain in-situ at the time of decommissioning, and a detailed decommissioning programme would be developed and agreed with the relevant authorities post-consent. Therefore, it is currently unknown if the full extent of the habitat loss would be long-term or permanent. For the purposes of this assessment, impacts are assumed to be permanent. 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 would also occur during the construction phase, in a staged manner, as foundations and cable protection are progressively installed.

Spawning grounds

10.276 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.

10.277 Habitat loss would not occur in identified suitable herring spawning habitat as the site-specific PSA results show that the windfarm site benthic substrate is not suitable spawning habitats for these species (**Section 10.5.4**). There is, therefore, no pathway for effect, and an effect of **no change** would be expected for herring spawning grounds from permanent habitat loss associated with the Project.

10.278 As discussed in **Section 10.5.4.1** the windfarm site is largely unsuitable habitat for sandeel. A small area of potentially suitable habitat exists in the southwest of the windfarm site (**Figure 10.5**), therefore 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.

10.279 Habitat loss may occur in suitable spawning habitat for other fish species within the windfarm site, with a value/sensitivity of **medium** assigned (pelagic spawning so less sensitive). The areas potentially affected are however small, in comparison to the wider spawning of grounds of the Irish Sea, giving a **negligible** magnitude.

10.280 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 permanent habitat loss associated with the Project. This is not significant in EIA terms.

Nursery grounds

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

10.282 Whilst the nursery grounds of many species potentially overlap with the windfarm site (see **Section 10.5.3**), 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** and an effect of **minor adverse** significance is expected from permanent habitat loss associated with the Project. This is not significant in EIA terms.

Molluscs

10.283 As the mollusc species assessed are generally sessile, then loss of habitats in which these species are inhabiting would occur. These species favour finer sediments and may be deterred from recolonisation within the hard substrates. The value/sensitivity of molluscs has therefore been assessed as **medium**.

10.284 Habitat loss would occur in less than 0.6% of the windfarm site, and an even smaller proportion of the wider habitats in the Irish Sea. This would result in a highly localised effect that would not be detectable within mollusc populations locally, or more regionally. The magnitude of impact on mollusc populations is therefore assessed as **negligible**.

10.285 An effect of **minor adverse** significance would be expected from permanent habitat loss associated with the Project. This is not significant in EIA terms.

Crustaceans

10.286 MarESA identifies that for some crustaceans, such as the brown crab, 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**.

10.287 Permanent habitat loss would occur in less than 0.6% of the windfarm site as a worst-case, which is an even smaller proportion of the wider habitats in the Irish 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**.

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

Designated sites

10.289 The value/sensitivity of designated sites (for fish and shellfish species) to the operation and maintenance phase of the Project has been assessed as **high**, given their conservation status.

10.290 The windfarm site does not overlap any designated sites and the separation achieved between the windfarm site and designated sites for fish and shellfish species (31km to the Wyre Lune MCZ, which is the closest site designated for fish and shellfish features), then no habitat loss in these sites or for their populations is anticipated and there is no pathway for change. An effect of **no change** would be expected from habitat loss associated with the Project. This is not significant in EIA terms.

Summary

Table 10.32 Summary of operation and maintenance impact 1: Permanent habitat loss

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	High/Medium	No Change/Negligible	No Change/ Negligible/Minor Adverse
Nursery Grounds	High	Negligible	Minor Adverse
Molluscs	Medium	Negligible	Minor Adverse
Crustaceans	Medium	Negligible	Minor Adverse
Designated Sites	High	No change	

10.6.3.2 Impact 2: Temporary habitat loss/physical disturbance, increased SSCs and sediment deposition

10.291 Maintenance activities may disturb the seabed and elevate suspended sediments. For example, when conducting repairs on the inter-array or platform link 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 operation and maintenance phase, including level of temporary habitat loss and increased SSCs, is outlined in **Table 10.2**. 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.

10.292 As discussed in **Chapter 7 Marine Geology, Oceanography and Physical Processes**, the maximum range of sediment plumes is 10km and, therefore, there is no effect pathway between the Project and herring spawning grounds, which lie 44km away. Furthermore, as demonstrated in the site-specific PSA results summarised in **Chapter 7 Marine Geology, Oceanography and Physical Processes**, the windfarm site itself does not contain suitable habitat for herring spawning and is largely unsuitable for sandeel, though these species do utilise spawning grounds in the wider area of the Irish Sea, spanning a large area. As per construction, there would be no expected pathway to sites designated for fish and shellfish, and with only localised effects in sites that are designated for supporting habitats (Fylde MCZ, Shell Flat and Lune Deep SAC and Liverpool Bay SPA).

10.293 The value/sensitivity of receptors is considered to be the same as in the construction phase (due to temporary habitat loss, disturbance and SSCs increase) as per **Sections 10.6.2.1** and **10.6.2.2**.

10.294 Due to reduced scope for increased SSCs during operation and maintenance 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 10.6.2.2** and **Table 10.19**). The magnitude of impact upon all receptors has therefore been assessed as **negligible**.

10.295 Considering the variation in receptor sensitivity, the resulting significance of effect has been assessed as **negligible adverse** to **minor adverse** for all species. The effects are summarised in **Table 10.33** and are not significant in EIA terms.

Summary

Table 10.33 Summary of operation and maintenance impact 2: Increased SSCs and sediments re-deposition

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	High/Medium	Negligible	Minor Adverse
Nursery Grounds	Medium	Negligible	Minor Adverse
Diadromous Fish	Low	Negligible	Negligible Adverse

Receptor group	Value/sensitivity	Magnitude	Significance
Elasmobranchs	Low	Negligible	Negligible Adverse
Demersal Fish	Low	Negligible	Negligible Adverse
Pelagic Fish	Low	Negligible	Negligible Adverse
Crustaceans	Medium	Negligible	Minor Adverse
Molluscs	Medium	Negligible	Minor Adverse
Designated Sites	High	Negligible	Minor Adverse

10.6.3.3 Impact 3: Underwater noise and vibration

10.296 The continuous noise associated with operation and maintenance, e.g. with WTG operation and work vessels, is of a much-reduced dB source level than that assessed for piling activities during the construction phase in **Section 10.6.2.4**. (**Appendix 11.1**).

10.297 Research into the operational noise of wind turbines is ongoing, however there are studies that report on measured operational noise of fixed foundation turbines that can be used to inform source levels (see: Nedwell *et al*. (2007) and Jansen (2016)). Fixed foundation turbine operational noise is known to fall below the threshold for negative impacts on fish (Nedwell *et al.*, 2007; Ward *et al.*, 2006; Jansen, 2016; Popper *et al.*, 2014).

10.298 Noise associated with operation and maintenance vessels has the potential to cause recoverable injury and TTS to the most sensitive (Groups 3 and 4) fish, to a maximum range from source of <50m, respectively (as outlined in **Appendix 11.1**). However, it should be noted that this impact assumes a stationary fish and a stationary vessel for a period of 48h and 24h for recoverable injury and TTS to occur respectively. Therefore, this impact is highly unlikely to occur in reality.

10.299 Overall, fish and shellfish sensitivity to operational noise has been assessed as **low** and has been conservatively assessed to have a **negligible** magnitude for all receptors, giving a **negligible adverse** significance (**Table 10.34**), except at designated sites where there is no change given impact distances and the separation of sites. This is not significant in EIA terms.

Summary

Table 10.34 Summary of operation and maintenance impact 3: Underwater noise and vibration impact assessment

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	Low	Negligible	Negligible Adverse
Nursery Grounds	Low	Negligible	Negligible Adverse

Receptor group	Value/sensitivity	Magnitude	Significance
Diadromous Fish	Low	Negligible	Negligible Adverse
Elasmobranchs	Low	Negligible	Negligible Adverse
Marine Demersal Fish	Low	Negligible	Negligible Adverse
Marine Pelagic Fish	Low	Negligible	Negligible Adverse
Cephalopods	Low	Negligible	Negligible Adverse
Crustaceans	Low	Negligible	Negligible Adverse
Molluscs	Low	Negligible	Negligible Adverse
Designated Sites	Low	No Change	

10.6.3.4 Impact 4: Interactions of EMF

10.300 The Project would transmit energy produced along the network of inter-array and platform link cables, linking the individual WTGs and the WTGs to the OSP(s). As energy is transmitted, the cables emit low-energy EMF. The electrical and magnetic fields generated increase proportionally to the amount of electricity transmitted.

10.301 The Project proposes to use inter-array cables that are 66kV to 132kV, and up to 220mm in diameter, with a fibre optic cable for monitoring and communication purposes. A platform link cable between substations (if more than one substation is required) would consist of a 275kV cable. A maximum of 70km of inter-array cables, and 10km of platform link cables 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. Cables would be buried to a depth range of 0.5-3m, and a target depth of 1.5m 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.

Diadromous fish, pelagic fish

10.302 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 windfarm site, 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. The value/sensitivity of these groups to EMF over the operation and maintenance phase of the Project has been assessed as **medium**.

10.303 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*. 2016) 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.

10.304 Most EMF exposures would be expected to be short, in the order of minutes, whilst these highly mobile species are moving through the windfarm site. The area around the cable where EMF is elevated is small (less than 10m, based on Taormina *et al*. (2020) analysis of export and interconnector cables), representing a very small fraction of the available habitat for these species, which may travel multiple kilometres per day, and are less likely to swim close to the seafloor (Snyder *et al*., 2019). The magnitude for this impact has therefore been assessed to be **negligible.**

10.305 Considering the medium receptor sensitivity and negligible magnitude of impact, an effect of **minor adverse** significance would be expected due to EMF from the Project. This is not significant in EIA terms.

Demersal fish

10.306 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. The value/sensitivity of demersal fish to EMF in the operation and maintenance phase of the Project has therefore been assessed to be **low**.

10.307 Given the long-term nature, but minimal spatial extent, a magnitude of **negligible** has been identified for this receptor group resulting in an effect of **negligible adverse** significance. This is not significant in EIA terms.

Elasmobranchs

10.308 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). The value/sensitivity of this receptor group has been assessed to be **medium**.

10.309 The area around which elasmobranchs can detect EMF is limited to a scale of metres around electrical cables buried to a target depth of 0.9-1.8m (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 windfarm site (60Hz), and therefore outside of the typical tuned range for elasmobranchs (Snyder *et al.*, 2019). 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 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 1.5m 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 northeast Atlantic are 50μT (Tasker *et al.*, 2010).

10.310 For highly mobile and pelagic elasmobranchs such as the basking shark, EMF effects are unlikely to cause significant behavioural changes, and barrier effects have not been documented from other offshore wind projects. Basking sharks spend up to 75% of their time at, or near, the surface, where their zooplankton prey is found (Rudd *et al*., 2021), therefore it is unlikely they would encounter EMF from the inter-array and platform link cables during their migration in summer months.

10.311 EMF emitted from inter-array and platform link cables is expected to cause minor, temporary behavioural effects on elasmobranchs, which is a primarily demersal species group. Therefore, the magnitude for this impact has been assessed to be **low.**

10.312 Considering the medium receptor sensitivity and low magnitude of impact, an effect of **minor adverse** significance on this receptor group would be expected due to EMF from the Project. This is not significant in EIA terms.

Crustaceans, molluscs

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

10.314 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.*, 2020).

10.315 European lobster have been shown to associate with EMF areas around sub-sea cables (Scott *et al.,* 2019), 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.,* 2022), whilst no effects were seen in embryonic development time, larval release time or swimming speed. It should be noted that the Scott *et al.* (2019) 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 platform link cables and animals were exposed constantly. The results are therefore not applicable to real-world scenarios.

10.316 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 1.5m 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 northeast Atlantic are 50µT (Tasker *et al.*, 2010). 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.

10.317 Molluscs identified in the wider study area, including ocean quahog are not mobile species and no records exist of magneto-sensitivity. The value/sensitivity of crustaceans and molluscs, as a group, has been assessed to be **medium**.

10.318 Given the small area around the Project cables where the presence of EMF may be detected by crustaceans, and the mobile nature of these species, contact with EMF would be limited and, in the context of the wider available habitat, the magnitude of this impact has been assessed to be **low**.

10.319 An effect of **minor adverse** significance has therefore assigned for this receptor group due to EMF from the Project. This is not significant in EIA terms.

Summary

Table 10.35 Summary of operation and maintenance impact 4: EMF effects

Receptor group	Value/sensitivity	Magnitude	Significance
Diadromous fish, pelagic fish	Medium	Negligible	Minor adverse
Demersal Fish	Low	Negligible	Negligible adverse
Elasmobranchs	Medium	Low	Minor adverse
Crustaceans and Molluscs	Medium	Low	Minor adverse

10.6.3.5 Impact 5: Barrier effects

10.320 Barrier effects during operation and maintenance are possible through the potential mechanisms of EMF and noise that may affect receptor groups.

10.321 EMF has been shown to alter the behaviour of certain taxa, including elasmobranchs and shellfish (crustaceans and molluscs), with temporary behavioural changes in the presence of EMF including both decreased and increased activity levels (Scott *et al*., 2009). However, this has only been shown in laboratory conditions, with field strengths orders of magnitude greater than those found in the field with subsea cables. In the field, EMF has not been shown to prevent crab species from crossing areas for foraging etc. (Love *et al.*, 2017). Mobile migratory, diadromous and pelagic species are expected to move over areas of EMF that are detectable, with only temporary changes in movement direction (Hutchison *et al.*, 2020) and, in the wider context of the Irish Sea, it is not expected to cause any significant barrier effects.

10.322 Barrier effects due to noise during operation and maintenance would be significantly less than those during construction and occur only when routine repairs and monitoring is required, which is less noisy and more localised (spatially and temporally) than construction noise (see **Section 10.6.3.3** and **Appendix 11.1**). Therefore, whilst the value/sensitivity of all receptor groups has been assessed to be **medium**, the magnitude of barrier effects during operation and maintenance has been assessed to be **negligible** for all groups, with a resultant effect significance of **minor adverse**. This is not significant in EIA terms.

10.6.3.6 Impact 6: Introduction of hard substrate

10.323 Man-made structures introduced to the 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 species are able to establish and thrive in previously hostile environments (Birchenough and Degraer, 2020; Coolen *et al*., 2020). This potentially increases ecological diversity, by acting as an artificial reef, and with the potential to act as fish aggregating devices.

10.324 The area of hard substrate within the windfarm site from GBS foundations, and associated scour and cable protection, that have the potential to be colonised, is less than 0.6km^2. Although, it is acknowledged that due to the three-dimensional nature of foundation design and scour protection, the actual area, including that available for colonisation, is likely to be greater. The rock would remain in place for the lifetime of the project and, therefore, the creation of any hard substrate habitat is assessed as a permanent effect.

10.325 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), introduction of hard substrate would also occur during the construction phase, 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 and maintenance phases.

10.326 Furthermore, it should be noted that this impact may be considered to be a beneficial one rather than adverse, depending on the species concerned. 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.

Spawning grounds

10.327 The value/sensitivity of spawning grounds to changes in substrate has been assessed to be **high**, given the importance of this life stage. Introduced hard substrate habitat would not be suitable for sandeel spawning, and site specific PSA analysis suggests the baseline sediment characteristics of the windfarm site do not support sandeel or herring spawning (**Section 10.5.4**).

10.328 Any introduced hard substrate (less than 0.6% of the windfarm site) would not affect the suitability of spawning grounds, which extend over spatial scales that are orders of magnitude greater than the introduced hard substrate (see **Figure 10.2**). Based on a **negligible** magnitude, a **minor adverse** effect would be expected from introduced habitat associated with the Project. This is not significant in EIA terms.

Nursery grounds

10.329 The value/sensitivity of fish nursery grounds to changes in substrate has been assessed as **high**, given the importance of this life stage. Introduced hard substrate habitat arising from the Project would have no effect on existing nursery grounds, which extend over spatial scales that are orders of magnitude greater than the introduced hard substrate (see **Figure 10.3**).

10.330 Based on a **negligible** magnitude, a **minor adverse** effect would be expected from introduced habitat associated with the Project. This is not significant in EIA terms.

Demersal fish

10.331 Introduced hard substrate may be suitable habitat for species such as cod, whiting and ling which prefer or utilise the rocky seabed. The value/sensitivity of demersal fish has been assessed as **low**. This impact, however, occurs in a very small percentage of the windfarm site (approximately 0.6%), and an even smaller proportion of the wider habitats in the Irish Sea, and so would have a highly localised effect that would not be detectable within the populations of these species locally, or more regionally. The magnitude of impact upon these demersal fish species has been assessed as **negligible**.

10.332 Considering the low receptor sensitivity and negligible magnitude of impact**,** an overall effect of **negligible adverse** significance would be expected for this receptor group. This is not significant in EIA terms.

Pelagic fish, diadromous fish and elasmobranchs

10.333 The sensitivity of these receptor groups to introduced hard substrate has been assessed as **low**. Introduced hard substrate would occur in a very small percentage of the windfarm site (approximately 0.6%), and an even smaller proportion of the wider habitats in the Irish Sea, and so would have a highly localised effect that would not be detectable within the populations of these species locally, or more regionally.

10.334 The magnitude of impact upon these groups has been assessed as **negligible**, with an overall effect of **negligible adverse** significance. This is not significant in EIA terms.

Crustaceans and molluscs

10.335 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. Taken together, the value/sensitivity of crustaceans and molluscs to the introduction of new substrate is considered, as a group, has been assessed to be **medium**.

10.336 This would, however, occur in a very small percentage of the windfarm site (approximately 0.6%), and an even smaller proportion of the wider habitats in the Irish Sea, and so would have a highly localised effect that would not be detectable within the populations of these species locally, or more regionally. The magnitude of impact upon these crustacean and mollusc species has therefore been assessed as **negligible**. This means an effect of **minor adverse** significance for crustaceans and molluscs would be expected from introduced habitat associated with the Project. This is not significant in EIA terms.

Designated sites

10.337 The value/sensitivity of designated sites (for fish and shellfish species) to the operation and maintenance phase of the Project has been assessed as **high**, given their conservation status.

10.338 Given the separation achieved between the windfarm site and designated sites for fish and shellfish species, as well as those designated for supporting habitats, the introduced hard substrate would not create any new habitat in these sites or for their designated species. An effect significance of **no change** for designated sites would therefore be expected from introduced habitat associated with the Project.

Summary

Table 10.36 Summary of operation and maintenance impact 6: Permanent habitat loss

Receptor group	Value/sensitivity	Magnitude	Significance
Spawning Grounds	High	Negligible	Minor adverse
Nursery Grounds	High	Negligible	Minor adverse
Demersal fish	Low	Negligible	Negligible adverse
Pelagic fish, diadromous fish and elasmobranchs	Low	Negligible	Negligible adverse
Crustaceans and molluscs	Medium	Negligible	Minor adverse
Designated Sites	High	No change	

10.6.3.7 Impact 7: Changes in fishing activity

10.339 As discussed in **Chapter 13 Commercial Fisheries**, there is potential for commercial fishing activity to be displaced from within the windfarm site, due to the presence of the subsurface structures associated with the WTGs and

OSP(s). These subsurface structures may act as a barrier to safe deployment of mobile fishing gear.

10.340 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). Given the within-group variation in receptor sensitivity to fishing, all receptor groups have been assessed to have **low** sensitivity to changes in fishing activity.

10.341 Fishing activity is expected to return to some degree to the windfarm site, during the operation and maintenance phase. Whilst displacement of fishing from within the windfarm site may result in a reduction in mortality risk to commercial species existing in close association with the windfarm site, 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 Irish Sea. Further, the level of fishing within the windfarm site is relatively low (potting is the predominant fishery), and as discussed in **Chapter 13 Commercial Fisheries**, no significant displacement effects are identified during the operation and maintenance phase. The magnitude has been assessed to be **low**.

10.342 The significance of effect is therefore **minor adverse**, and not significant in EIA terms.

10.6.4 Potential effects during decommissioning

10.343 Decommissioning would be subject to a separate consent process and suitable environmental impact assessment prior to works commencing.

10.344 The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in **Chapter 5 Project Description** and the detail would be agreed with the relevant authorities at the time of decommissioning.

10.345 During the decommissioning phase, there is potential for WTG and OSP foundation and cable removal activities to cause changes in suspended sediments, and/or seabed levels, because of sediment disturbance effects. The types of effect would be comparable to those identified for the construction phase.

- Impact 1: Temporary habitat loss/physical disturbance
- Impact 2: Increased SSCs and sediment deposition
- Impact 3: Remobilisation of contaminants
- Impact 4: Underwater noise and vibration

- Impact 5: Barrier effects
- Impact 6: Changes in fishing activity
- Impact 7: Collision risk

10.346 The magnitudes of effect would be comparable to, or less than, those identified for the construction phase. Accordingly, given the construction phase assessments concluded **no change, negligible adverse** and **minor adverse** effects for fish and shellfish ecology receptors, it is anticipated that the same would be valid for the decommissioning phase, regardless of the final decommissioning methodologies.

10.347 In addition, the removal of hard substrate is considered as a separate impact. Any removal of hard subsea windfarm infrastructure would allow the baseline habitat to be returned. However, colonisation of structures by other species would be lost. Given the scale impact in the context of the wider availability of similar habitats in the Irish Sea, effects would not be detectable within the populations of these species locally, or more regionally, and the impact has been assessed to have a **negligible** magnitude. Considering the sensitivity of receptors, the effect would be **negligible** to **minor adverse** and not significant in EIA terms. However, details of decommissioning would be developed and discussed with regulators at an appropriate time.

10.7 Cumulative effect assessment

10.348 In order to undertake the CEA, and as per the PINS advice note (PINS, 2019), the potential for cumulative effects has been established considering each Project-alone effect (and the ZoI of each impact) alongside the list of plans, projects and activities that could potentially interact. These stages are detailed below.

10.7.1 Identification of potential cumulative effects

10.349 Part of the cumulative assessment process was the identification of which individual impacts assessed for the Project have the potential for a cumulative effect on receptors (impact screening). This information is set out in **Table 10.37** and **Figure 10.9**. Screening considers the ZoI of the impacts and the plans and projects identified in **Table 10.38**. Impacts for which the significance of effect is assessed in the Project-alone assessment as ‘negligible’, or above, were considered in the CEA screening (i.e. only those assessed as ‘no change’ are not taken forward as there is no potential for them to contribute to a cumulative effect).

Table 10.37 Potential cumulative impacts (impact screening)

Impact	Project-alone residual effect significance*	Potential for cumulative effect	Rationale
Construction phase			
Impact 1: Temporary habitat loss/physical disturbance	Minor adverse	Yes	There is the potential for overlap of sediment plumes and incremental habitat loss/disturbance in the region if overlapping with other construction activities.
Impact 2: Increased SSCs and sediment re-deposition	Minor adverse	Yes	
Impact 4: Underwater noise and vibration	Minor adverse	Yes	Other developments within the Eastern Irish Sea have the potential to also have a noise impact on fish and shellfish sensitive receptors. Therefore, in the context of noise impacts, there could be cumulative effects.
Impact 5: Barrier effects	Minor adverse	Yes	Barrier effects for noise only are identified to present cumulative effects
Impact 6: Changes in fishing activity	Minor adverse	No	A reduction in fishing pressure during the construction phase is confined to the windfarm site. Cumulative displacement effects on the fishing industry are assessed in **Chapter 13 Commercial Fisheries**.
Impact 7: Collision risk (basking sharks)	Minor adverse	Yes	Collision risk for the Project would be managed at a Project level via embedded mitigation so that there is minimal contribution to cumulative effects, however increased traffic gives rise to the potential for cumulative effects.

Impact	Project-alone residual effect significance*	Potential for cumulative effect	Rationale
Operation and maintenance phase			
Impact 1: Permanent habitat loss	Minor adverse	Yes	Impacts are highly localised, however incremental changes in the region are considered.
Impact 2: Temporary habitat loss/physical disturbance, increased SSCs and sediment deposition	Minor adverse	No	Impacts would occur only at discrete locations within the windfarm site and for a time-limited duration. Given the scale/frequency of Project-alone effect, there would be no interaction of effects and negligible additive effects across the study area.
Impact 3: Underwater noise and vibration	Negligible adverse	Yes	Other developments within the Eastern Irish Sea have the potential to also have a noise impact on fish and shellfish sensitive receptors. Therefore, in the context of noise impacts, there could be cumulative effects.
Impact 4: Interactions of EMF	Minor adverse	No	The effects of EMF during the Project lifetime would be highly localised within the immediate vicinity (in the order of metres, at worst) of the subsea cables. 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.
Impact 5: Barrier effects	Minor adverse	No	Assessments for the impacts of noise and EMF in their standalone sections (**Sections 10.6.2.4, 10.6.2.5, 10.6.3.4,** and **10.6.3.5**) do not suggest that a meaningful barrier effect would occur for migratory species from either impact pathway.
Impact 6: Introduction (or removal assessed in	Minor adverse	Yes	Additive introduction of other hard substrates from foundations and scour protection throughout the region may have a cumulative effect.

Impact	Project-alone residual effect significance*	Potential for cumulative effect	Rationale
decommissioning) of hard substrate			
Impact 7: Changes in fishing activity	Minor adverse	No	A reduction in fishing pressure during the operation and maintenance phase is confined to the windfarm site. Cumulative displacement effects on the fishing industry are assessed in **Chapter 13 Commercial Fisheries**.

* Worst-case significance levels reported. All receptors are assessed as receiving an effect less than or equal to the significance level reported here.

10.7.2 Identification of other plans, projects and activities

10.350 The identification and review of the other plans, projects and activities that may result in cumulative effects (described as 'project screening') is undertaken alongside an understanding of Project-alone effects. The project screening information is set out in **Table 10.38.** This includes consideration of the relevant details of each project, including current status (e.g. under construction), planned construction period, distance to the Project, status of available data and rationale for including or excluding from the CEA.

10.351 All projects considered for CEA across all topics have been identified within **Appendix 6.1 CEA Project Long List** (Document Reference 5.2.6.1), which forms an exhaustive list of plans, projects and activities relevant to the Project. For fish and shellfish, a screening distance of 30km (extending to 50km for piling noise impacts) has been used. This reflects the ZoI of impacts, as well as a suitable scale upon which to assess regional effects at a detectable level.

10.352 The plans and projects screened into the CEA also consider:

- Overlap with the same spawning and/or nursery grounds for the fish and shellfish species assessed for the Project
- Location in the wider study/screening area and are likely to impact the same fish and shellfish receptors
- Have potential that construction, operation and maintenance, and decommissioning phases could overlap with the Project.

Table 10.38 Summary of projects considered for the CEA in relation to fish and shellfish ecology

Project	Status (at the time of assessment)	Construction period	Closest distance from the Project (km)	Screened into the CEA (Y/N)	Rationale
Morgan Offshore Wind Project and Morecambe Offshore Windfarm: Transmission Assets	Pre-application stage. PEIR published in October 2023.	2026 – 2029	0 (adjacent)	Y	Small potential for temporal overlap and some interaction between the dredging plumes from the export cable installation or other activities such as booster station installation. Considered cumulatively with this Project for habitat disturbance/loss, noise and increased SSCs/sedimentation.
Vodafone Lanis 1 telecom cable	Operational	N/A	0 (bisects the windfarm site)	Y	There is potential for some interaction between the sediment plumes arising from maintenance activities and plumes from cable operation and maintenance activities. Existing cables and pipelines outside of the windfarm site are not considered given the small scale and low frequency of any maintenance activities.
EXA Atlantic (formerly GTT Hibernia Atlantic) telecom cable	Operational	N/A	0 (along the southern boundary of the windfarm site)	Y	
Carbon Capture Storage Area (EIS Area 1)	Licences awarded in 2023 (see Morecambe Net Zero Cluster Project below)	Unknown	0	Y	Licence area noted and awarded to Spirit Energy (the project considers repurposing the North and South Morecambe natural gas fields to create a carbon storage cluster). Exploration surveys are being undertaken (2024), however, project timescales are unknown and there are no specific details of associated offshore works. It is
Morecambe Net Zero Cluster Project (carbon storage cluster)	Early planning				

Project	Status (at the time of assessment)	Construction period	Closest distance from the Project (km)	Screened into the CEA (Y/N)	Rationale
					possible existing infrastructure would be used.
South Morecambe DP3 (gas platform)	Decommissioned	N/A	0	N	Gas platform and jacket decommissioning activities completed in 2023 with no above ground infrastructure remaining.
Calder CA1 platform (and associated cables and pipelines)	Operational	N/A	0 (the associated cables and pipelines bisect the windfarm site, whilst the platform itself is located 0.9km to the west of the windfarm site)	Y	Limited activities at the platform anticipated to interact with marine physical processes. Possible interaction with maintenance activities. Other existing oil and gas infrastructure located at a greater distance from the Project windfarm site is not considered cumulatively given the small scale and low frequency of any maintenance activities and uncertainty around potential decommissioning timeframes.
South Morecambe CPP1 (and surrounding South Morecambe platforms)	Operational	N/A	1.6		
Gateway Gas Storage Project	On hold	N/A	4.1	Y	Project noted, however, there is insufficient information available as the project has been on hold since 2010.

Project	Status (at the time of assessment)	Construction period	Closest distance from the Project (km)	Screened into the CEA (Y/N)	Rationale
Isle of Man Interconnector	Operational	N/A	4.6	Y	Licence for maintenance works to repair/replace cable protection. Programme unknown.
South Morecambe DP4 (gas platform)	Decommissioned	N/A	5.1	N	As per South Morecambe DP3.
Carbon Capture Storage Licence (CS004)	Licenced in 2020	Unknown	7.5	Y	Licence area linked to the HyNet North West project. Applications for the HyNet Carbon Dioxide pipeline and HyNet North West Hydrogen Pipeline projects encompass onshore works only and there are no specific details of associated offshore works, however it is possible existing infrastructure would be used.
Liverpool Bay aggregate production area (Area 457)	Open	N/A	9.7	Y	There is potential for some interaction between the dredging plumes from the aggregate exploration and option areas and sediment plumes from cable/foundation installation /decommissioning and operation and maintenance activities from the Project. As non-impulsive noise impact ranges are modelled to be less than 50m for fish and shellfish (see **Appendix 11.1**), noise impacts would not combine cumulatively with these other projects.

Project	Status (at the time of assessment)	Construction period	Closest distance from the Project (km)	Screened into the CEA (Y/N)	Rationale
Mona Offshore Wind Project	Pre-application stage. PEIR submitted 2023.	2026 – 2029	10.0	Y	Potential for temporal overlap and some interaction between the increased SSCs and plumes from the cable/foundation installation, regional habitat loss/disturbance and noise (and associated barrier effects) and introduction of new structures.
West of Duddon Sands Offshore Windfarm	Operational	N/A	12.9	Y	Operational windfarms would only be subject to small scale operation and maintenance activities, however regional incremental effects are considered. As non-impulsive noise impact ranges are modelled to be less than 50m for fish and shellfish (see **Appendix 11.1**), noise impacts would not combine cumulatively with these other wind projects.
Morgan Offshore Wind Project Generation Assets	Pre-application stage. PEIR submitted 2023.	2026 – 2029	16.7	Y	As per Mona Offshore Wind Project.
Site Y Disposal Area	Open	N/A	16.8	Y	There is potential for some interaction between the dredging plumes and SSCs increases during construction and operation and maintenance of the Project, which may increase the magnitude of the increased SSCs and sediment deposition impacts on fish and

Project	Status (at the time of assessment)	Construction period	Closest distance from the Project (km)	Screened into the CEA (Y/N)	Rationale
					shellfish receptors discussed in **Sections 10.6.2.2** and **10.6.3.2**. As non-impulsive noise impact ranges are modelled to be less < 50m for fish and shellfish (see **Appendix 11.1**), noise impacts would not combine cumulatively with these other projects.
Walney Extensions Offshore Windfarms	Operational	N/A	18.8	Y	As per West of Duddon Sands Offshore Windfarm.
Walney 1 Offshore Windfarm	Operational	N/A	20.3		
Barrow Offshore Windfarm	Operational	N/A	21.0		
Walney 2 Offshore Windfarm	Operational	N/A	22.7		
IS205 Barrow D Disposal Area	Open	N/A	22.7	Y	As per Site Y Disposal Area.
Size Z Disposal Area	Open	N/A	23.9		
Liverpool Bay aggregate exploration and option area (Area 1801)	Open	N/A	25.7	Y	As per Liverpool Bay aggregate production area (Area 457)

Project	Status (at the time of assessment)	Construction period	Closest distance from the Project (km)	Screened into the CEA (Y/N)	Rationale
Ormonde Offshore Windfarm	Operational	N/A	27.0	Y	As per West of Duddon Sands Offshore Windfarm.
AyM Offshore Windfarm	Consented	2027 - 2030	28.9	Y	As per Mona Offshore Wind Project.
Gwynt y Môr Offshore Windfarm	Operational	N/A	28.9	Y	As per West of Duddon Sands Offshore Windfarm.
Hilbre Swash aggregate production area	Active	N/A	29.0	Y	As per Liverpool Bay aggregate production area (Area 457).
Burbo Bank Extension Offshore Windfarm	Operational	N/A	29.1	Y	As per West of Duddon Sands Offshore Windfarm
Morecambe Bay: Lune Deep Disposal Area	Open	N/A	30.1	Y	As per Site Y Disposal Area.
Mooir Vannin Offshore Windfarm	Concept/ pre-planning	2030 - 2032	43.7	N	While there is the potential for noise impact ranges during construction (based on highly precautionary behavioural impact criteria) to overlap, current project scheduling mean construction windows would not overlap with the Project construction, with offshore construction noted as 2030-32 for Mooir Vannin.

10.7.3 Assessment of cumulative effects

10.353 Having established the residual effects from the Project with the potential for a cumulative effect, along with the other relevant plans, projects and activities, 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 (in line with **Table 10.37**).

10.354 As shown in **Table 10.37** the impacts with potential pathways for cumulative effects to fish and shellfish ecology include:

- Increased SSCs and sediment deposition (construction)
- Temporary habitat loss and disturbance (construction)
- Noise (and associated barrier effects) (construction and operation and maintenance)
- Permanent habitat loss (operation and maintenance)
- Introduction of hard substrate (operation and maintenance)
- Collision risk (construction)

10.355 Given the interconnected nature of the Project and the Morgan and Morecambe Offshore Wind Farms: Transmission Assets, a separate 'combined' assessment of these is provided within the CEA (**Section 10.7.3.1**). Thereafter, the cumulative assessment considers all plans, projects and activities screened into the CEA. before an assessment of all plans and projects (**Section 10.7.3.2**).

10.7.3.1 Cumulative assessment – the Project and Transmission Assets (combined assessment)

10.356 While the Transmission Assets[15] are considered in a separate ES as part of a separate DCO application (combined with the Morgan Offshore Wind Project transmission assets), given the functional link, a 'combined' assessment has been made considering both the Project and Transmission Assets for the purposes of cumulative assessment. This provides an assessment including impact interactions and additive effects and thus any change in the significance of effects as assessed separately.

10.357 The Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023a) informs the assessment. The

[15] As the Transmission Assets includes infrastructure associated with both the Project and the Morgan Offshore Wind Project Generation Assets, it should be noted that the combined assessment considers the transmission infrastructure for both the Project and the Morgan Offshore Wind Project Generation Assets.

assessment is also undertaken in reference to the baseline presented in **Section 10.5.**

10.358 Only the marine elements of the Transmission Assets would interact with the Project in relation to fish and shellfish, including:

- Export cables adjoining the Morgan Offshore Wind Project and the Project and making landfall south of Blackpool
- Booster station required for the Morgan Offshore Wind Project[16]
- OSP(s) (for the Project and Morgan Offshore Wind Project)

10.359 The following (project-alone) impacts were concluded in the Transmission Assets PEIR (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023):

- Temporary habitat loss/disturbance – **minor adverse** effect (not significant in EIA terms)
- Underwater sound from piling, UXO clearance and geophysical surveys impacting fish and shellfish receptors – **minor adverse** effect (not significant in EIA terms)
- Underwater sound from all other activities – **negligible adverse** effect (not significant in EIA terms)
- Increased SSCs and associated sediment deposition – **minor adverse** effect (not significant in EIA terms)
- Long term habitat loss – **minor adverse** effect (not significant in EIA terms)
- Injury due to increased risk of collision with vessels – **minor adverse** effect (not significant in EIA terms)
- Disturbance/remobilisation of sediment-bound contaminants – **minor adverse** effect (not significant in EIA terms)
- Introduction of hard substrata – **minor adverse** effect (not significant in EIA terms)
- EMFs from subsea electrical cabling – **minor adverse** effect (not significant in EIA terms)

[16] At the time of writing this ES a decision had been taken that the OSPs would not be included within the DCO Application for the Transmission Assets. This decision post-dated the Transmission Asset PEIR (within which the OSPs are also assessed). The final ES for the Transmission Assets will therefore not include the OSPs or associated interconnector cables. Additionally, a decision had been taken since the PEIR that the Morgan OBS would no longer be required. Whilst the OSPs, offshore booster station and interconnector cables will not form part of the DCO Application for the Transmission Assets, they are included here as they were contained within the Transmission Asset PEIR which has been used to inform this ES and summary document.

10.360 These impacts align with those assessed for the Project. While all effects are additive between the Project and the Transmission Assets, due to the localised and spatially separate effects, there is no material change in the significance of effects when considering the majority of impacts together (in line with impact screening in **Table 10.37**). There is however the potential for interaction relating to the following impacts which are assessed in further detail:

- Long-term regional habitat change/loss to the physical presence of infrastructure during operation and maintenance (following habitat disturbance/loss during construction)
- Suspended sediments and deposition (potential for plumes to coalesce)
- Underwater noise (generated during construction)
- Introduction of hard substrata
- Collision risk (increased vessel traffic and the risk of vessel collisions for basking shark)

Cumulative impact 1: Cumulative habitat loss and disturbance

10.361 The cumulative temporary habitat loss/disturbance from the Project and the Transmission Assets during the construction phase (when temporary loss would be greatest) would equate to approximately 46.87km^2 (**Table 10.39**). This includes the approximate 2.33km^2 associated with the Project (**Table 10.2**), plus approximately 44.54km^2 associated with the Transmission Assets.

10.362 The cumulative temporary habitat loss/disturbance footprint from the Project and the Transmission Assets during the operation and maintenance phase would equate to approximately 11.06km^2 (**Table 10.39**). This includes the approximate 0.16km^2 associated with the Project (**Table 10.2**) plus 10.9km^2 associated with the Transmission Assets (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023).

Table 10.39 Summary of temporary habitat loss/disturbance for the Project and Transmission Assets during the construction and operation and maintenance phases (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023)

Activity	Footprint (km^2)	
	Transmission Assets	The Project
Construction phase		
Sandwave clearance for export & interconnector cables	38.4	N/A
Sandwave clearance for inter-array cables	N/A	1.8
Sandwave clearance for platform link cables	N/A	0.3

	Footprint (km^2)	
Sandwave clearance for WTG/OSPs	N/A	0.2
Jack up installation vessels	0.03	N/A[17]
Anchor placements	0.01	0.03
Pre-lay preparation (boulder and debris clearance) for export and interconnector cables	6.0	N/A
Sandwave clearance for OSPs & booster station	0.1	N/A
Total	**46.8**	
Operation and maintenance phase		
Jack-up vessel footprint	0.1	0.03
Cable repair/replacement and/or reburial	10.8	0.1
Anchoring events	N/A	0.03
Total	**11.06**	

10.363 The sensitivity of affected receptors to temporary habitat loss and disturbance is described previously for the construction phase of the Project-alone in **Section 10.6.2.1**. Spawning and nursery grounds have **high** sensitivity, fish receptor groups have **low** sensitivity, shellfish receptor groups have **medium** sensitivity, and designated sites have **high** sensitivity.

10.364 As set out in **Table 10.39** the cumulative temporary disturbance and habitat loss for the Project and the Transmission Assets during construction is 46.8km^2.

10.365 The cumulative long term/permanent presence of physical infrastructure from the Project and the Transmission Assets during the operation and maintenance phase (leading to a change in habitat type and loss of soft sediment) would equate to approximately 2.0km^2 (**Table 10.40**). This includes approximately 0.51km^2 associated with the Project (**Table 10.2**), plus approximately 1.5km^2 associated with the Transmission Assets (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023).

[17] Encompassed within the sandwave clearance footprint for WTGs/OSP(s)

Table 10.40 Summary of long term/permanent presence of physical infrastructure for the Project and Transmission Assets during the operation and maintenance phase (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023)

	Footprint (km^2)	
Instructure	**Transmission Assets**	**The Project**
Foundations (WTGs/OSPs/booster station) and scour protection	0.1	0.25
Cable protection	1.2	0.15
Crossings	0.2	0.07
Replacement scour protection material and cable protection	N/A	0.04
Total	**2.01**	

10.366 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 windfarm site 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.

10.367 In terms of disturbance and habitat loss (during all Project phases) the habitat types found within the windfarm site have a high recoverability (see **Chapter 9 Benthic Ecology**), and the temporary and permanent habitat disturbance/loss associated with the Project and Transmission Assets (**Table 10.39**) 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**).

Cumulative impact 2: Increased SSCs and deposition

10.368 The cumulative volume of material likely to be disturbed during the construction phase of the Project and the Transmission Assets (when the maximum amount of sediment disturbance is anticipated) would be in the region of 13.4 million m^3 (**Table 10.41**). This includes the approximately 1.1 million m^3 associated with the Project (see **Table 10.2**) plus approximately

12.3 million m³ associated with the Transmission Assets (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023).

10.369 As described in **Chapter 9 Benthic Ecology**, ‘heavy’ deposition would only occur within a very short distance of the source of disturbance, and at more than 1km distance, SSCs increases and deposition levels would be low. As such, areas of interaction between plumes from the Project and Transmission Assets would largely see ‘light’ deposition (in the order of millimetres).

10.370 Sediment (via disturbance associated with the Project and the Transmission Assets) would be advected on the tide (not towards one another) and these activities would be of limited spatial extent and frequency, with plume interactions likely to be limited and short of duration. For both the Project and the Transmission Assets, the majority of sedimentation would occur within close proximity (i.e. within 1km) to each installation activity and, given the active sediment transport regime, deposited material would be redistributed across the vicinity.

10.371 The overall combined magnitude has been assessed to be **negligible**, relative to the scale of the populations of 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**).

Table 10.41 Summary of sediment volume disturbed for the Project and Transmission Assets (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023)

Activity	Sediment volume (m^3)	
	Transmission Assets	The Project
Sandwave clearance for export & interconnector cables	8,163,200	N/A
Sandwave clearance for inter-array cables	N/A	70,000
Sandwave clearance for platform link cables	N/A	10,000
Sandwave clearance for WTG/OSPs	N/A	481,463
Export & interconnector cable installation	3,015,000	N/A
Inter-array cable installation	N/A	472,500
Platform link cable installation	N/A	67,500
Sandwave clearance for OSPs & booster station	1,148,965	N/A
Total	**13,428,628**	

Cumulative impact 3: Underwater noise and vibration (and associated barrier effects)

10.372 The key components of the Transmission Asset that require piling comprise of four OSPs at Morgan, two OSPs at Morecambe, and the Morgan offshore booster station. The maximum number of monopiles for the transmission assets is 6, to be piled over 4 days. The maximum hammer energy is 5,500kJ, lower than the 6,600kJ for the Project.

10.373 The construction phase of the Transmission Assets may have temporal and spatial overlap with the Project in terms of sound associated with piling, potentially resulting in a cumulative impact. The assessment of sound impacts associated with piling for the Project-alone has been presented above (**Section 10.6.2.4**), with a low magnitude identified based on a range of technical specifications and sound modelling outputs. There is the potential for piling to occur concurrently at the Project and the Morgan offshore booster substation and Morgan OSP(s).

10.374 Sound modelling for the Transmission Assets indicated similar patterns as those for the Project, with injury and mortality from sound produced within the Transmission Assets for a single monopile (maximum hammer energy of 5,500kJ to ranges of up to 755m for Group 1 fish, 2,020m for Group 2 fish and 2,800m calculated for Group 3 and 4 fish, if modelled as stationary receptors (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023). See **Section 10.6.2.4** for an explanation of fish sound sensitivity groups. Recoverable injury distances were calculated to reach out to up to 4,340m for Group 2 stationary receptors with similar patterns for all other groups of fish, in comparison to the worst-case 7.1km modelled for a single monopile for the Project (**Appendix 11.1**).

10.375 As with the Project, mitigation measures including soft starts would reduce the risk of injury and mortality to some fish and shellfish receptors (see **Section 10.3.3**).

10.376 As with the Project, the behavioural impact ranges expected for the Transmission Assets when striking a monopile with maximum hammer energy are in the range of tens of kilometres (bearing in mind the likely conservatism when considering impulsive noise impacts over these ranges (see **Section 10.6.2.4**).

10.377 Overall, the short piling duration expected for the Transmission Assets would only represent a very short-term increase in the ensonified area when considered cumulatively with planned piling at the Project.

10.378 The construction phase of the Transmission Assets may have temporal overlap with the Project in terms of UXO clearance, potentially resulting in a cumulative impact with construction activities. The assessment for UXO clearance for the Transmission Assets has determined a low magnitude for impact, and based on modelling, finds similar mortality and potential mortal injury ranges for high order detonations of explosive quantities of 1.2kg to 907kg with ranges up to 590m (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023a), with the Project finding equivalent maximum impact ranges of up to 710m (**Section 10.6.2.4**).

10.379 As noted for the Project-alone assessment, there is a short term intermittent nature of impact, which remains true both alone and cumulatively. There is a relatively small proportion of spawning habitats affected at any one time (given the broadscale nature of these habitats) and cumulative effects on spawning would only occur if piling/UXO clearance occurs simultaneously during the peak spawning periods for these species. For example, in the case of Atlantic cod spawning, the maximum recoverable injury range for piling is in the order of 7.1km or 4.34km (**Appendix 11.1**), and Transmission Assets (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023a), respectively) which remain small in the context of the extent of the high intensity spawning grounds which encompass the majority of the Eastern Irish Sea, covering an area of approximately 6,700km^2 (Ellis *et al*., 2012) (see **Figure 10.8**).

10.380 In this context, an additional six monopiles and UXO clearance from the Transmission Assets, does not alter the **negligible** to **low** magnitude of impact and the **negligible** to **minor** adverse significance of effect as assessed for the Project-alone.

Cumulative impact 4: Introduction of hard substrates

10.381 The area of hard substrate introduced within the Project windfarm site is a worst-case of 0.51km^2. This hard substrate would be colonised by encrusting organisms, thereby forming hard substrate-associated biological communities (including the aggregation of fish species, which would feed on the encrusting organisms). The hard substrate would remain in place for the lifetime of the Project and, therefore, the creation of any hard substrate habitat is assessed as a permanent effect. Subsea infrastructure and cable protection associated with the Transmission Assets would cause similar permanent introductions of hard substrate, and the changes in biological communities that are associated with the additional hard substrate. In this way, there is the potential for incremental cumulative effects as more hard substrate is added to the region. As set out in **Table 10.40**, the Transmission Assets would contribute an additional 1.5km^2 of hard substrate.

10.382 Given the highly localised effects associated with introduced hard substrate habitat (see **Section 10.6.3.6**), and the small areas affected, the cumulative impact of introduced hard substrate for the Project and the Transmission

Assets on populations of fish and shellfish is not anticipated to be significantly greater than the effects of the Project-alone (**minor adverse**).

Cumulative impact 5: Collision risk

10.383 Increased vessel traffic as a result of overlapping construction activities between the Project and Transmission Assets could lead to an increased risk of vessel collision with basking sharks. The Project has embedded mitigations to reduce any risk and as such reduce the potential for cumulative effects.

10.384 Based on currently publicly available information concerning the Transmission Assets, this would increase construction vessel numbers by a maximum of 70 construction vessels at any one time (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023a). Considering the maximum of 30 construction vessels expected for the Project a total of 100 construction vessels could be on site within the study area cumulatively.

10.385 An offshore PEMP would be implemented for the Project and separately for the Transmission Assets that outlines instructions for vessel behaviour and vessel operators, including advice to operators to not deliberately approach basking shark and to avoid sudden changes in course or speed. Therefore, the risk of collision is anticipated to be reduced and would only be present for transiting vessels (as opposed to stationary). Therefore, collision effects are not considered to be significantly increased from Project-alone effects (**minor adverse**).

10.7.3.2 Cumulative assessment – All plans and projects

10.386 Based on both the impacts (**Table 10.37**) and plans and projects (**Table 10.38**) identified where there is the potential for significant effects, a detailed cumulative assessment is undertaken considering all relevant information from the Project and other plan and projects (including the Transmission Assets).

Cumulative impact 1: Cumulative habitat loss and disturbance

10.387 Existing plans and projects, including offshore windfarms, aggregate production areas and disposal areas, would contribute to regional habitat loss. The aggregate and disposal areas are well-established and work within a defined area. For this reason, no new habitat loss would occur during the activities of these areas, and they can be considered part of the baseline.

10.388 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 of gravelly sand for herring spawning). Suitable habitat for fish and shellfish receptors that is present in the windfarm site 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.

10.389 In terms of disturbance (during all Project phases) the habitat types found within the windfarm site have a high recoverability rate (see **Chapter 9 Benthic Ecology**), and the temporary habitat disturbance associated with this Project and other projects identified in **Table 10.38** 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**).

10.390 In terms of permanent habitat loss, there is the potential for incremental effects resulting from the loss of habitat, due to the construction of other planned offshore windfarms in the region. Morgan Offshore Wind Project Generation Assets, the Transmission Assets, Mona Offshore Wind Project and AyM Offshore Wind Farm are all planned to be constructed in the region and would therefore cause additional permanent habitat loss.

10.391 Permanent habitat loss for the windfarm site for the Project would occur over a worst-case of less than 0.6% of the windfarm site, which was assessed to be negligible in the context of the extent of habitat in the wider region (see **Section 10.6.3.1**).

10.392 Similar effects have been identified from the infrastructure installation activities (such as seabed preparation) for the AyM Offshore Wind Farm, Mona Offshore Wind Project and Morgan Offshore Wind Project Generation Assets. Considering estimates of seabed disturbance footprints at these projects and the effects identified at each, the cumulative magnitude of impact of habitat loss and disturbance would remain negligible given that a very small proportion of the subtidal sand/gravel and mud habitats available in the wider Eastern Irish Sea would be affected (see **Chapter 9 Benthic Ecology**).

10.393 Considering habitat loss from other plans and projects, this has been assessed as an impact of **negligible** magnitude, in relation to the extent of habitat in the region. Based on this there would be no significant cumulative effect or elevation beyond the Project-alone assessment (**minor adverse**).

Cumulative impact 2: Increased SSCs and deposition

10.394 There is potential for construction and operation and maintenance works (and decommissioning), at other projects including offshore windfarms, aggregate production areas and disposal areas, to result in suspended sediment plumes in addition to those produced in the Project windfarm site. As discussed in **Sections 10.6.2.2** and **10.6.3.2**, any increased SSCs associated with Project works is temporary and localised in all Project phases. Therefore, for any plume interaction to occur, works in nearby projects would need to occur simultaneously (however additive effects are considered for sequential disturbance events).

10.395 Increases in SSCs, caused by maintenance activities of other projects, would be minimal, and considerably less than during construction. For example (and as shown for the Project-alone impacts), existing windfarms would only have minimal activities that would cause seabed disturbance, such as infrequent cable repair. The majority of increased SSCs arising from each maintenance activity of existing windfarms, and dredging/aggregate activities, would fall rapidly to the seabed after the initial suspension and would not travel further than one spring tidal excursion, within minimal levels above background. Therefore, no cumulative impact is anticipated with existing windfarms or dredging/aggregate activities in the Irish Sea. This is the same for existing infrastructure, such as the existing cables within and near to the site, and oil and gas infrastructure.

10.396 The ZoI for increased SSCs for the Project during construction phases (the phase during which the greatest amount of suspended sediment is produced) has been assessed as 10km. The direction of travel of sediment plumes of other projects would be dictated by the directionality of the currents at the time of the works associated with those projects. The regional direction of current flow would cause sediment plumes from nearby projects (if occurring at the same time as e.g., construction of the Project), to travel in largely the same direction as sediment plumes from the Project. The spring tidal excursion at the Project windfarm site is approximately 10km, in an east-west orientation.

10.397 This means that, for sediment plumes from multiple projects to interact, the projects would likely need to be situated within 10km of the Project windfarm site, with sediment-producing works occurring simultaneously. The Mona Offshore Wind Project and the Transmission Assets have the greatest potential for this, with their construction phases (the phases with the greatest potential for increased SSCs) potentially overlapping temporally (and being situated <15km from the Project). Other projects, which have construction phases that overlap with the Project temporally, such as AyM and Morgan Offshore Wind Project, are too far away (>15km) to have cumulative suspended sediment effects (**Table 10.38**).

10.398 In the worst-case scenario, where the construction of multiple projects coincides with the Project construction, there may be additive effects in respect of increased SSCs and sediment deposition. However, these impacts are time-limited and localised, so the scope for temporal and spatial overlap is limited. The overall combined magnitude has been assessed to be **negligible**, relative to the scale of the populations of 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**).

Cumulative impact 3: Underwater noise and vibration (and associated barrier effects)

Underwater noise from piling

10.399 There is potential for piling during construction of the Project and other windfarm projects, including Morgan Offshore Wind Project, Mona Offshore Wind Project, AyM Offshore Windfarm, Transmission Assets, and Mooir Vannin offshore windfarm to result in cumulative effects on fish and shellfish species.

10.400 The potential cumulative effect would be the result of either spatial, or temporal, effects resulting from concurrent, or sequential, piling at different offshore windfarms, or a combination of both. It is noted that considering project timescales as currently published there would be no overlap with the construction of the Project and the Mooir Vannin Offshore Wind Farm.

10.401 For fish, the largest recoverable injury ranges (Project-alone) for monopiles are predicted to be 12km, assuming a stationary receptor; and if a fleeing receptor is assumed, the impact ranges are reduced to 1.7km (**Appendix 11.1**), 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 and Morgan (including Transmission Assets), and Mona projects conduct piling operations simultaneously. The piling parameters for the Project, Transmission Assets, Morgan Generation Assets, Mona, and AyM are set out in **Table 10.42**.

Table 10.42 Piling parameters for Projects considered in the CEA

Project	Reference	Max number of piles	Scenario	Piling duration
The Project	**Table 10.2** and **Section 10.6.2.4**	37	Monopile 6,600kJ Single	37 days (assuming 1 foundation per day)
Transmission Assets	Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023	6	Monopile 5,500kJ Concurrent	4 days
Morgan Offshore Wind Project Generation Assets	Morgan Offshore Wind Limited, 2023	70	Monopile 5,500kJ Concurrent	35 days

Project	Reference	Max number of piles	Scenario	Piling duration
Mona Offshore Wind Project	Mona Offshore Wind Limited, 2023	70	Monopile 5,500kJ Concurrent	35 days
AyM Offshore Wind Farm	AyM Offshore Wind Farm Ltd., 2022	36	Monopile 5,00kJ	74 days
Totals	-	219	-	185

10.402 For the AyM Offshore Windfarm, noise modelling indicated similar patterns as those for the Project, with injury and mortality from noise produced within the AyM Array Area to ranges of up to 1.3km for Group 1 fish, 6.3km for Group 2 fish, and 8.6km calculated for Group 3 and 4 fish, if modelled as static receptors (AyM Offshore Wind Ltd, 2022). In all cases, modelling the fish as fleeing receptors significantly reduced mortality distances, down to <100m even for Group 3 and 4 fish. Injury distances were calculated to extend to up to 12km for Group 3 and 4 static receptors, with this again reducing to 120m when fish were modelled as fleeing receptors, with similar patterns for all other groups of fish.

10.403 For the Mona Offshore Wind Project, noise modelling indicated similar patterns as those for the Project, with injury and mortality from noise produced within the Mona Array Area to ranges of up to 1.1km for Group 1 fish, 2km for Group 2 fish, and 2.9km calculated for Group 3 and 4 fish, if modelled as static receptors (Mona Offshore Wind Limited, 2023). In all cases, modelling the fish as fleeing receptors significantly reduced mortality distances, down to <100m even for Group 3 and 4 fish. Injury distances were calculated to reach out to up to 4.4km for Group 3 and 4 static receptors, with this again reducing to <100m in all cases when fish were modelled as fleeing receptors, with similar patterns for all other groups of fish.

10.404 For the Morgan Offshore Wind Project Generation Assets, noise modelling indicated similar patterns as those for the Project, with injury and mortality from noise produced within the Morgan Array Area to ranges of up to 745m for Group 1 fish, 2.1km for Group 2 fish, and 3.0km for Group 3 and 4 fish, if modelled as static receptors (Morgan Offshore Wind Limited, 2023). In all cases, modelling the fish as fleeing receptors significantly reduced mortality distances, down to <100m even for Group 3 and 4 fish. Injury distances were calculated to extend to up to 4.8km for Group 3 and 4 static receptors, with this again reducing to <100m in all cases when fish were modelled as fleeing receptors, with similar patterns for all other groups of fish.

10.405 Sound modelling for the Transmission Assets indicated similar patterns as those for the Project, with injury and mortality from sound produced within the Transmission Assets for a single monopile (maximum hammer energy of 5,500kJ to ranges of up to 755m for Group 1 fish, 2,020m for Group 2 fish and 2,800m calculated for Group 3 and 4 fish, if modelled as stationary receptors (Morgan Offshore Wind Limited and Morecambe Offshore Windfarm Ltd, 2023).

10.406 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.

Spawning and nursery grounds

10.407 The species with the greatest spawning ground sensitivity (due to their demersal spawning and specific substrate requirements) are herring and sandeel. It is known that there is a low risk of behavioural impact when far removed (i.e. thousands of metres) from the piling location (Popper *et al.* 2014). As previously stated, the worst-case range for behavioural disturbance form pile driving noise from the Project-alone does not overlap with the IoM herring spawning ground as defined by Coull *et al*., (1998) and last 10 years of NIHLS data (**Figure 10.6**) (**Section 10.6.2.3**).

10.408 AyM is too distant from the IoM herring spawning grounds to contribute to a cumulative effect on herring spawning (Awel y Môr Offshore Wind Farm Ltd., 2022).

10.409 When considering the Morgan Offshore Wind Project, Mona Offshore Wind Project and the Transmission Assets, similarly to the Project, they report conservative 135dB SEL_{SS} behavioural disturbance impact ranges for spawning herring. Whilst these projects stress the limitation of this threshold, highlighting the fact that Hawkins *et al.*, (2014) do not recommend that the data from this study is used as a standardised impact threshold, they report overlap with IoM herring spawning grounds for potential behavioural disturbance. There is therefore a potential that if the construction phases of these projects overlap, then pile driving could occur concurrently, causing greater noise levels and hence greater behavioural disturbance effects on spawning herring. Whilst the Project does not overlap with the historical extent of the IoM herring spawning ground, which is supported by appraisal of more recent NIHLS data (**Figure 10.6**), the 135dB behavioural disturbance contour for the Project does approach the outer border of the low intensity IoM herring spawning grounds. Therefore, there is potential for some limited additive noise to the ensonified area, if piling at the Project coincides with Morgan and Mona piling during the herring spawning season (autumn). When combining decibel levels from two sound sources, they do not simply add together numerically; the increase in the combined sound level is dependent on the difference between the individual sound levels that are contributing to the combined level. In this way, the addition of two sound sources of the same level causes an increase of approximately 3dB (e.g. 120dB + 120dB = 123dB). Whereas if there is a 10dB difference between the two sound sources, the combined sound level is only approximately 0.4dB higher (e.g. 120dB + 110dB = 120.4dB). If there is a greater than 10dB difference between sound sources, then the combined sound level is not meaningfully greater than the sound level of the loudest individual source (Engineering Toolbox, 2024). On comparison of the location of the 135dB SEL_{SS} herring behavioural disturbance contours for the Project in relation to those reported for Mona and Morgan Wind Projects (Morgan Offshore Wind Limited, 2023; Mona Offshore Wind Limited, 2023), as well as Transmission Assets, the difference in modelled SEL_{SS} levels for the projects in the vicinity of the IoM herring spawning grounds is equal or greater than 10dB, which means that the sound from Project piling would not meaningfully increase the instantaneous single strike exposure levels in the area if happening simultaneously to other projects. Taken with the fact that as impulsive noise, the pile strikes from multiple projects are unlikely to coincide exactly, even if piling periods overlap, this further reduces the ability of the Project to contribute to a cumulative effect with regard to the instantaneous 135db SEL_{SS} threshold for herring spawning.

10.410 With regard to SEL_{cum} impact ranges, the worst-case TTS range for the Project, resulting from three sequentially piled monopiles is 33km, which is approximately 15km away from the IoM herring spawning grounds. Once again, there is no potential to meaningfully contribute to cumulative impacts in this case.

10.411 Both Morgan and Mona Offshore Wind projects PEIRs identify minor adverse effects and note that piling would be intermittent and temporary. The Morgan Offshore Wind Project Generation Assets PEIR states: *"However, there is potential for significant effects on herring spawning, due to the proximity of the Morgan Generation Assets to the nearby herring spawning grounds. This increased level of impact would likely occur, with disturbance to spawning herring, if piling takes place during the spawning period (September-October). Despite this potential impact, the overall significance is still considered to be minor adverse, due to the noted reversibility of disturbance effects and lack of long-term noise disturbance impacts to herring spawning populations, with herring expected to continue to spawn in existing spawning habitats post-construction."*

10.412 They go on to state in terms of mitigation, that: *"Measures to minimise the risk of significant effects on herring spawning are currently being investigated and* *will be discussed with relevant stakeholders via the EWG and included in the Environmental Statement."*

10.413 For the reasons set out above, mitigation would not be necessary for the Project, alone or cumulatively, given that the reduction in the windfarm site from PEIR has increased the separation to the IoM spawning ground. Nor would any mitigation options effectively mitigate for noise produced by other projects.

10.414 With regard to sandeel, based on PSA analysis, the Project windfarm site is generally unsuitable habitat for sandeel (**Section 10.5.4**). Therefore, there is limited pathway for noise associated with piling in other projects to contribute to noise induced disturbance of sandeel within the windfarm site (**Section 10.5.4**). For sandeel habitat beyond the Project windfarm site, without PSA analysis or benthic sampling, it is difficult to assess against a reliable baseline of the true spatial extent of sandeel habitat in the wider region. However, it should be noted that, as a demersal species with no swim bladder, sandeel are considered the least sensitive grouping (Group 1 (Popper *et al.*, 2014)) with respect to underwater sound, and long range interactions of sound from multiple projects is highly unlikely. To illustrate this, the greatest modelled range for recoverable injury impacts on sandeel, due to piling for this Project, were <2.9km as an absolute worst-case (assuming a stationary animal for 4 sequential pin piles (18 hours duration)) (see **Appendix 11.1** for details).

10.415 Other species with known spawning grounds in the area, such as Atlantic cod have very wide spawning grounds (see **Figure 10.8** for worst-case noise impact contours in relation to the spawning ground), with a very localised and limited proportion of the total available habitat predicted to be impacted from underwater noise associated with the construction of the Project and other plans and projects.

10.416 Overall, cumulative effects of piling noise have been assessed not to be greater than Project-alone effects for spawning and nursery grounds (**minor adverse**) given the minimal contribution of the Project, the temporary nature of effects and scale of impacts in comparison to wider range of spawning and nursery grounds.

Pelagic, demersal, diadromous and elasmobranch fish species

10.417 With regard to migratory diadromous fish, given the low sensitivity to noise (Hawkins and Johnstone, 1978; Scottish Government, 2011), any noise-induced behavioural effects during migration are expected to be highly temporary and not detrimental to the migration (**Section 10.6.2.3** and **10.6.2.5**). For this reason, whilst similar temporary behavioural effects could arise from piling associated with other projects to migratory species before or after passing through the windfarm site, cumulative effects have also also assessed to be temporary and not detrimental to the migration as a whole.

10.418 For migratory seabass, as discussed in **Section 10.6.2.4**, based on tracking data, individuals are known to undertake annual migrations between the Celtic Sea and the Morecambe Bay area, however there is no evidence for or against barrier effects to European sea bass movement in the laboratory or in the field. However, in experimental pens floating in open water, temporary behavioural effects due to impulsive noise playbacks using an underwater speaker have been observed, namely increased swim speed, swim depth and school cohesion. These effects may occur within tens of kilometres of maximum energy monopiling, but as discussed in **Section 10.6.2.4**, the impulsive characteristic of the sound would likely degrade over these ranges. Given the evidence of habituation of European sea bass to multiple exposures to impulsive noise (Radford *et al*., (2016); Neo *et al*. (2018)) cumulative projects in the region are not as a whole likely to cause barriers to strong biological migratory drivers as a whole.

10.419 Overall, cumulative effects of piling noise are deemed not to be greater than Project-alone effects (**minor adverse**).

UXO clearance

10.420 In the case of the Project's requirement to clear UXO, various possible types and sizes of UXO were modelled (see **Appendix 11.1** for further details). As noted in **Section 10.6.2.4**, 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.

10.421 As identified in **Appendix 11.1**, the worst-case range for mortality and potential mortal injury from a high order UXO detonation is 710m. 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. It is not expected that UXO clearance from the Project would be undertaken at the same time as piling for the Project, however UXO clearance from other sites e.g. the Morgan and Mona Offshore Wind Projects is possible at the same time as piling at the Project. Worst-case impact ranges of UXO clearance from other projects are in the order of that modelled for the Project (975m, and 985m worst case for Mona, and Morgan Offshore Wind Projects, respectively). Therefore, following consideration of the worst-case impact ranges, and the fact that a blast would last for a very short duration, no pathway for cumulative effect is identified.

Operation and maintenance noise

10.422 During the operation and maintenance phase there may be potential for operational noise from the proposed Project to add cumulatively to noise generated by other projects and activities.

10.423 However, as outlined in the assessment of operation and maintenance noise for the Project-alone, the impact ranges expected during operation and maintenance would be very small and localised in nature (<50m) (**Section 10.6.3.3**).

10.424 Monitoring data from operational offshore windfarms does not suggest that operational noise has potential to result in any discernible effect on fish and shellfish species. With this in mind and taking consideration of the types and distances of other projects (**Table 10.38**), it is considered that cumulative effects of operation and maintenance noise would not occur beyond Project-alone effects (**negligible adverse**).

Cumulative impact 4: Introduction of hard substrates

10.425 The area of hard substrate introduced within the Project windfarm site is a worst-case of $0.51km^2$. This hard substrate would be colonised by encrusting organisms, thereby forming hard substrate-associated biological communities (including the aggregation of fish species, which would feed off the encrusting organisms). The hard substrate would remain in place for the lifetime of the Project and, therefore, the creation of any hard substrate habitat is assessed as a permanent effect. Other windfarms constructed in the region would cause similar permanent introductions of hard substrate, and the changes in biological communities that are associated with the additional hard substrate. In this way, there is the potential for incremental cumulative effects as more hard substrate is added to the region.

10.426 It is expected that the characteristics of fish and shellfish communities associated with hard substrate introduced into sandy environments would vary over time. Lindeboom *et al.* (2011) undertook a review of short-term ecological effects of the Egmond aan Zee OWF in the Netherlands, based on two years of post-construction monitoring, found that, within the first year, the dominant pelagic species switched from herring to sandeel (Lindeboom *et al.* 2011). Species richness of demersal fish also increased after the first year of construction (Lindeboom *et al.,* 2011). The Lillgrund OWF in Sweden undertook the longest monitoring programme to date, that showed no overall increase in total abundance, although there was an increase in abundance associated with the base of the foundations for some species (Andersson, 2011). These studies correlate with an MMO review of environmental data associated with post-consent monitoring of windfarms (MMO, 2014), where there were minor changes in fish communities reported due to the addition of hard substrate at sites including North Hoyle and Kentish Flats.

10.427 Given the highly localised effects associated with introduced hard substrate habitat (see **Section 10.6.3.6**), the distance between the Project windfarm site and other projects (see **Table 10.38**), and the very small areas affected in each windfarm and other projects, the cumulative impact of introduced hard substrate on populations of fish and shellfish is not anticipated to be significantly greater than the effects of the Project-alone (**minor adverse**).

Cumulative impact 5: Collision risk

10.428 Increased traffic as a result of overlapping construction activities could lead to an increased risk of vessel collision with basking sharks. The Project has embedded mitigations to reduce any risk and as such reduce the potential for cumulative effects. An offshore PEMP (with an Outline PEMP provided as part of the DCO Application (Document Reference 6.2) would be implemented for the Project that outlines instructions for vessel operators, including advice to operators to not deliberately approach basking shark and to avoid sudden changes in course or speed. Mitigation has also been committed to by Morgan Offshore Wind Project Generation Assets, Mona Offshore Wind Project, Transmission Assets, and AyM Offshore Wind Farm, which would produce and adhere to a Code of Conduct for all vessels. The Code of Conduct outlines instructions for vessel behaviour and vessel operators, including advice to operators to not deliberately approach basking shark and to avoid sudden changes in course or speed. This would further reduce the likelihood of cumulative effects occurring. Therefore, the risk of collision is anticipated to be reduced and would only be present for transiting vessels (as opposed to stationary). Collision effects are not therefore considered to be significantly increased from Project-alone effects (**minor adverse**).

10.7.4 Summary of cumulative effects assessment

10.429 All potential cumulative effects (see **Table 10.37**) arising from all identified relevant projects (see **Table 10.38**) have been considered holistically. Overall, cumulative effects are not identified as significant in EIA terms. In the case of herring spawning at the IoM spawning grounds, there is no assessed potential for the Project to contribute to a significant behavioural effect alone or cumulatively for the reasons set out in **Paragraphs 10.409** to **10.413**.

10.8 Transboundary effects

10.430 As discussed in **Section 10.4.5** 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.

10.431 Considering that the ZoI transboundary effects resulting from suspension of sediment cannot occur for this Project (see **Chapter 7 Marine Geology,**

Oceanography and Physical Processes and **Chapter 8 Marine Sediment and Water Quality**).

10.432 There is potential for underwater noise from piling during construction to travel into the territorial waters of the IoM (noting the IoM is not an EEA state but a self-governing British Crown Dependency). The impact ranges for construction piling on fish receptors, as determined by a dedicated modelling study (**Appendix 11.1**), are discussed in **Section 10.6.2.3**. The worst-case 135dB SEL_{ss} impact ranges displayed in **Figure 10.6**, 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 10.6.2.3**.

10.433 Aside from herring (see **Figure 10.6**), the greatest noise impact range for all other fish and shellfish species is 33km for TTS. This 33km ZoI for noise-induced TTS does not extend into IoM waters.

10.434 Isle of Man MNRs are located within 3nm of the Isle of Man and while several of them were originally designated as closed or restricted area for fisheries management purposes they also contain important conservation features. The MNRs are, as highlighted above outside the predicted impacts of the Project, however species assemblages relevant to the Isle of Man are assessed within **Section 10.6** and **10.7**.

10.9 Inter-relationships

10.435 There are clear inter-relationships between the fish and shellfish ecology topic and several other topics that have been considered within this ES. **Table 10.43** provides a summary of the principal inter-relationships and signposts to where those issues have been addressed in the relevant chapters.

10.436 For all impacts, any biological impacts to fish and shellfish populations also informs **Chapter 13 Commercial Fisheries**, which considers effects to commercial species and effects on the fishing industry.

Table 10.43 Fish and shellfish ecology inter-relationships

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Nursery and spawning grounds	**Chapter 9 Benthic Ecology**	Spawning and nursery grounds are assessed throughout this chapter.	Many of the benthic species identified in **Chapter 9 Benthic Ecology** are prey for fish and shellfish species outlined in this chapter.

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Temporary habitat loss/physical disturbance	**Chapter 9 Benthic Ecology**	Effects on fish and shellfish are assessed in **Section 10.6.2.1**	Many of the prey species identified in **Chapter 9 Benthic Ecology** are prey to fish and shellfish receptors and as such impacts to benthic species are considered in the fish and shellfish assessment.
Increased SSCs and sediment deposition	**Chapter 7 Marine Geology, Oceanography and Physical Processes** **Chapter 8 Marine Sediment and Water Quality**	Effects on fish and shellfish are assessed in **Sections 10.6.2.2** & **10.6.3.2**	A conceptual evidence-based assessment of increases in SSCs and seabed level changes are presented in **Chapter 7 Marine Geology, Oceanography and Physical Processes** and **Chapter 8 Marine Sediment and Water Quality**. Changes in SSCs and smothering during deposition could potentially affect fish and shellfish communities within the ZoI.
Remobilisation of existing contaminated sediments	**Chapter 8 Marine Sediment and Water Quality**	Effects on fish and shellfish are scoped out, justified in **Section 10.6.2.3**	Levels of contaminants are described in **Chapter 8 Marine Sediment and Water Quality** and inform the risk to fish and shellfish species.
Long-term habitat loss	**Chapter 9 Benthic Ecology**	Effects on fish and shellfish are assessed in **Section 10.6.3.1**	Many of the prey species identified in **Chapter 9 Benthic Ecology** are prey to fish and shellfish receptors and as such impacts to benthic species are considered in the fish and shellfish assessment.
Changes in fishing activity	**Chapter 13 Commercial Fisheries**	Effects on fish and shellfish are assessed in **Sections 10.6.2.6** & **10.6.3.7**	Displacement levels are described in **Chapter 13 Commercial Fisheries**, with the effects on fish and shellfish populations

Topic and description	Related chapter	Where addressed in this chapter	Rationale
			more widely considered in this chapter.

10.10 Interactions

10.437 The impacts identified and assessed in this chapter have the potential to interact with each other. The areas of potential interaction between impacts are presented in **Table 10.44**. This provides a screening tool for which of these impacts have the potential to interact. The impacts are assessed relative to each development phase (i.e., construction, operation and maintenance or decommissioning) to see if (for example) multiple construction impacts affecting the same receptor could increase the level of impact upon that receptor.

10.438 Following this, a lifetime assessment has been undertaken which considers the impact interactions identified as well as effects on receptors relevant across all development phases (**Table 10.45**).

Table 10.44 Interaction between impacts – screening (construction and decommissioning phase)

Potential interaction between construction phase impacts							
	Impact 1: Temporary habitat loss/physical disturbance	Impact 2: Increased SSCs and sediment deposition	Impact 3: Contamination redistribution	Impact 4: Underwater noise and vibration	Impact 5: Barrier effects	Impact 6: Changes in fishing activity	Impact 7: Collision risk
Impact 1: Temporary habitat loss/physical disturbance		Yes	N/A	No	No	No	No
Impact 2: Increased SSCs and sediment deposition	Yes		N/A	No	Yes	No	Yes
Impact 3: Contamination redistribution	N/A	N/A		N/A	N/A	N/A	N/A
Impact 4: Underwater noise and vibration	No	No	N/A		Yes	No	No
Impact 5: Barrier effects	No	Yes	N/A	Yes		No	No
Impact 6: Changes in fishing activity	No	No	N/A	No	No	-	No
Impact 7: Collision Risk	No	Yes	N/A	Yes	No	No	-

Table 10.45 Interaction between impacts – screening (operation and maintenance phase)

	Potential interaction between operation and maintenance phase impacts						
	Impact 1: Permanent habitat loss	Impact 2: Temporary habitat loss and disturbance and increased SSCs and sediment deposition	Impact 3: Underwater noise and vibration	Impact 4: Interaction of EMF	Impact 5: Barrier effects	Impact 6: Introduction of hard substrate	Impact 7: Changes in fishing activity
Impact 1: Permanent habitat loss		Yes	No	No	No	Yes	No
Impact 2 Temporary habitat loss and disturbance and increased SSCs and sediment deposition	Yes		No	No	Yes	No	No
Impact 3: Underwater noise and vibration	No	No		No	Yes	No	No
Impact 4: Interaction of EMF	No	No	No		Yes	No	No
Impact 5: Barrier effects	No	No	Yes	Yes		No	No

	Potential interaction between operation and maintenance phase impacts						
	Impact 1: Permanent habitat loss	Impact 2: Temporary habitat loss and disturbance and increased SSCs and sediment deposition	Impact 3: Underwater noise and vibration	Impact 4: Interaction of EMF	Impact 5: Barrier effects	Impact 6: Introduction of hard substrate	Impact 7: Changes in fishing activity
Impact 6: Introduction of hard substrate	Yes	No	No	No	No		No
Impact 7: Changes in fishing activity	No	No	No	No	No	No	

Table 10.46 Interaction between impacts – phase and lifetime assessment

Receptor	Highest significance level				
	Construction	**Operation and maintenance**	**Decommissioning**	**Phase assessment**	**Lifetime assessment**
Fish and shellfish species	Minor adverse	Minor adverse	Minor adverse	No greater than individually assessed impact. **Construction** Underwater noise impacts would be greatest in spatial extent for foundation piling but these would occur only during a short part of the construction phase, therefore there is limited potential for interaction with habitat disturbance from seabed preparation, installation of cables etc. and associated effects (increased SSCs). The effects resulting from habitat disturbance would be localised, temporary and episodic with limited potential for interaction (i.e. causing increased barrier effects). The potential for noise to cause barrier effects has already been captured in the barrier effect **Section 10.6.2.5**. It is therefore considered that these impacts would not	No greater than individually assessed impact. The greatest magnitude of effect would be the spatial footprint of construction noise (i.e. foundation piling) and the habitat disturbance from seabed preparation, installation of cables etc. Once this disturbance impact has ceased all further impacts during construction, operation and maintenance and decommissioning would be small scale, localised and episodic. The potential for EMF to cause barrier effects has already been captured in the standalone barrier effect **Section 10.6.2.5**. It is therefore considered that over the project lifetime these impacts would not interact to change the significance level overall.

Highest significance level					
				interact to change the significance level overall. **Operation and maintenance** Disturbance to or loss of habitat would be confined to the immediate footprint of the infrastructure/activities. The magnitude of effect is, in all cases, low to negligible. Temporary habitat loss or disturbance during the operation and maintenance phase would be additional to the permanent habitat loss due to infrastructure footprint, however this would remain a localised and temporary effect with low to negligible magnitude in the context of the broadscale habitat in the Irish Sea. EMF and noise effects would also be locally confined and again the magnitude of effect is low to negligible and relates to largely the same spatial footprint. The potential for noise and EMF to cause barrier effects has already been considered in the standalone barrier effect impact assessment **Section 10.6.2.5**.	

Highest significance level					
				It is therefore considered that none of these impacts would interact to increase the significance level overall. **Decommissioning** It is anticipated that the decommissioning impacts would be similar in nature to those of construction.	

10.11 Potential monitoring requirements

10.439 Monitoring requirements are described in the In Principle Monitoring Plan (IPMP) (Document Reference 6.4), submitted alongside the DCO Application, and would be further developed and agreed with stakeholders, prior to construction, based on the IPMP and taking account of the final detailed design of the Project.

10.440 No monitoring is proposed in relation to fish and shellfish ecology. This is on account of the outcomes of the assessment, which has concluded that all of the potential impacts considered would result in either **no** or, at worse, **minor adverse** effects. The conclusions can be made with a sufficient degree of certainty, based on the collection of recent site specific data from a benthic survey to inform herring and sandeel habitat suitability, the most recent 10 years of Irish Sea NIHLS herring larvae data, recent tracking studies for Atlantic salmon and seabass, recent commercial landings data, combined with site-specific underwater noise modelling based on conservative assumptions (details in **Section 10.5**). However, the Applicant would remain in dialogue with stakeholders, including nearby projects to discuss any regional or strategic projects that may be in planning that may assist in verifying EIA conclusions.

10.12 Assessment summary

10.441 This chapter has provided a characterisation of the existing environment for fish and shellfish ecology, based on both existing and site-specific survey data, and an assessment of the effects on the identified receptors (spawning grounds, nursery grounds, pelagic fish, demersal fish, diadromous fish, elasmobranchs, molluscs, crustaceans, designated sites) during construction, operation and maintenance, and decommissioning phases of the Project.

10.442 The specific impacts that have been identified in relation to this topic are temporary habitat loss/physical disturbance, permanent habitat loss, increased SSCs and sediment re-deposition, underwater noise and vibration, barrier effects, collision risk (basking sharks), changes in fishing activity, interactions of EMF and introduction (and removal) of hard substrate.

10.443 The effects that have been assessed are mostly anticipated to result in a **negligible adverse** to **minor adverse** significance for the above-mentioned receptors, due to the relatively small-scale nature of the Project in the context of the wider Irish Sea, available alternative habitats, and temporary nature of the major construction activities. A summary of the impact assessment for fish and shellfish is provided in **Table 10.47.**

Table 10.47 Summary of potential effects on fish and shellfish ecology

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
Construction							
Impact 1: Temporary habitat loss/ physical disturbance	Spawning grounds	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Nursery grounds	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Pelagic fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Demersal fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Elasmobranchs	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Diadromous fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Molluscs	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Crustaceans	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Designated sites	High	Not Significant (No change)		N/A	No change	
Impact 2: Increased SSCs and sediment deposition	Spawning grounds	High/ Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Nursery Grounds	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Diadromous fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Demersal fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Pelagic fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Elasmobranchs	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Molluscs	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Crustaceans	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Designated sites	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
Impact 3: Remobilisation of existing contaminated sediments if present	Scoped out						NA
Impact 4: Underwater noise and vibration	Spawning Grounds	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Nursery Grounds	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Diadromous Fish	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Elasmobranchs	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Marine Demersal Fish	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Marine Pelagic Fish	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Crustaceans	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Molluscs	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Designated Sites	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
Impact 5: Barrier effects	Diadromous fish	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Crustaceans	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	All other receptors	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
Impact 6: Changes in fishing activity	Commercially targeted stocks	Low	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
Impact 7: Collision risk	Basking sharks	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
Operation and maintenance phase							
Impact 1: Permanent habitat loss	Spawning grounds	High/Medium	Negligible/No change	Not Significant (Minor adverse)/ No Change	N/A	Not Significant (Minor adverse)	As per Project-alone
	Nursery grounds	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Molluscs	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Crustaceans	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Designated sites	High	Not Significant (No change)		N/A	Not Significant	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
						(No change)	
Impact 2: Temporary habitat loss and disturbance and increased SSCs	Spawning grounds	High/Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Nursery grounds	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Diadromous fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Demersal fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Pelagic fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Elasmobranchs	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Molluscs	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Crustaceans	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Designated sites	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
Impact 3: Underwater noise and vibration	All receptors (except designated sites where there is no change)	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	As per Project-alone
Impact 4: Interactions of EMF	Diadromous fish and pelagic fish	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Demersal fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Elasmobranchs	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Crustaceans	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Molluscs	Medium	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
Impact 5: Barrier effects	All receptors	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
Impact 6: Introduction of hard substrate	Spawning grounds	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
	Nursery grounds	High	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Demersal fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Pelagic Fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Diadromous Fish	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	
	Elasmobranchs	Low	Negligible	Not Significant (Negligible adverse)	N/A	Not Significant (Negligible adverse)	

Potential impact	Receptor	Value/ sensitivity	Magnitude	Significance of effect	Additional mitigation measures proposed	Residual effect	Cumulative residual effect
	Crustaceans	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Molluscs	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	
	Designated sites	High	Not Significant (No change)		N/A	Not Significant (No change)	
Impact 7: Changes in fishing activity	All receptors	Low	Low	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone
Decommissioning phase							
Potential impacts from decommissioning would be similar to those for construction, with the magnitude of impacts likely to be less that construction. The removal of hard substrate is assessed separately.							
Impact 1: Removal of hard substrate	All receptors	Medium	Negligible	Not Significant (Minor adverse)	N/A	Not Significant (Minor adverse)	As per Project-alone

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