Environmental Impact Assessment Report - Volume 2B

Chapter 9

Fish and Shellfish Ecology

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

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Energy for generations

ORIEL WIND FARM PROJECT

Environmental Impact Assessment Report
Chapter 9: Fish and Shellfish Ecology

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9 CHAPTER 9 – FISH AND SHELLFISH ECOLOGY

9.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) provides an assessment of the potential impacts of the Oriel Wind Farm Project (hereafter referred to as "the Project") on fish and shellfish ecology. Specifically, this chapter considers the potential impact of the offshore infrastructure (i.e. the offshore wind farm and offshore cables) of the Project below the High-Water Mark (HWM) during the construction, operational and maintenance, and decommissioning phases.

The assessment presented is informed by the following technical chapters:

- Chapter 7: Marine Processes; and
- Chapter 8: Benthic Subtidal and Intertidal Ecology.

This chapter summarises detailed information contained within a baseline technical report, provided in appendix 9-1: Fish and Shellfish Ecology Technical Report. Appendix 9-2: Herring Spawning – Technical Report provides supplementary baseline information on herring spawning and has been used to inform this assessment. Technical Reports developed to understand underwater noise emissions and suspended sediment concentrations associated with the Project activities are provided in appendix 10-2: Subsea Noise Technical Report and appendix 7-1: Marine Processes Technical Report respectively.

The details and competencies of the specialist who prepared this chapter can be found in volume 2A, chapter 1: Introduction.

9.2 Purpose of this chapter

The primary purpose of this EIAR chapter is to provide an assessment of the direct and indirect likely significant effects of the Project on fish and shellfish. In particular, this EIAR chapter:

- Presents the existing fish and shellfish ecology baseline established from desk studies and consultation with stakeholders (section 9.7);
- Identifies any assumptions and limitations encountered in compiling the environmental information (section 9.7.4);
- Presents the likely significant effects on fish and shellfish ecology arising from the Project, based on the information gathered and the analysis and assessments undertaken (section 9.10). An assessment of potential cumulative impacts is provided in section 9.11 and an assessment of transboundary effects is outlined in section 9.12; and
- Highlights any necessary monitoring and/or measures to prevent, minimise, reduce or offset the likely significant adverse environmental effects identified in the assessment process (sections 9.8.2 and 9.10.6).

9.3 Study area

The Zone of Influence (ZoI) for fish and shellfish ecology encompasses two study areas due to the temporal and spatial variability of fish and shellfish:

- The Fish and Shellfish Ecology Study Area; and
- The Western Irish Sea Fish and Shellfish Ecology Study Area.

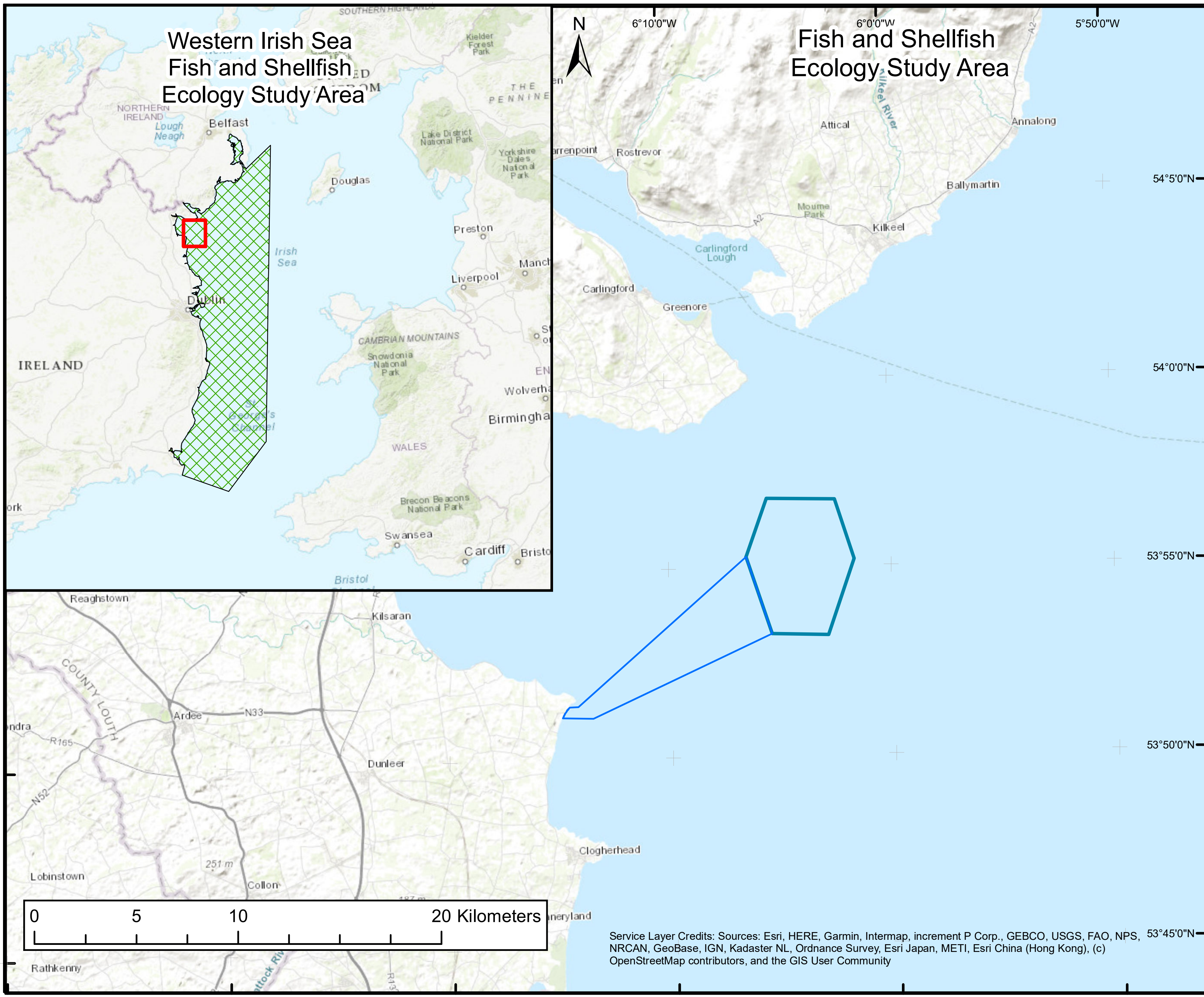
The Fish and Shellfish Ecology Study Area includes the offshore wind farm area, the offshore cable corridor and the area in the immediate vicinity of the intertidal area (Figure 9-1). This is the area where potential likely significant effects from the Project from the majority of impacts (e.g. subtidal habitat loss/disturbance, increases in suspended sediment concentrations (and associated sediment deposition) and electromagnetic fields (EMF) from subsea electrical cabling) on fish and shellfish are expected to occur.

It is also necessary to define a wider contextual study area (i.e. the Western Irish Sea Fish and Shellfish Ecology Study Area) in the western portion of the Irish Sea[1] from Ballyquintin Point (55.5 km north east of the offshore wind farm area) to Carnsore Point (191.5 km south of the offshore wind farm area) (Figure 9-1). This area is defined to assess the likely significant effects which may extend beyond the project boundary (e.g. injury and/or disturbance to fish from underwater noise during pile-driving) and also to account for the highly mobile nature of some fish and shellfish species, in particular diadromous fish species.

The Western Irish Sea Fish and Shellfish Ecology Study Area is also used to inform the cumulative impact assessment (see section 9.11). Any Northern Ireland and Republic of Ireland projects falling inside the study area that have the potential to have cumulative effects on fish and shellfish ecology with the Project have been assessed.

The study areas were defined based on professional judgement and author experience of offshore wind farm impact assessments.

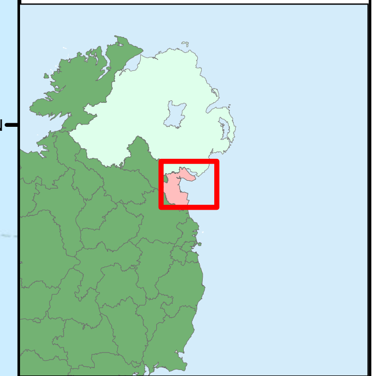
[1] Delineated by the continental shelf (a natural barrier for most fish species), and artificially extended to the centre point between Ballyquintin Point (Northern Ireland) and the Mull of Galloway peninsula (Scotland).



Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- Western Irish Sea Fish and Shellfish Ecology Study Area

Data Sources: Client



Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title

Figure 9-1
Fish and Shellfish Ecology Study Area and Western Irish Sea Fish and Shellfish Ecology Study Area

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Issue Details

Drawn By:	NA	**Project No.**	EOR0822 (MDR1520B)
Checked By:	NA	**File Ref:**	
Approved By:	KL		EOR0822_FAS_E_1201_FINAL
Scale:	1:250,000 @ A4	**Projection:**	ITM (IRENET95)
Date:	07/03/2024		Geographic Co-ordinates: ETRS89

NOTE:
1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin Head.
3. Ordnance Survey Ireland Licence EN 0005019

9.4 Policy context

Planning policy on renewable energy infrastructure is presented in volume 2A, chapter 2: Policy and Legislation. This section presents planning policy that specifically relates to fish and shellfish ecology, which is contained in the Offshore Renewable Energy Development Plan I (OREDP) (DECC, 2022) and the National Marine Planning Framework (NMPF), Government of Ireland (2021). A summary of the policy provisions relevant to fish and shellfish ecology within the Fish and Shellfish Ecology Study Area are provided in Table 9-1 and Table 9-2, with other relevant policy provisions set out in Table 9-3.

In February 2023, the 'OREDP II - National Spatial Strategy for the transition to the Enduring Regime' was published in draft and subject to consultation. The draft OREDP II does not define specific provisions similar to OREDP I. The key objectives of OREDP II are:

- *"Assess the resource potential for ORE in Ireland's maritime area.*
- *Provide an evidence base to facilitate the future identification of Broad Areas of Interest most suitable for the sustainable deployment of ORE in Ireland's maritime area.*
- *Identify critical gaps in marine data or knowledge and recommend prioritised actions to close these gaps."*

The OREDP II will provide an evidence base to facilitate the future identification of Broad Areas of Interest most suitable for the sustainable deployment of ORE in Ireland's maritime area, to be assessed in greater detail at regional scale. This assessment will subsequently inform the identification of more refined areas as part of the designation process for Designated Maritime Area Plans (DMAP).

When published, the OREDP II will update the original OREDP published in 2014.

Table 9-1: Summary of OREDP provisions relevant to fish and shellfish ecology.

Summary of OREDP project-level mitigation measures	How and where considered in the EIAR
Fish and Shellfish	
Disturbance: surveys to identify key breeding and migration routes, avoid sensitive sites/areas where possible, where development occurs near to sensitive sites / areas avoid installation during sensitive seasons, programme works to reduce potential for noisy or other disturbing activities to occur at the same time, programme works to reduce potential for installation periods to coincide with other developments in order to reduce potential for cumulative effects from developments, programme maintenance works to avoid sensitive seasons (e.g. breeding and migration).	See chapter 4: Consideration of Alternatives for details on site selection and avoidance of sensitive sites. Fish and shellfish receptors have been identified through a desktop study and are discussed in section 9.7. The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 9.10. The measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2. These include measures to minimise impacts from noise and accidental pollution. EMF is addressed in section 9.10.5. Cumulative effects of the Project in combination with other projects are assessed in section 9.11.
Displacement: surveys to identify key breeding and migration routes, avoid locating developments on key migration routes/in key breeding areas, where development occurs near to sensitive sites /areas avoid installation during sensitive seasons, programme works to reduce potential for noisy or other disturbing activities to occur at the same time, programme works to reduce potential for installation periods to coincide with other developments to reduce potential for cumulative effects from developments, programme maintenance works to avoid sensitive seasons (e.g. breeding).	
Smothering: Avoid sensitive sites/species/periods.	
Noise: implementation of the National Parks and Wildlife Service (NPWS) Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters, adherence to Irish Whale and Dolphin Group (IWDG) recommendations to minimise impacts on marine mammals, undertaking studies to determine site-specific noise effects, minimising use of high noise emission activities such as impact piling, avoid installation during sensitive periods (breeding and migration), soft starting piling activities/passive acoustic deterrents, use of passive acoustic monitoring to facilitate implementation of exclusion area, programme noisy activities to avoid cumulative effects.	

Summary of OREDP project-level mitigation measures	How and where considered in the EIAR
Accidental contamination: design devices to minimise risk of leakage of pollutants, risk assessment and contingency planning.	
Substratum loss: avoid sensitive sites/species, site specific surveys, workshops with stakeholders.	
Changes in wave and tidal regime: Avoid sensitive sites/species/periods.	
Barrier to movement: studies to identify location of key migration corridors and sensitive habitats, avoid large installations in migratory corridors, avoid sensitive areas (breeding, feeding and nursery areas), avoid placement of devices within constrained areas where array could completely block or cause a significant perceptual barrier to fish.	
EMF: cable configuration and orientation can reduce field strength, cable burial where possible.	

Table 9-2: Summary of NMPF provisions relevant to fish and shellfish ecology.

Summary of NMPF provision	How and where considered in the EIAR
Biodiversity	
Biodiversity Policy 1: Proposals incorporating features that enhance or facilitate species adaptation or migration, or natural native habitat connectivity will be supported, subject to the outcome of statutory environmental assessment processes and subsequent decision by the competent authority, and where they contribute to the policies and objectives of this NMPF. Proposals that may have significant adverse impacts on species adaptation or migration, or on natural native habitat connectivity must demonstrate that they will, in order of preference and in accordance with legal requirements: a) avoid, b) minimise, or c) mitigate Significant adverse impacts on species adaptation or migration, or on natural native habitat connectivity.	The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 9.10, including effects on fish migration and access to key habitats. The measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2.
Biodiversity Policy 2: Proposals that protect, maintain, restore and enhance the distribution and net extent of important habitats and distribution of important species will be supported, subject to the outcome of statutory environmental assessment processes and subsequent decision by the competent authority, and where they contribute to the policies and objectives of this NMPF. Proposals must avoid significant reduction in the distribution and net extent of important habitats and other habitats that important species depend on, including avoidance of activity that may result in disturbance or displacement of habitats.	The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 9.10, including assessment of disturbance of the habitats on which fish and shellfish receptors rely.
Biodiversity Policy 3: Where marine or coastal natural capital assets are recognised by Government: • Proposals must seek to enhance marine or coastal natural capital assets where possible. • Proposals must demonstrate that they will in order of preference, and in accordance with legal requirements: a) avoid, b) minimise, or c) mitigate significant adverse impacts on marine or coastal natural capital assets, or d) if it is not possible to mitigate significant adverse impacts on marine or coastal natural capital assets proposals must set out the reasons for proceeding.	The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 9.10. Measures included in the Project are discussed in section 9.8.2.

Summary of NMPF provision	How and where considered in the EIAR
Biodiversity Policy 5: Proposals must demonstrate that they will, in order of preference and in accordance with legal requirements: a) avoid, b) minimise, or c) mitigate significant disturbance to, or displacement of, highly mobile species.	The potential effects of the construction, operational and maintenance and decommissioning phases of the Project including assessment of disturbance of the habitats on which fish and shellfish receptors rely have been assessed in section 9.10. The measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2.
Protected Marine Sites (PMS)	
PMS Policy 1: Proposals must demonstrate that they can be implemented without adverse effects on the integrity of Special Areas of Conservation (SACs) or Special Protection Areas (SPAs). Where adverse effects from proposals remain following mitigation, in line with Habitats Directive Article 6(3), consent for the proposals cannot be granted unless the prerequisites set by Article 6(4) are met.	Designated sites have been identified through a desktop study and are discussed in section 9.7. The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 9.10. The measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2. A Natura Impact Statement (NIS) has been prepared for the Project and accompanies the application. The NIS concludes that the Project will not result in adverse effects on the integrity of any SAC or SPA with the implementation of mitigation measures.
PMS Policy 2: Proposals supporting the objectives of protected marine sites should be supported and: • be informed by appropriate guidance; • must demonstrate that they are in accordance with legal requirements, including statutory advice provided by authorities relevant to protected marine sites.	
PMS Policy 3: Proposals that enhance a protected marine site's ability to adapt to climate change, enhancing the resilience of the protected site, should be supported and: • be informed by appropriate guidance; • must demonstrate that they are in accordance with legal requirements, including statutory advice provided by authorities relevant to protected marine sites	
PMS Policy 4: Until the ecological coherence of the network of protected marine sites is examined and understood, proposals should identify, by review of best available evidence (including consultation with the competent authority with responsibility for designating such areas as required), the features, under consideration at the time the application is made, that may be required to develop and further establish the network. Based upon identified features that may be required to develop and further establish the network, proposals should demonstrate that they will, in order of preference, and in accordance with legal requirements: a) avoid, b) minimise, or c) mitigate significant impacts on features that may be required to develop and further establish the network, or d) if it is not possible to mitigate significant impacts, proposals should set out the reasons for proceeding	
Planning	
Non-indigenous Species Policy 1: Reducing the risk of the introduction and / or spread of non-indigenous species is a requirement of all proposals. Proposals must demonstrate a risk management approach to prevent the introduction of and / or spread of non-indigenous species, particularly when: a) moving equipment, boats or livestock (for example fish or shellfish) from one water body to another, b) introducing structures suitable for settlement of non-indigenous species, or the spread of non-indigenous species known to exist in the area of the proposal	Appendix 5-3: Marine Invasive Non-Native Species Management Plan (volume 2A) has been created to manage and prevent the introduction/spread of invasive species.

Summary of NMPF provision	How and where considered in the EIAR
Underwater Noise	
Underwater Noise Policy 1: Proposals must take account of spatial distribution, temporal extent, and levels of impulsive and / or continuous sound (underwater noise) that may be generated and the potential for significant adverse impacts on marine fauna. Where the potential for significant impact on marine fauna from underwater noise is identified, a Noise Assessment Statement must be prepared by the proposer of development. The findings of the Noise Assessment Statement should demonstrably inform determination(s) related to the activity proposed and the carrying out of the activity itself. The content of the Noise Assessment Statement should be relevant to the particular circumstances and must include: Demonstration of compliance with applicable legal requirements, such as necessary assessment of proposals likely to have underwater noise implications, including but not limited to: »Appropriate Assessment (AA); »Environmental Impact Assessment (EIA); »Strategic Environmental Assessment (SEA); »Specific response to 'strict protection' requirements of Article 12 of the Habitats Directive in relation to certain species listed in Annex IV of the Directive; and »Species protected under the Wildlife Acts. An assessment of the potential impact of the development or use on the affected species in terms of environmental sustainability; Demonstration that significant adverse impacts on marine fauna resulting from underwater noise will, in order of preference and in accordance with legal requirements be: a) avoided, b) minimised, or c) mitigated, or d) if it is not possible to mitigate significant adverse impacts on marine fauna, the reasons for proceeding must be set out. This policy should be included as part of statutory environmental assessments where such assessments require consideration of underwater noise	The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have from underwater noise on fish and shellfish ecology been assessed in section 9.10.2. The measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2.
Transboundary	
Transboundary Policy 1: Proposals that have transboundary impacts beyond the maritime area, on either the terrestrial environment or neighbouring international jurisdictions, must show evidence of consultation with the relevant public authorities, including terrestrial planning authorities and other country authorities. Proposals should consider transboundary impacts throughout the lifetime of the proposed activity.	The potential transboundary effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 9.12. Details on consultation with neighbouring international jurisdictions is provided in chapter 6: Consultation (volume 2A).

Table 9-3: Summary of other policy provisions relevant to fish and shellfish ecology.

Summary of provision	How and where considered in the EIAR
Fish and shellfish ecology	
Marine Strategy Framework Directive (MSFD): adopted in July 2008. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, Annex I of the Directive identifies 11 high level qualitative descriptors for determining GES. These include biological diversity, non-indigenous species, elements of marine food webs, sea floor integrity, alteration of hydrographical conditions and contaminants (European Union, 2008).	Effects of construction, operational and maintenance, and decommissioning phases of the Project on fish and shellfish ecology, including biodiversity, elements of marine food webs, and sea floor integrity, have been assessed in section 9.10. The measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2.

Summary of provision	How and where considered in the EIAR
Ireland's National Biodiversity Plan 2023-2030: sets out Ireland's vision, objectives and outcomes for biodiversity in Ireland. Objective number 2 is to 'Meet Urgent Conservation and Restoration Needs. Outcome 2D: Biodiversity and ecosystem services in the marine and freshwater environment are conserved and restored. This includes 16 targets and 21 actions. (Department of Culture, Heritage and the Gaeltacht (DCHG), 2023).	Effects of construction, operational and maintenance, and decommissioning phases of the Project on fish and shellfish ecology, including biodiversity, have been assessed in section 9.10 with measures included in the Project for the fish and shellfish receptors with greatest biodiversity importance (see section 9.8.2).
Ireland's Integrated Marine Plan (2012): identifies the marine environment as an area that needs to be protected, managed and developed and as a key component of Ireland's economic recovery and sustainable growth. The second goal of the Integrated Marine Plan is to achieve healthy ecosystems that provide monetary and non-monetary goods and services (Inter-Departmental Marine Coordination Group, 2012).	Effects of construction, operational and maintenance, and decommissioning phases of the Project on fish and shellfish ecology have been assessed in section 9.10 with measures included in the Project for the fish and shellfish receptors with greatest biodiversity importance (see section 9.8.2).

9.5 Consultation

below summarises the issues raised relevant to fish and shellfish ecology which have been identified during consultation activities undertaken to date, together with how these issues have been considered in the production of this EIAR chapter. Chapter 6: Consultation (volume 2A) provides details on the types of consultation activities undertaken for the Project between 2019 and 2024 and the consultees that were contacted.

Table 9-4: Summary of key consultation issues raised during consultation activities undertaken for the Project relevant to fish and shellfish ecology.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
September 2019	Inland Fisheries Ireland (email)	Identified that Dundalk Bay is promoted as an angling venue for a range of species and the bay receives waters from a number of rivers in the Neagh International River Basin District. These include species which are valuable from a fisheries perspective and contain a number of migrating species which include Annex II species under the European Habitats Directive such as salmon and sea lamprey. Highlighted importance of mitigation measures to ensure protection and conservation of the aquatic habitats.	Fish and shellfish receptors have been identified through a desktop study and are discussed in section 9.7. Further details are provided in appendix 9-1: Fish and Shellfish Ecology Technical Report. Measures included in the Project to prevent, minimise, reduce likely significant adverse effects are discussed in section 9.8.2.
March 2021	Inland Fisheries Ireland (meeting)	Consultation regarding: Baseline data – specifically presence of sea bass in Dundalk Bay; Approach to scoping impacts (specifically temperature increases from cables); Underwater noise assessment and potential effects on fish, particularly diadromous fish, including barrier effects to migratory species from underwater noise Discussion of effects on recreational fisheries.	Baseline information provided and included in appendix 9-1: Fish and Shellfish Ecology Technical Report. Justification for scoping impacts out of assessment (including temperature changes from cables) is presented in section 9.8.3. Effects of underwater noise are fully assessed in section 9.10.2. Effects on recreational fisheries are considered in chapter 16: Infrastructure, Marine Recreation and Other Users.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
March 2021	Marine Institute (email)	Provided additional data sets to be used to characterise the baseline including marine institute data and monitoring reports from offshore wind parks in Belgium. The Marine Institute recommended the consideration of ecosystem service provision of habitats assessed. Suggested it would be useful to provide a list of the designated conservation sites to be considered in the assessment. Provided information on brown crab landings.	Additional data sets have been included to characterise the baseline in section 9.7. Impacts on ecosystem services have indirectly been assessed whereby the baseline ecological features have been considered alongside identified benefits to humans as part of chapter 12: Commercial Fisheries and chapter 16: Infrastructure, Marine Recreation and Other Users Designated sites considered in the fish and shellfish assessment are listed in Table 9-6.
April 2021	National Parks and Wildlife Service (meeting)	Discussion regarding the baseline data sources, assessment methodology, important ecological receptors and impacts scoped in/out. Discussion on the consideration of the impact of a change in fish and shellfish prey species on ornithological receptors. Discussion on whether the assessment considered changes in fishing practices within the Project offshore wind farm area. Discussion on whether the introduction of hard substrate will promote colonisation of the area by larger predatory fish due to the reef effect and therefore reduce the smaller fish availability.	Consideration of the impact of a change in fish and shellfish prey species on ornithological receptors is considered in chapter 11*:* Offshore Ornithology. Based on RPS experience, offshore wind farms in the North Sea have been able to co-exist with the fishing industry, particularly shellfish potting. There is not expected to be a change in the benthic communities as a result of changes to fishing activities. The impact of colonisation of hard substrate has been scoped out and justification provided in Table 9-11.
January/February 2023	Members of the public during public consultation	Query regarding potential impacts of the Project on fish stocks.	The potential impacts of the Project on demersal, pelagic and migratory fish species as well shellfish species are assessed in section 9.10.
September 2023	Department of Agriculture, Environment and Rural Affairs (including Natural Environment Division's response)	Consultation regarding the following: • MPAs; • Marine Invasive species; • Marine National Protected Species; • Marine Policy Statements	Designated sites have been considered in section 9.7.1. Appendix 5-3: Marine Invasive Non-Native Species Management Plan has been created to manage and prevent the introduction/spread of invasive species (vol. 2A) Section 9.7.2 describes fish and shellfish species of importance and in the appendix 9-1: Fish and Shellfish Ecology Technical Report. Policy has been discussed in section 9.4 and chapter 2: Policy and Legislation.
October 2023	Loughs Agency	Consultation regarding the following: • Validity of data and consideration of climate change; • Consideration of surveys to support the knowledge gap;	The validity of data has been described in section 9.7.4. With the effects of climate change considered in section 9.7.3.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
		• Consequences of climate change; • Suggested modelling of receptor effects and their interactions; • Consideration of quantitative assessments; • Value of fish be given weighting.	Pre-construction/construction surveys have been considered in section 9.14. Based on RPS experience and the size of the Project, modelling is not required (beyond underwater noise and physical processes modelling) as impacts have been assessed as to be not significant in EIA terms. The potential impacts of the Project on demersal, pelagic and migratory fish species as well shellfish species are assessed in section 9.10. Potential inter-related effects have been considered in chapter 32: Interactions. Criteria for giving value to fish and shellfish species has been described in section 9.7.2 and in the appendix 9-1: Fish and Shellfish Ecology Technical Report.
October 2023	Isle of Man Government	• Consideration of MPAs; and • Potential effects on *Nephrops* (note that this comment is in relation to the fishing ground).	Designated sites have been considered in section 9.7.1. The potential impacts of the Project on *Nephrops* are assessed in section 9.10.
June & November 2023	An Bord Pleanála; pre-application consultation	• Concerns raised with regards to herring spawning and the effects of sedimentation during construction; and • Consider 'wake effects' (loss of wind energy being transmitted to the water column due to the presence of turbines may impact herring spawning) as a potential impact.	Baseline information provided in appendix 9-2: Herring Spawning-Technical Report, includes a detailed report on the Herring spawning grounds. The potential impacts of the Project on spawning species are assessed in section 9.10. Regarding 'wake effects', the potential changes to the wave and tidal regime from the operational wind turbines area considered in chapter 7 Marine Processes This demonstrated that any changes to marine processes would be very limited and would not impact seabed habitats, including sediments on which herring are reliant for spawning.

9.6 Methodology to inform the baseline

9.6.1 Desktop study

Information on fish and shellfish ecology within the Western Irish Sea Fish and Shellfish Ecology Study Area was collected through a detailed desktop review of existing studies and datasets with the data sources used to collect baseline information presented in appendix 9-1: Fish and Shellfish Ecology Technical Report.

9.6.2 Identification of designated sites

All designated sites within the Western Irish Sea Fish and Shellfish Ecology Study Area that could be affected by the construction, operation and maintenance, and decommissioning of the Project were identified using the three-step process summarised below and provided in detail in appendix 9-1: Fish and Shellfish Ecology Technical Report:

- Step 1: All designated sites of international, national and local importance within the Western Irish Sea Fish and Shellfish Ecology Study Area were identified using a number of sources summarised in appendix 9-1: Fish and Shellfish Ecology Technical Report.
- Step 2: Information was compiled on the relevant qualifying fish and shellfish features for each of these sites. The known occurrence of species within the Western Irish Sea Fish and Shellfish Ecology Study Area was based on the relevant desktop information presented within appendix 9-1: Fish and Shellfish Ecology Technical Report.
- Step 3: Using the above information and expert judgement, sites were included for further consideration if:
  - A designated site directly overlaps with the Western Irish Sea Fish and Shellfish Ecology Study Area;
  - Sites and associated features were located within the potential ZoI (i.e. the Western Irish Sea Fish and Shellfish Ecology Study Area) for impacts associated with the Project (e.g. habitat loss/disturbance, underwater noise during construction);
  - Features of a designated site were either recorded as present during historic surveys within the area, or identified during the desktop study as having the potential to occur within the Western Irish Sea Fish and Shellfish Ecology Study Area;
  - Where national and locally designated sites (e.g. Natural Heritage Areas (NHAs) and Areas of Special Scientific Interest (ASSIs)) fall within the boundaries of an internationally designated site (e.g. Special Area of Conservation (SAC)), only the international site has been considered, except when a national site forms a component of an international site, but the latter designation does not list a qualifying interest (QI) that is present on the NHA/ASSI citation; and
  - Where a national site falls outside of an international site, but within the Western Irish Sea Fish and Shellfish Ecology Study Area, the national site will be taken forward for further assessment for a particular feature of interest.

9.7 Baseline environment

The baseline environment has been described in detail within appendix 9-1: Fish and Shellfish Ecology Technical Report. The fish and shellfish receptors that could be potentially impacted by the Project have been determined by the desktop review of available data/information which are referenced in the text and listed in appendix 9-1: Fish and Shellfish Ecology Technical Report. Through this process a number of demersal, pelagic, elasmobranch and migratory species were identified. It was found that surface seabed substrate is a determining factor in the fish and shellfish assemblage, with the Fish and Shellfish Ecology Study Area mainly comprised of muddier sediments, and sands and gravels present further inshore along the offshore cable corridor. Species that were identified as potentially occurring within the Fish and Shellfish Ecology Study Area included:

- **Demersal – Flatfish:** plaice *Pleuronectes platessa*, sole *Solea solea*, brill *Scophthalmus rhombus*, dab *Limanda limanda*, lemon sole *Microstomus kitt*, scaldfish *Arnoglossus laterna*, solenette *Buglossidium luteum, thickback sole Microchirus variegatus, witch, Glyptocephalus cynoglossus,* megrim *Scomber scombrus*, flounder *Platichthys flesus*;
- **Demersal – Gadoids:** cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, poor cod *Trisopterus minutus*, whiting *Merlangius merlangus*, ling *Molva molva*, pollack *Pollachius pollachius*, hake *Merluccius merluccius* and coalfish *Pollachius virens*;
- **Other demersal species:** gobies *Gobiidae*, blennies *Blenniiformes* wrasse species *Labridae*, conger eel *Conger conger*, anglerfish *Lophius piscatorius*, bull-rout *Myoxocephalus scorpius*, common dragonet *Callionymus lyra*, spotted dragonet *Callionymus maculatus*, grey gurnard *Eutrigla gurnardus*, pogge

Agonus cataphractus, lesser weever fish *Echiichthys vipera*, butterfish *Pholis gunnellus*, two-spotted clingfish *Diplecogaster bimaculata*, bass *Dicentrarchus labrax*, lesser sandeel *Ammodytes tobianus*, and greater sandeel *Hyperoplus lanceolatus*;

- **Pelagic species:** herring *Clupea harengus*, mackerel *Scomber scombrus* and sprat *Sprattus sprattus*;
- **Elasmobranchs:** small-spotted catshark *Scyliorhinus canicula*, spotted ray *Raja montagui*, common skate *Dipturus batis*, and tope *Galeorhinus galeus*, nursehound *Scyliorhinus stellaris*, spurdog *Squalus acanthias*, porbeagle *Lamna nasus*, kitefin shark *Dalatias licha*, shortfin mako *Isurus oxyrinchus*, blue shark *Prionace glauca*;
- **Migratory species:** Atlantic salmon *Salmo salar*, European eel *Anguilla anguilla*, sea trout *Salmo trutta*, river lamprey *Lampetra fluviatilis*, sea lamprey *Petromyzon marinus* and twaite shad *Alosa fallax*;
- **Shellfish – Crustaceans:** edible crab *Cancer pagurus*, Norwegian lobster *Nephrops norvegicus*, European lobster *Homarus gammarus*, brown shrimp *Crangon crangon*, spider crab *Maja squinado*, green shore crab *Carcinus maenus*, velvet swimming crab *Necora puber*, swimming crabs *Liocarcinus* spp.; and
- **Shellfish – Molluscs:** blue mussels *Mytilus edulis*, common whelk *Buccinum undatum*, king scallop *Pecten maximus*, queen scallop *Aequipecten opercularis*, cockle *Cerastoderma edule*, razor clam *Ensis* spp., squid *Loligo spp*. and Pacific oyster *Crassostrea gigas*.

Of the migratory species identified, Atlantic salmon are recognised as Annex II (EU Habitats Directive) species, an OSPAR species and declared as Vulnerable on the Ireland Red List. European eel is an OSPAR species, is listed on the Ireland Red List as Critically Endangered (King *et al.,* 2011) and has a European Union Management Plan. Sea trout are an OSPAR species and identified as Least Concern on the Ireland Red List. River and sea lamprey are Annex II (EU Habitats Directive) species and are listed as Near Threatened on the Ireland Red List. The twaite shad has been categorised as an Annex II and V (EU Habitats Directive) species and Vulnerable on the Ireland Red List.

The spawning and nursery habitats present in the Fish and Shellfish Ecology Study Area are summarised in Table 9-5 based on Ellis *et al*. (2012) and Coull *et al*. (1998). Nursery and spawning habitats were categorised by Ellis *et al*. (2012) as either high or low intensity dependent on the level of spawning activity or abundance of juveniles recorded. Spawning grounds identified by Coull *et al.* (1998) are classified as low, high or undetermined, again based on the level of spawning activity, however the intensity of nursery grounds is not specified. The Department of Housing, Local Government and Heritage (DHLGH, 2023) report identified herring spawning ground at the Mourne area as a potential feature for a proposed MPA (for further information on the Mourne herring ground, see section 9.7.1: Designated Sites).

Table 9-5: Species that have spawning and nursery areas that overlap with the Fish and Shellfish Ecology Study Area; additionally, spawning periods have been provided (Ellis et al., 2012; Coull et al., 1998; and DHLGH, 2023).

Common Name	Species	Spawning area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Nursery area
Demersal Species															
Anglerfish	*Lophius piscatorius*														Low
Lemon Sole	*Microstomus kitt*	Undetermined													Not specified
Plaice	*Pleuronectes platessa*	Low													Low
Sandeel	*Ammodytidae*	Low													Low
Sole	*Solea solea*	Low													
Whiting	*Merlangius merlangus*	Low													High
Cod	*Gadus morhua*	Low													High
Haddock	*Melanogrammus aeglefinus*														Not specified
Ling	*Molva molva*	Low													
Pelagic Species															
Herring	*Clupea harengus*														High
Mackerel	*Scomber scombrus*	Low													Low
Sprat	*Sprattus sprattus*	Undetermined													
Elasmobranchs															
Spotted ray	*Raja montagui*														Low
Thornback ray	*Raja clavata*														Low
Spurdog	*Squalus acanthias*		Viviparous species (reproduce all year)												High
Tope	*Galeorhinus galeus*		Viviparous species (reproduce all year)												Low

Spawning period

Peak spawning

Anecdotal evidence supports spawning in these months

Overlap with Fish and Shellfish Ecology Study Area

9.7.1 Designated sites

Designated sites which have fish and shellfish QIs and which have been considered in the fish and shellfish assessment are described in Table 9-6 below.

Table 9-6: Designated sites and relevant qualifying interests for the fish and shellfish assessment[a].

Designated Site	Closest Distance and Direction from the Fish and Shellfish Ecology Study Area (km)	Relevant Qualifying Interest
River Boyne And River Blackwater SAC	23.5 Southwest	• River Lamprey *Lampetra fluviatilis* • Atlantic Salmon *Salmo salar*
Slaney River Valley SAC	102.1 South	• Freshwater Pearl Mussel *Margaritifera margaritifera*[b] • Sea Lamprey *Petromyzon marinus* • River Lamprey *Lampetra fluviatilis* • Twaite Shad *Alosa fallax* • Atlantic Salmon *Salmo salar*

a Note: other non-fish features (e.g. mammals such as otter and seal) of these SACs are not presented (see chapter 10: Marine Mammals and Megafauna). Similarly, those purely freshwater fish features (e.g. brook lamprey) are also not presented as there is no impact pathway.

b Note: Although no direct impact pathway exists between the freshwater pearl mussel and the Project, this species lives on the gills of salmon and brown trout in the first year of life and hence could feasibly be impacted by the Project if these species are impacted (e.g. if fish migration to the relevant rivers is impeded).

In addition to the above identified designated sites, the report released by DHLGH (2023) 'Ecological sensitivity analysis of the western Irish Sea to inform future designation of Marine Protected Areas (MPAs)' has undertaken an analysis of the best available evidence of the western Irish Sea to determine the potential MPAs within the region. Forty biological and environmental features were identified that have the potential to be recommended for spatial protection in the western Irish Sea under the forthcoming MPA legislation.

As the MPAs have not been determined as of yet (February 2024), fish and shellfish features of concern listed within this report that have high population density and direct overlap with the Project have been considered within the baseline, and where relevant have been taken forward for assessment. These include:

- Herring *Clupea harengus* – due to the modelled presence of the herring spawning ground at Mourne.
- American Plaice *Hippoglossoides platessoides* - due to high presence within the Oriel area, note no spawning or nursery grounds.

9.7.2 Important ecological features

The important ecological features (IEFs) are those that are considered to be important and could be potentially affected by the Project. The importance of ecological features is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM, 2022). IEFs have been identified based on biodiversity importance, recognised through international or national legislation or through local, regional or national conservation plans (e.g. Annex II species under the Habitats Directive, species listed as threatened and/or declining by OSPAR, or Ireland Red List species), and on assessment of value according to the functional role of the species. Table 9-7 presents the criteria applied to determining the ecological value of IEFs within the geographic frame of reference applicable to the Fish and Shellfish Ecology Study Area.

Table 9-7: Criteria used to inform the importance of fish and shellfish receptors in the Fish and Shellfish Ecology Study Area.

Value of IEF	Defining Criteria
International	Internationally designated sites. Species protected under international law (i.e. Annex II species listed as QIs of SACs).
National	Nationally designated sites. Species protected under national law. Annex II species which are not listed as QIs of SACs in the Fish and Shellfish Ecology Study Area. OSPAR List of Threatened and/or Declining Species or Irish Red List species that have nationally important populations within the Fish and Shellfish Ecology Study Area, particularly in the context of species/habitat that may be rare or threatened in Irish waters. Species that have spawning or nursery areas within the Fish and Shellfish Ecology Study Area that are important nationally (e.g. may be primary spawning/nursery area for that species).
Regional	OSPAR List of Threatened and/or Declining Species or Irish Red List species that have regionally important populations within the Fish and Shellfish Ecology Study Area (i.e. are locally widespread and/or abundant). Species that are of commercial value to the fisheries which operate within the Fish and Shellfish Ecology Study Area. Species that form an important prey item for other species of conservation or commercial value and that are key components of the fish assemblages within the Fish and Shellfish Ecology Study Area. Species that have spawning or nursery areas within the Fish and Shellfish Ecology Study Area that are important regionally (i.e. species may spawn in other parts of Irish waters but this is a key spawning/nursery area within the Fish and Shellfish Ecology Study Area).
Local	Species that are of commercial importance but do not form a key component of the fish assemblages within the Fish and Shellfish Ecology Study Area (e.g. they may be exploited in deeper waters outside the Fish and Shellfish Ecology Study Area). The spawning/nursery area for the species are outside the Fish and Shellfish Ecology Study Area. The species is common throughout Irish waters but forms a component of the fish assemblages in the Fish and Shellfish Ecology Study Area.

Table 9-8 identifies the key fish and shellfish species likely to occur within the Fish and Shellfish Ecology Study Area and the wider Western Irish Sea Fish and Shellfish Ecology Study Area, based on the desktop review set out in appendix 9-1: Fish and Shellfish Ecology Technical Report. This also presents the value/importance as an ecological receptor based on the criteria outlined in Table 9-7. Specific reference is made to each species' commercial, conservation and ecological importance, where this is known. These species will be taken forward for assessment (see section 9.10).

Table 9-8: Summary of fish and shellfish important ecological features (IEFs) and their value/importance within the Fish and Shellfish Ecology Study Area.

Common Name	Scientific Name	Importance	Justification
Demersal Fish			
Benthic Fish			
Plaice	*Pleuronectes platessa*	Regional	Low intensity nursery and low intensity spawning habitat. Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Commercially important fish species in the region.
American plaice	*Hippoglossoides platessoides*	Regional	Due to high presence within the Oriel area, note no spawning or nursery grounds. IUCN Red List species – least concern. Whilst this species could be considered within the category as 'other flatfish species', following the precautionary principle, a regional IEF status has been given.
Other flatfish species	-	Local	Other flatfish species including, sole, lemon sole, turbot, flounder and megrim are all commercially important species in the region and are likely to occur within the Project site. These species either

Common Name	Scientific Name	Importance	Justification
			have no known spawning or nursery grounds or low intensity/undetermined nursery and spawning grounds.
Conger eel	*Conger conger*	Local	No known spawning or nursery grounds in the area. Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences.
Other small benthic fish species	-	Local	Small demersal species including wrasse, gobies and blennies are likely to be present and likely to be prey items for fish, bird and marine mammal species. No information is available on the spawning or nursery habitats of these species, they have little or no commercial importance and are not listed under any nature conservation legislation.
Benthopelagic Fish			
Cod	*Gadus morhua*	National	Low intensity spawning and high intensity nursery ground. Fish and Shellfish Ecology Study Area coincides with Irish Sea Cod Recovery Plan area. Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Commercially important species. Listed by OSPAR as threatened and/or declining and listed as vulnerable on the IUCN Red List.
Haddock	*Melanogrammus aeglefinus*	Regional	Spawning ground of unspecified intensity. Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Commercially important fish species in the region. IUCN Status: Vulnerable.
Whiting	*Merlangius merlangus*	Regional	Low intensity spawning and high intensity nursery habitats. Commercially important fish species in the region and a key prey species for other marine species (particularly harbour porpoise). Not identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences but is a target for local fisheries.
Other gadoids	-	Local	Other gadoid species including ling, Pollack, coalfish and hake have been identified as being likely to occur within the Project site and are likely to have some commercial importance in the region. These species either have no known spawning or nursery grounds or low intensity/undetermined nursery and spawning grounds.
Sea bass	*Dicentrarchus labrax*	Regional	Sea bass is a species that is targeted by recreational fisheries in the area. Dundalk Bay is important for this species, with spawning grounds potentially occurring in the area (IFI, pers. comm, 2021)
Anglerfish	*Lophius piscatorius*	Local	Low intensity nursery ground. Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Important commercial species in the Irish Sea, but not in local area.
Lesser sandeel	*Ammodytes tobianus*	Local	Low intensity nursery and spawning ground. Important prey species for fish, birds and marine mammals. Commercially important species. Not identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences.
Greater sandeel	*Hyperoplus lanceolatus*		
Pelagic Fish			
Herring	*Clupea harengus*	National	High intensity nursery, and Mourne spawning ground. Important prey species for larger fish, birds and marine mammals. Whilst currently not a feature of a designated MPA, the Mourne herring spawning grounds have been identified as a potential feature for consideration for a potential MPA. Therefore, following the precautionary principle, the herring spawning grounds have been given a National IEF value.
Mackerel	*Scomber scombrus*	Regional	Low intensity nursery and spawning ground. Identified as likely to occur within the Project site in the 2007 baseline study, based on

Common Name	Scientific Name	Importance	Justification
			habitat preferences. Important prey species for larger fish, birds and marine mammals.
Sprat	*Sprattus sprattus*	Local	Spawning ground of undetermined intensity. Not identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Important prey species for larger fish, birds and marine mammals.
Migratory Fish			
Sea lamprey	*Petromyzon marinus*	International	Very likely to migrate through the Project site. Annex II species and listed as QIs of a number of SACs within the Western Irish Sea Fish and Shellfish Ecology Study Area.
River lamprey	*Lampetra fluviatilis*		
Twaite shad	*Alosa fallax*		
Atlantic salmon	*Salmo salar*		
Sea trout	*Salmo trutta*	National	Very likely to migrate through the Project site. Listed as OSPAR threatened/declining species. Not a QI or feature of any designated sites in the Western Irish Sea Fish and Shellfish Ecology Study Area.
European eel	*Anguilla anguilla*	National	Very likely to migrate through the Project site. Listed as an OSPAR threatened/declining species and listed as critically endangered on the IUCN Red List and the Ireland Red List. Not a QI or feature of any designated sites in the Western Irish Sea Fish and Shellfish Ecology Study Area.
Elasmobranchs			
Small-spotted catshark	*Scyliorhinus canicula*	Local	Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Common and listed as of Least Concern on the IUCN Red List.
Nursehound	*Scyliorhinus stellaris*	Regional	Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Common, but listed as of Near Threatened on the IUCN Red List due to declines in the Mediterranean population.
Tope	*Galeorhinus galeus*	Regional	Low intensity nursery ground. Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Listed on Ireland Red List as Vulnerable.
Spurdog	*Squalus acanthias*	National	Not identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences, but the area has since been identified as a high intensity nursery ground. Listed on Ireland Red List as Endangered.
Rays	-	Local	Rays (most likely including thornback and spotted rays) were identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Low intensity nursery ground. Listed on Ireland Red List as Least Concern.
Skate	*Dipturus batis*	Regional	Not identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences, but has been noted as occurring in the general area. Skate are listed as Critically Endangered on the IUCN Red List.
Pelagic sharks	-	Regional	Large pelagic shark species including the porbeagle, kitefin, shortfin mako and blue shark are likely to be very occasional visitors to this area. Many of these species are listed as threatened on the IUCN Red List.
Shellfish			
Crustaceans			
Edible crab	*Cancer pagurus*	Regional	Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Important commercial species.

Common Name	Scientific Name	Importance	Justification
Norway lobster	*Nephrops norvegicus*	Regional	Spawning and nursery area 2.3 km and 5.8 km from the Project site. Not identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Second most valuable species fished by the Irish fleet and an important fishery in the local area.
European lobster	*Homarus gammarus*	Regional	Identified as likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. Important commercial species.
Other crustaceans	-	Local	Other crustaceans including velvet swimming crab, green shore crab, swimming crabs, spider crabs and brown shrimp have been identified as being likely to occur within the Project site in the 2007 baseline study, based on habitat preferences. They are all important commercial species, but not in the local area.
Molluscs			
Freshwater Pearl Mussel	*Margaritifera margaritifera*	International	Listed in Annexes II and V of the EU Habitats and Species Directive and Appendix III of the Bern Convention. Listed as Endangered on the IUCN Red List and is a QI of the Slaney River Valley SAC. This species lives on the gills of salmon and brown trout in the first year of life.
Cockles	*Cerastoderma edule*	National	Main cockle bed found in Dundalk Bay is under a Natura 2000 site management regime and a fishery Natura plan. Main cockle fishery in Ireland.
Razor clams	*Ensis spp.*	Regional	Dundalk Bay is designated as a shellfish water for its high density of razor clams. The Project site is located within a razor clam conservation area.
Blue mussel	*Mytilus edulis*	Regional	Important commercial species. Likely to be found along the offshore cable corridor. Cultivated in the Boyne Estuary and Carlingford Lough.
Pacific oysters	*Crassostrea gigas*	Regional	Important commercial species. Cultivated at Carlingford Lough and Annagassan.
Common whelk	*Buccinum undatum*	Regional	Important commercial species. Fished locally. Whilst whelk are not a protected species, there is concern about the fishery in general terms because of recent increases in its commercial value and uncertainties surrounding its size at maturity. Prey species for cod and other large fish and elasmobranchs.
Other mollusc species		Local	Other mollusc species are thought likely to occur in the area including the king scallop and queen scallop which are important commercial species. The main fishing grounds for these species are however, further offshore. There are also periwinkle grounds located at Carlingford Lough, Rathcor, Corstown Bridge and Skerries.
Squid	*Loligo*	Local	Important commercial species in the Irish Sea, but not in local area.

9.7.3 Future baseline scenario

The European Union (Planning and Development) (Environmental Impact Assessment) Regulations 2018 (hereafter the EIA Regulations 2018) require that "*a description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge*" is included within the EIAR.

In the event that the Project is not constructed, an assessment of the future baseline conditions has been carried out and is described below.

The baseline environment is not static and will exhibit some degree of natural change over time, even if the Project is not developed, due to naturally occurring cycles and processes. Therefore, when undertaking impact assessments, it will be necessary to place any potential impacts in the context of the envelope of change that might occur naturally over the timescale of the Project.

Further to potential change associated with existing cycles and processes, it is necessary to take into account the potential effects of climate change on the marine environment. Variability and long-term changes on physical influences may bring direct and indirect changes to fish and shellfish populations and communities in the mid to long term future (Heath *et al.,* 2012).

Records of sea surface temperature from around Ireland show a mean warming trend below the global average between 1850 and 2008 of 0.3 ˚C. However recent temperature records around Ireland show an accelerated rate of warming with temperatures rising by 0.6 ˚C per decade since 1994. Part of this dramatic increase has been attributed to global warming. The warmest sea temperature years on record have been 2005, 2006 and 2007 with particularly strong warming in the southeast of Ireland (Nolan *et al*., 2010). Changes in temperature will have an effect on fish at all biological levels (cellular, individual, population, species, community and ecosystem) both directly and indirectly. As sea temperatures rise, species adapted to cold water (e.g. cod and herring) will begin to disappear while warm water adapted species will become more established.

Any changes that may occur during the design life of the Project should be considered in the context of both greater variability and sustained trends occurring on national and international scales in the marine environment.

9.7.4 Data validity and limitations

The data sources used in this chapter are detailed in appendix 9-1: Fish and Shellfish Ecology Technical Report. The desktop data used are the most up to date publicly available information which can be obtained from the applicable data sources as cited. Data that has been collected is based on long-term existing literature, consultation with stakeholders, wider available survey data and identification of habitats to inform likely fish and shellfish species. No site-specific surveys have been carried out to inform the assessment, therefore, it is possible that fish and shellfish species have not been identified. However, given the detailed desktop study completed and the conservative approach adopted, which has included identification of a regional Fish and Shellfish Ecology Study Area (i.e. the Western Irish Sea Fish and Shellfish Ecology Study Area), it is unlikely that key species have been omitted from the assessment.

Where older datasets are used, such as Ellis *et al*., 2012 and Coull *et al*., 1998, fish and shellfish spawning, and nursery grounds are unlikely to have significantly changed and these datasets are informed by long term datasets which show consistent patterns in fish habitats. However, additional literature has been used to corroborate the information within these reports to ensure areas are still present.

9.8 Key parameters for assessment

9.8.1 Project design parameters

The project description is provided in volume 2A, chapter 5: Project Description. Table 9-9 outlines the project design parameters that have been used to inform the assessment of potential impacts of the construction, operational and maintenance and decommissioning phases of the Project on fish and shellfish.

Due to the potential for unexpected ground conditions and obstructions, the final route and length of the offshore export cable and offshore inter array cables will be confirmed during construction (see design flexibility details in chapter 5: Project Description (volume 2A). For the purposes of the assessment presented in section 9.10, the maximum length of cables has been considered to ensure the potential for maximum impact is assessed. Should the lengths of cables be less than those specified, then the potential for effects will not change the assessment outlined in section 9.10. An alternative route within the offshore wind farm area or offshore cable corridor will also not change the assessment in section 9.10.

Table 9-9: Project design parameters considered for the assessment of potential impacts on fish and shellfish ecology.

Potential impact	Phase[1] C	O	D	Project design parameters	Justification
Temporary subtidal habitat loss/disturbance	✓	✓	✓	**Construction Phase** 709,500 m^2 of temporary habitat loss/disturbance due to: • 54,000 m^2 due to the use of jack-up vessels during foundation installation, with two jack-up events per wind turbine generator (WTG) and four jack-up events for the offshore substation (OSS); • 570,000 m^2 due to the installation of 41 km inter-array cables and 16 km offshore cable with seabed disturbance width of 10 m; and • 85,500 m^2 due to sand wave clearance for 10% of inter-array cables and 10% of the offshore cable. Offshore construction phase duration of 15 months. **Operational and Maintenance Phase** 387,000 m^2 of temporary habitat loss/disturbance due to: • 51,000 m^2 due to component replacement activities using jack-up vessel associated with 25 WTGs and OSS; • 210,000 m^2 due to inter-array cables: seven repair events and seven reburial events over the lifetime of the Project; and • 126,000 m^2 due to offshore cable: three repair events and three reburial events over the lifetime of the Project (three intertidal and three subtidal). Operational phase of 40 years. **Decommissioning Phase** 624,000 m^2 of temporary habitat loss/disturbance. Parameters are assumed to be the same as for the construction phase with the exception that that there will be no sand wave clearance or seabed clearance associated with foundation installation.	The accounted number of WTGs and OSS and the maximum length of cables resulting in greatest extent of temporary habitat loss.
Injury and/or disturbance to fish from underwater noise during pile-driving	✓	✗	✗	**Construction Phase** • 26 monopiles (WTGs and OSS) of 9.6 m diameter; • Average maximum hammer energy of 2,500 kJ (absolute maximum of up to 3,500 kJ); • Average five hours piling per pile (maximum of eight hours) with one pile expected to be installed in each 24-hour period; • Maximum of 208 hours piling over a total of 26 days.	The assessment considers the maximum hammer energies and maximum piling duration for monopile installation. In many cases, monopile installation will require lower hammer energies and shorter piling durations.
Increased suspended sediment concentrations and associated sediment deposition	✓	✓	✓	**Construction phase** WTGs and OSS installed on monopile foundations: • Drilled installation of 9.6 m diameter pile. Installation of inter-array cables and offshore cable: • Disturbance of seabed material from a 1 m wide trench for inter-array cables, 3 m wide trench for offshore cable and 3 m deep trench; and • Modelled cable lengths over areas of sand and muddy sand. **Operational and Maintenance Phase**	Greatest volume of sediment released into the water column. See chapter 7: Marine Processes for further justification.

Potential impact	Phase[1] C	O	D	Project design parameters	Justification
				Cable repair/reburial activities: • Inter-array cables: seven repair events and seven reburial events; and • Offshore cable: three repair events and three reburial events (three subtidal and three intertidal). **Decommissioning Phase** WTGs and OSS on monopile foundations: • Cutting and removal of monopile foundations to approximately 2 m below seabed. Removal of inter-array cables and offshore cable: • Disturbance of seabed material from a 1 m wide trench for inter array cables, 3 m wide trench for offshore cable and 3 m deep trench.	
Long-term subtidal habitat loss	✗	✓	✗	**Operational and Maintenance Phase** 332,060 m^2 of long-term habitat loss due to: • Presence of 26 (i.e. 25 x WTG + 1 x OSS) monopile foundations with base diameter of 9.6 m and associated scour protection; and • Presence of cable protection associated with 41 km inter-array cables and 16 km offshore cable. Assumes 50% of inter-array cable route and 50% of offshore cable may require cable protection. Operational phase - 40 years.	The accounted number of WTG and OSS foundation type and associated scour protection; maximum length of cables and cable protection resulting in greatest extent of habitat loss.
Electromagnetic Fields (EMF) from subsea electrical cabling	✗	✓	✗	**Operational and Maintenance Phase** Presence of inter-array cables and offshore cable: • 41 km of 66 kV AC inter-array cables; • 16 km of 220 kV offshore cable; • Burial depths of between 0.5 m and 3 m; and • 50% of inter-array cable route and 50% of offshore cable corridor may require cable protection. Operational phase of 40 years.	Maximum length of cables and minimum burial depth (the greater the depth the more the EMF is attenuated).

1. *C= Construction, O = Operation, D = Decommissioning*

9.8.2 Measures included in the Project

As part of the project design process, a number of measures have been proposed to prevent or reduce the potential for impacts on Fish and Shellfish Ecology (see Table 9-10). As there is a commitment to implement these measures, they are considered inherently part of the design of the Project and have therefore been considered in the assessment presented in section 9.10 below (i.e. the determination of magnitude and therefore significance assumes implementation of these measures). These measures are considered standard industry practice for this type of development.

Table 9-10: Measures included in the Project.

Measures included in the Project	Justification
An Environmental Management Plan (EMP) (see volume 2A, appendix 5-2: Environmental Management Plan) will be implemented during the construction, operational and maintenance and decommissioning phases of the Project. The EMP includes project specific measures and	To ensure that the potential for release of pollutants from construction, operational and maintenance, and decommissioning plant is minimised. In this manner, accidental release of contaminants from vessels will be strictly controlled, thus providing protection for marine life across all phases of the Project.

Measures included in the Project	Justification
commitments and a Marine Pollution Contingency Plan (MPCP). Measures also include designated areas for refuelling where spillages can be easily contained, storage of chemicals in secure designated areas in line with appropriate regulations and guidelines, double skinning of pipes and tanks containing hazardous substances, and storage of these substances in impenetrable bunds.	
Burial and protection of cables - The cables will be buried below the seabed wherever possible, to a minimum burial depth of 0.5 m and a maximum burial depth of 3of 3 m. The appointed contractor will be required prior to the construction phase to submit details on the cable specification and installation methodology. This will include details on the cable laying, including geotechnical data, cable laying techniques and a cable burial risk assessment. Also, in advance of any cable repair, the contractor will be required to submit details on the parameters of the repair or reburial activities and the proposed methodology.	While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and marine mammal and megafauna (and fish and shellfish) receptors, thereby potentially reducing the effect on those receptors.
During piling operations, soft starts will be used (in accordance with international best practices for underwater noise, which includes the 'Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters' (NPWS, 2014)2). This will involve the implementation of lower hammer energies (i.e. approximately 10-15% of the maximum hammer energy; see section 9.10.2 below) at the beginning of the piling sequence before energy input is 'ramped up' (increased) over time to required higher levels.	This measure will minimise the risk of injury to fish species in the immediate vicinity of piling operations, allowing individuals to flee the area before noise levels reach a level at which injury may occur.

9.8.3 Impacts scoped out of the assessment

On the basis of the baseline environment and the project description outlined in volume 2A, chapter 5: Project Description, a number of impacts are proposed to be scoped out of the assessment for fish and shellfish ecology. These impacts are outlined, together with a justification for scoping them out, in Table 9-11.

[2] It is expected that this guidance will be updated in 2024. The final guidance will be included in this measure.

Table 9-11: Impacts scoped out of the assessment for fish and shellfish ecology.

Potential impact	Justification
Seabed disturbance leading to the release of sediment contaminants and resulting potential effects on fish and shellfish ecology	Site specific sediment sampling for contaminants will be carried out prior to construction of the Project. Although site specific sediment contamination levels are unknown at this time, it is considered unlikely that sources of contamination will be present in any greater concentrations than trace amounts. There is limited potential of contamination to sediments from anthropogenic activities given the levels identified within the offshore wind farm area and offshore cable corridor. In addition, sediments at the offshore wind farm area and offshore cable corridor contain sand and coarse sediment which will not retain contamination substances as coarser sediments are harder to combine with and any contamination will be washed away and diluted to negligible levels. Assessment of any possible contamination on benthic ecology receptors considered the impact to be negligible (chapter 8: Benthic Subtidal and Intertidal Ecology). As such, there is no potential for significant effects on fish and shellfish receptors from this impact and this impact has therefore been scoped out of the assessment.
Accidental release of pollutants	The measures set out in Table 9-10 will minimise the likelihood of accidental release of pollutants (e.g. spillage of chemicals) and in the unlikely event that such an incident occurs, they will limit the severity of any such release. The offshore wind farm area is relatively close to operational port facilities and as such offshore refuelling will not occur. All offshore operations will be subject to the measures set out in a Marine Pollution Contingency Plan (see annex 2 in appendix 5-2: Environmental Management Plan (volume 2A), and intertidal works will be subject to an Environmental Management Plan. As such, significant effects on fish and shellfish receptors from this impact are unlikely and this impact has therefore been scoped out of the assessment.
Disturbance to fish from underwater noise generated by vessels during construction, operation and decommissioning	Underwater noise modelling presented in appendix 10-2: Subsea Noise Technical Report showed that underwater noise generated from vessels will be low and effects from noise emissions would only occur if fish species remained within immediate vicinity of the vessel (i.e. within metres) for a period longer than 12 hours which is highly unlikely. As such, there is no potential for significant effects on fish and shellfish receptors from this impact and this impact has therefore been scoped out of the assessment.
Disturbance to fish from underwater noise generated by wind turbines during operation	Noise generated by operational wind turbines is of a very low frequency and low sound pressure level (Andersson *et al.,* 2011). Studies have found that sound levels are only high enough to possibly cause a behavioural reaction within metres from a wind turbine (Sigray and Andersson, 2011; Andersson *et al.,* 2011) and therefore such levels are not considered to have potentially significant effects on fish and shellfish receptors. This impact has therefore been scoped out of the assessment.
Colonisation of hard structures	There is the potential for subsurface structures to provide suitable substrate for colonisation of some mollusc species. However, the increase in surface area suitable for colonisation would be extremely small in the context of hard and soft sediment habitats in the Fish and Shellfish Ecology Study Area and therefore this would not have a potentially significant effect on the diversity or population levels associated with shellfish receptors within the Fish and Shellfish Ecology Study Area. This impact has therefore been scoped out of the assessment.
Impacts (injury and behavioural effects) to fish from geophysical survey noise generated during operational and maintenance surveys.	Injury ranges associated with geophysical surveys would be orders of magnitude smaller than those associated with piling activities. For geophysical surveys, injury has the potential to occur in very close proximity to geophysical survey equipment (i.e. within metres, if injury occurs at all), however injury will be avoided through the use of a ramp up procedure (i.e. where energy levels of survey equipment are slowly increased to the maximum to allow time for receptors to move away from noise levels that may cause injury). Temporary and reversible behavioural responses to geophysical surveys would be limited to tens to low hundreds of metres from the mobile geophysical survey vessel (again, where these occur at all). These impacts has therefore been scoped out of the assessment.
Temperature rises from the subsea cables causing a barrier effect	Warming of subsea cables may cause an increase in temperature of the seabed habitats (i.e. sands and gravels). All cables will be buried either beneath surface sediments or cable protection and as such, any increases in temperature at the sediment surface will be very small and highly localised in extent (i.e. any

Potential impact	Justification
	temperature increase would only occur in the immediate vicinity of the buried cable, i.e. within ~1 m). Due to the small changes predicted at the seabed and the highly localised nature of the change, it is not predicted to affect fish and shellfish receptors.

9.9 Impact assessment methodology

9.9.1 Overview

The fish and shellfish ecology assessment has followed the methodology set out in volume 2A, chapter 3: EIA Methodology. Specific to the fish and shellfish ecology assessment, the following guidance and policy documents have also been considered:

- EPA (2022) Guidelines on the Information to be Contained in Environmental Impact Assessment Reports;
- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2022);
- Guidance on Marine Baseline Ecological Assessments & Monitoring Activities for Offshore Renewable Energy Projects Parts 1 and 2 (DCCAE, 2018);
- Marine Strategy Framework Directive (European Union, 2008);
- Ireland's National Biodiversity Plan 2023-2030 (DCHG, 2022); and
- Ireland's Integrated Marine Plan 2012.

In addition, the fish and shellfish ecology assessment has considered the legislative framework as defined by:

- The Wildlife Act 1997 (Amendment 2000); and
- European Communities (Birds and Natural Habitats) Regulations 2011.

9.9.2 Impact assessment criteria

Determining the significance of effects is a process that involves defining the magnitude of the impacts and the sensitivity of the receptors. This section describes the criteria applied in this chapter to assign values to the magnitude of potential impacts and the sensitivity of the receptors. The terms used to define magnitude and sensitivity are based on those which are described in further detail in volume 2A, chapter 3: EIA Methodology.

The criteria for defining impact magnitude in this chapter are outlined in Table 9-12 below.

Table 9-12: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition
High	Loss of resource and/or quality and integrity of resource; severe damage to key characteristics, features or elements (Adverse)
	Large scale or major improvement of resource quality; extensive restoration or enhancement; major improvement of attribute quality (Beneficial)
Medium	Loss of resource, but not adversely affecting integrity of resource; partial loss of/damage to key characteristics, features or elements (Adverse)
	Benefit to, or addition of, key characteristics, features or elements; improvement of attribute quality (Beneficial)
Low	Some measurable change in attributes, quality or vulnerability, minor loss or, or alteration to, one (maybe more) key characteristics, features or elements (Adverse)

Magnitude of impact	Definition
	Minor benefit to, or addition of, one (maybe more) key characteristics, features or elements; some beneficial impact on attribute or a reduced risk of negative impact occurring (Beneficial)
Negligible	Very minor loss or detrimental alteration to one or more characteristics, features or elements (Adverse)
	Very minor benefit to, or positive addition of one or more characteristics, features or elements (Beneficial)

The sensitivity of fish and shellfish IEFs has been defined by an assessment of the combined vulnerability of the receptor to a given impact and the likely rate of recoverability to pre-impact conditions. Vulnerability is defined as the susceptibility of a species to disturbance, damage or death, from a specific external factor. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. Recoverability is dependent on a receptor's ability to recover or recruit subject to the extent of disturbance/damage incurred. Information on these aspects of sensitivity of the fish and shellfish IEFs to given impacts has been informed by the best available evidence following environmental impact or experimental manipulation in the field and evidence from the offshore wind industry and analogous activities such as those associated with aggregate extraction, electrical cabling, and oil and gas industries. These assessments have been combined with the assessed conservation status (i.e. the level of designation/importance) of the affected receptor as defined in section 9.7 and as presented in Table 9-8 for the fish and shellfish IEFs considered in this assessment. The criteria for defining receptor sensitivity in this chapter are outlined in Table 9-13 below.

Table 9-13: Definition of terms relating to the sensitivity of the receptor.

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

The significance of the effect upon fish and shellfish ecology is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The particular method employed for this assessment is presented in Table 9-14. Where a range of significance of effect is presented in Table 9-14, the final assessment for each effect is based upon calculated assessment and professional judgement.

For the purposes of this assessment, any effects with a significance level of slight or less have been concluded to be not significant in terms of the EIA Regulations.

Table 9-14: Matrix used for the assessment of the significance of the effect.

Sensitivity of receptor	Magnitude of impact			
	Negligible	**Low**	**Medium**	**High**
Negligible	Imperceptible	Imperceptible or slight	Imperceptible or slight	Slight
Low	Imperceptible or slight	Imperceptible or slight	Slight	Slight or moderate
Medium	Imperceptible or slight	Slight	Moderate	Moderate or major
High	Slight	Slight or moderate	Moderate or major	Major or Profound

9.9.3 Designated sites

Where Natura 2000 sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the QIs of internationally designated sites as described within section 9.7 of this chapter (with the assessment on the site itself deferred to the Natura Impact Statement (NIS) for the Project).

With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site and where QIs of the Natura site are also features of interest of the nationally designated sites (e.g. natural heritage areas (NHAs) which underpin a Natura site), only the international site has been taken forward for assessment. This is because potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken). However, where a nationally designated site falls outside the boundaries of an international site, but within the Fish and Shellfish Ecology Study Area, an assessment of the impacts on the overall site is made in this chapter using the EIA methodology.

9.10 Assessment of significance

The potential impacts arising from the construction, operational and maintenance and decommissioning phases of the Project are listed in Table 9-9, along with the project design parameters against which each impact has been assessed.

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

9.10.1 Temporary subtidal habitat loss/disturbance

Direct temporary habitat loss/disturbance of subtidal benthic habitats within the offshore wind farm area and offshore cable corridor during the construction, operational and maintenance, and decommissioning phases will occur as a result of a range of activities including use of jack-up vessels during foundation installation/maintenance, installation and maintenance of inter-array cables and offshore cable and anchor placements associated with these activities. Disturbance to these habitats has the potential to affect identified fish and shellfish IEFs directly (e.g. removal or injury of individuals) and indirectly (e.g. loss of important fish and shellfish habitats, such as spawning grounds).

Construction Phase

Magnitude of impact

The installation of infrastructure within the offshore wind farm area and offshore cable corridor may lead to temporary subtidal habitat loss/disturbance. The project design parameter is for 709,500 m^2 of temporary habitat loss/disturbance during the construction phase (Table 9-9)). This equates to 1.3% of the offshore wind farm area and offshore cable corridor and as such represents a very small proportion of the Project.

Jack-up footprints associated with foundation installation will result in compression of seabed sediments beneath spud cans where these are placed on the seabed. These will infill over time, although may remain on the seabed for a number of years, as demonstrated by monitoring studies of UK offshore wind farms (BOWind, 2008; EGS, 2011). Monitoring at the Barrow offshore wind farm showed depressions were almost entirely infilled 12 months after construction (BOWind, 2008). Monitoring at Lynn and Inner Dowsing offshore wind farm also showed some infilling of the footprints, although the depressions were still visible a couple of years post construction (EGS, 2011). In areas where mobile sands and coarse sediments are present such as in the majority of the offshore wind farm area (see chapter 8: Benthic Subtidal and Intertidal Ecology), jack-up depressions are likely to be temporary features which will only persist for a period of months to a small number of years.

Temporary habitat loss will also occur as a result of the installation of 41 km of inter-array cables and 16 km of offshore cable, with seabed disturbance occurring within a 10 m wide corridor. A recent review commissioned by The Crown Estate reviewed the effects of cable installation on subtidal sediments and habitats (RPS, 2019), drawing on monitoring reports from over 20 UK offshore wind farms. This review showed that sandy sediments recover quickly following cable installation, with trenches infilling quickly following cable installation and little or no evidence of disturbance in the years following cable installation. It also presented evidence that remnant cable trenches in coarse and mixed sediments and muddy sediments were conspicuous for several years after installation. However, these shallow depressions were of limited depth (i.e. tens of cm) relative to the surrounding seabed, over a horizontal distance of several metres and therefore did not represent a large shift from the baseline environment (RPS, 2019).

Activities resulting in the temporary subtidal habitat loss/disturbance will occur intermittently throughout the construction phase. The offshore construction phase which includes activities resulting in temporary habitat loss/disturbance will occur over a period of 15 months.

The temporary habitat loss/disturbance is predicted to be of localised spatial extent, medium term duration (although only a small proportion of the total area will be affected at any one time with individual elements of construction having much shorter durations), intermittent and high reversibility following the construction phase. It is predicted that the impact will affect fish and shellfish receptors directly or indirectly dependent on species life strategies. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

In general, mobile fish species are able to avoid areas subject to temporary habitat disturbance (EMU, 2004). The most vulnerable species are likely to be shellfish which are much less mobile than fish. For example, egg bearing lobster are thought to be more restricted to an area based on a mark and recapture study in Norway which showed that 84% of berried female lobster remained within 500 m of their release site (Agnalt *et al*., 2007). Evidence from other stocks around the world are less clear, with limited movement recorded for some stocks and long-distance migrations documented for other stocks (e.g. Campbell and Stasko,1985; Comeau and Savoie, 2002).

Indirect effects on fish and shellfish species also include loss of feeding habitat and prey items. For example, green shore crab and swimming crabs are considered important prey species for larger fish. However, since this impact is predicted to affect only a small proportion of benthic habitats in the offshore wind farm area, with similar habitats (and prey species) occurring throughout the Fish and Shellfish Study Area (see chapter 8: Benthic Subtidal and Intertidal Ecology), these effects are likely to be limited.

The fish and Shellfish Ecology Study Area was found to coincide with known habitat for a number of commercially important shellfish species such as edible crab, lobster and velvet swimming crab. Habitat loss in this area will represent a relatively small temporary disturbance to these habitats (e.g. during cable laying), with recovery of sediments, and following this, recovery of associated communities (see chapter 8: Benthic Subtidal and Intertidal Ecology) including shellfish populations into these areas. The recoverability and rate of recovery of an area after large-scale seabed disturbance (e.g. dredging or trawling activities) is linked to the substrate type (Newell *et al*., 1998; Desprez, 2000). Mud or sand habitats, similar to those found in the Fish and Shellfish Ecology Study Area, have been shown to return to baseline species abundance after approximately one to two years (Newell *et al*., 1998; Desprez, 2000; chapter 8: Benthic Subtidal and Intertidal Ecology). Harder gravely and rocky substrate takes proportionally longer to re-establish: up to ten years for boulder coastlines (Newell *et al*., 1998).

Larger crustacea (e.g. Nephrops, European lobster) are classed as equilibrium species (Newell *et al*., 1998) and are only capable of recolonising an area once the original substrate type has returned. The sensitivity of these fish and shellfish receptors is therefore higher than for smaller benthic organisms which move in and colonise new substrate immediately after the effect. Therefore, although recovery of benthic assemblages may occur over relatively fast timescales (e.g. within one to two years; see chapter 8: Benthic Subtidal and Intertidal Ecology), recovery of the equilibrium species may take up to ten years in some areas of coarse sediments (Phua *et al*., 2002). Larval settlement will also increase the rate of recovery in an area (Phua *et al*., 2002), with shellfish spawning and nursery habitats in the vicinity of the Project (see section 9.7) potentially increasing the rate of recovery into disturbed areas. A recent study undertaken during construction of the Westernmost Rough Offshore Wind Farm located on the northeast coast of England, within a European lobster fishing ground, found that the size and abundance of lobster individuals increased following temporary closure or the area for construction of the wind farm. This study shows that the activities associated with construction of the wind farm which included installation of turbines and cables did not impact on resident lobster populations and instead allowed some respite from fishing activities for a short time period before reopening following construction (Roach *et al.,* 2018).

The fish species within the Fish and Shellfish Study Area which are likely to be most sensitive to temporary habitat loss are those species which spawn on or near the seabed sediment (e.g. herring, sandeel and elasmobranchs including the spotted ray). Construction operations (including cable installation) within the Fish and Shellfish Ecology Study Area are not likely to impact on spawning and nursery habitats for *Nephrops*, as these areas are located approximately 2.3 km and 5.8 km from the Fish and Shellfish Study Area respectively (appendix 9-1: Fish and Shellfish Ecology Technical Report). Of the IEF fish species that spawn on or near the seabed, sandeel and herring are known to spawn within the vicinity of the offshore wind farm area and offshore cable corridor. Therefore, any significant seabed disturbance activities carried out during spawning periods may result in mortality of eggs and reduced opportunity due to removal of suitable habitat. Any such effects would, however, be temporary, with sediments quickly recovering to baseline conditions as set out above.

Physical disturbance to sandeel habitats may also lead to direct effects on adult and juvenile sandeel (e.g. increased mortality), where individuals are not able to colonise viable sandy habitats in the immediate vicinity, or where habitats may be at carrying capacity. Sandeel may also be particularly vulnerable during their winter hibernation period when they bury themselves in the seabed substrates and are therefore less mobile. Recovery of sandeel populations would be expected, however, following construction operations, with the rate of recovery dependent on the recovery of sediments to a condition suitable for sandeel recolonization. Effects of offshore wind farm construction (Jensen *et al*., 2004) and operation (i.e. post-construction van Deurs *et al*., 2012) on sandeel populations have been examined through short term and long-term monitoring studies at the Horns Rev offshore wind farm in the Baltic Sea, Denmark. These monitoring studies have shown that offshore wind farm construction and operation has not led to significant negative effects on sandeel populations.

Further information on the recovery potential of sandeel populations can also be inferred from a study by Jensen *et al*. (2010), who found sandeel populations would mix within fishing grounds to distances of up to 28 km. This suggests that some recovery of adult populations is likely following construction operations, with adults recolonising suitable sandy substrates from adjacent un-impacted habitats. Recovery may also occur through larval recolonisation of suitable sandy sediments with sandeel larvae likely to be distributed throughout the Fish and Shellfish Ecology Study Area during spring months following spawning in winter/spring (see Ellis *et al*., 2012; appendix 9-1: Fish and Shellfish Ecology Technical Report). As effects on sandeels (and other prey species) are predicted to be limited in extent (particularly in the context of available habitats in the wider area), temporary and reversible, with recovery of sandeel populations occurring post construction, species reliant on sandeels and other small prey species (e.g. sea trout, bass and cod) would similarly not be expected to be significantly affected.

Of the herring spawning grounds, appendix 9-2: Herring Spawning - Technical Report details the suitable alternate available habitat for herring spawning within and around the Fish and Shellfish Ecology Study Area. Whilst 709,500 m^2 of habitat could be temporarily lost or disturbed, this is unlikely to have a significant effect on the herring population as herring will likely use the suitable alternative habitat available. The construction impacts considered in this assessment are also temporary and sediments will recovery following cessation of construction activities, as set out above. Furthermore, once the construction phase is complete, the presence of the turbines, cable and scour protections measures will introduce additional hard substrate into the area, creating more spawning habitat for herring to use. Should construction be undertaken outside of the spawning period, then this receptor is unlikely to have any temporary impact.

Most fish and shellfish receptors in the Fish and Shellfish Ecology Study Area are deemed to be of low vulnerability, high recoverability and of local to international importance within the Fish and Shellfish Ecology Study Area. The sensitivity of these fish and shellfish receptors is therefore considered to be low.

European lobster and *Nephrops* are deemed to be of high vulnerability, medium to high recoverability and of regional importance within the Fish and Shellfish Ecology Study Area. The sensitivity of these fish and shellfish receptors is therefore considered to be medium.

Sandeel are deemed to be of high vulnerability, medium recoverability and of regional importance within the Fish and Shellfish Ecology Study Area. The sensitivity of these fish and shellfish receptors is therefore considered to be medium.

Herring are deemed to be of medium vulnerability, medium recoverability and of national importance within the Fish and Shellfish Ecology Study Area. The sensitivity of herring to this impact is therefore considered to be medium.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low to medium. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Operational and maintenance phase

Magnitude of impact

Operational and maintenance activities within the offshore wind farm area and offshore cable corridor may lead to temporary subtidal habitat loss/disturbance. The project design parameter is for up to 387,000 m^2 of temporary habitat loss/disturbance during the operational and maintenance phase (Table 9-9). This equates to 0.7% of the offshore wind farm and offshore cable corridor combined (chapter 8: Benthic Subtidal and Intertidal Ecology), therefore this represents a very small proportion of the offshore wind farm area and offshore cable corridor combined. It should also be noted that only a small proportion of the total habitat loss/disturbance is likely to be occurring at any one time over the 40-year operational phase of the Project.

Temporary habitat loss will occur as a result of the use of jack-up vessels during any component replacement activities and during any inter-array and offshore cable repair activities. Impacts of jack-up vessel activities will be similar to those identified for the construction phase above and will be restricted to the immediate area around the wind turbine foundation or cable repair site, where the spud cans are placed on the seabed, with recovery occurring following removal of spud cans. Inter-array and offshore cable repair or reburial activities will also affect benthic habitats in the immediate vicinity of these operations, with effects on seabed habitats also expected to be similar to the construction phase. The spatial extent of this impact is very small in relation to the offshore wind farm area and offshore cable corridor, although there is the potential for repeat disturbance to the habitats because of these activities (e.g. placement of spud cans on or in close proximity to where these were placed during construction; remedial burial of a length of cable installed during the construction phase, affecting the same area of seabed). Activities resulting in the temporary subtidal habitat loss/disturbance will occur intermittently throughout the operational and maintenance phase.

The temporary habitat loss/disturbance is predicted to be of localised spatial extent, short term duration (individual maintenance operations would occur over the period of days to weeks) intermittent and high reversibility. It is predicted that the impact will affect fish and shellfish receptors directly or indirectly depending on the fish species life strategies. The magnitude is therefore, considered to be negligible.

Sensitivity of the receptor

The sensitivity of the fish and shellfish receptors can be found in the construction phase assessment above.

Significance of the effect

Overall, the magnitude of the impact is deemed to be negligible and the sensitivity of the fish and shellfish receptors is considered to be low to medium. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Decommissioning Phase

Magnitude of impact

Decommissioning activities within the offshore wind farm area and offshore cable corridor may lead to temporary subtidal habitat loss/disturbance. The project design parameter is for up to 624,000 m^2 of temporary habitat loss/disturbance during the decommissioning phase (Table 9-9). This equates to 1.2% of the offshore wind farm area and offshore cable corridor combined, which represents a very small proportion of the offshore wind farm area and offshore cable corridor combined. For the purposes of this assessment, the impacts of decommissioning are predicted to be similar to those for the construction phase, as set out above.

The temporary habitat loss/disturbance is predicted to be of localised spatial extent, medium term duration (although only a small proportion of the total area will be affected at any one time with individual elements of decommissioning having much smaller durations) intermittent and high reversibility following the decommissioning phase. It is predicted that the impact will affect fish and shellfish receptors directly or indirectly dependent on species life strategies. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

The sensitivity of the fish and shellfish receptors can be found in the construction phase assessment above.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low to medium. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

9.10.2 Injury and/or disturbance to fish from underwater noise during pile-driving

Construction Phase

Magnitude of impact

The installation of foundations within the offshore wind farm area may lead to injury and/or disturbance to fish from underwater noise during pile driving. As outlined in Table 9-9, the parameter assessed considers the maximum hammer energy and maximum piling duration, with 26 monopiles (WTGs and OSS), with each monopile installed via impact/percussive piling with an average maximum hammer energy of 2,500 kJ and absolute maximum hammer energy of up to 3,500 kJ. A maximum duration of 208 hours of piling activity, over a maximum 26-day period, may take place during the construction phase.

To understand the magnitude of noise emissions from piling during construction activity, subsea noise modelling has been undertaken considering the key parameters summarised above. Full details of the modelling undertaken are presented in appendix 10-2: Subsea Noise Technical Report, based on the piling scenario outlined above. Piling activities were modelled for monopiles at two locations, at the westernmost and easternmost extremes of the offshore wind farm area (based on hypothetical wind turbine locations in order to provide the most extreme case). Two events were modelled, an unmitigated event during which piling starts at maximum energy, and a mitigated event in which all soft start and low energy phases of piling are applied. The implications of the modelling for fish and shellfish injury and behaviour are outlined in the sensitivity section below.

The impact of construction related underwater noise is predicted to be of regional spatial extent, short term duration, intermittent and high reversibility following cessation of piling activities during the construction phase. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

Underwater noise can potentially have a negative impact on fish species ranging from physical injury/mortality to behavioural effects. Recent peer reviewed guidelines have been published by the Acoustical Society of America (ASA) and provide directions and recommendations for setting criteria (including injury and behavioural criteria) for fish. The Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*., 2014) were considered to be most relevant for impacts of underwater noise on fish species (see appendix 10-2: Subsea Noise Technical Report). The Popper *et al*. (2014) guidelines broadly group fish into the following categories according to the presence or absence of a swim bladder and on the potential for that swim bladder to improve the hearing sensitivity and range of hearing (Popper *et al*., 2014):

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

Relatively few studies have been conducted on impacts of underwater noise on invertebrates, including crustacean species, and little is known about the effects of anthropogenic underwater noise upon them (Hawkins and Popper, 2012; Morley *et al.,* 2013, Williams *et al.,* 2015). No injury criteria have therefore been developed. However, to determine the level of significance on shellfish receptors a review of literature sources has been undertaken, as set out below.

An assessment of the potential for injury/mortality and behavioural effects to be experienced by fish and shellfish receptors with reference to the sensitivity criteria described above is presented in turn below.

Injury

Table 9-15 summarises the fish injury criteria recommended for pile driving based on the Popper *et al*. (2014) guidelines, noting that dual criteria are adopted in these guidelines to account for the uncertainties associated with effects of underwater noise on fish.

Table 9-15: Criteria for onset of injury to fish due to impulsive piling (Popper *et al*., 2014).

Group	Type of animal	Parameter	Mortality and potential mortal injury	Recoverable injury
1	Fish: no swim bladder (particle motion detection)	SEL, dB re 1 μPa^2s	>219	>216
		Peak, dB re 1 μPa	>213	>213
2	Fish: where swim bladder is not involved in hearing (particle motion detection)	SEL, dB re 1 μPa^2s	210	203
		Peak, dB re 1 μPa	>207	>207
3 and 4	Fish: where swim bladder is involved in hearing (primarily pressure detection)	SEL, dB re 1 μPa^2s	207	203
		Peak, dB re 1 μPa	>207	>207
N/A	Eggs and larvae	SEL, dB re 1 μPa^2s	>210	(*Near*) Moderate[a] (*Intermediate*) Low (*Far*) Low
		Peak, dB re 1 μPa	>207	

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

The full results of the underwater noise modelling are presented in appendix 10-2: Subsea Noise Technical Report. In order to inform this assessment, Table 9-16 and Table 9-17 display the predicted injury ranges associated with the installation of one 9.6 m diameter monopile at the east of the offshore wind farm area, for peak sound pressure levels (SPL_{pk}) and cumulative sound exposure level (SEL_{cum}) respectively. This modelled event resulted in the greatest predicted injury ranges and therefore forms the focus of the assessment for injury[3].

For cumulative SEL, injury ranges were calculated for piling activities. This assumed that piling commenced with a soft start, where piling energy was increased gradually over a period of time (see appendix 10-2: Subsea Noise Technical Report), allowing for sensitive receptors to move out of the areas where greatest noise levels would be experienced. Injury ranges for peak sound pressure levels are presented for the maximum hammer energy (i.e. 3,500 kJ) and therefore represent the maximum design parameter (spatial) for injury ranges (noting that hammer energies and therefore injury ranges, are expected to be well below the maximum).

For peak pressure noise levels when piling energy is at its maximum (i.e. 3,500 kJ), recoverable injury to fish may occur within approximately 357 m of the piling activity. The potential for mortality or mortal injury to fish eggs would also occur at distances of up to 357 m (Table 9-16). It should be noted that these ranges are the maximum ranges for the maximum hammer energy, and it is unlikely that injury will occur in this range due to the implementation of soft starts during piling operations (see Table 9-10), which will allow fish to move away from the areas of highest noise levels, before they reach a level that would cause an injury. As outlined in Table 9-16 below, the initial injury ranges for soft start initiation are considerably lower (i.e. approximately 118 m to approximately 172 m, depending on the fish species considered).

For cumulative noise levels over a period of 24 hours, recoverable injury to fish may occur within approximately 20 m of the piling activity, while for eggs and larvae mortality could occur to ranges of up to 362 m.

The injury ranges presented are for the maximum design parameter, but in reality, the risk of fish injury will be considerably lower due to the hammer energies being lower than the absolute maximum modelled, the expected fleeing behaviour of fish from the area affected when exposed to high levels of noise and the soft start procedure which will be employed for all piling to ensure that fish have sufficient time to vacate the areas where injury may occur prior to noise levels reaching that level.

Table 9-16: Summary of peak pressure maximum injury ranges for fish due to installation of one 9.6 m diameter monopile at the east of the offshore wind farm area (assuming hammer energy of 3,500 KJ).

Fish Type	Injury Type	Threshold (SPL_{pk}, dB re 1 µPa)	Range (m)	
			Full Energy	First Strike (soft start)
No swim bladder (particle motion detection)	Mortality	213	245	118
	Recoverable injury	213	245	118
Swim bladder not involved in hearing (particle motion detection)	Mortality	207	357	172
	Recoverable injury	207	357	172
Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	357	172
	Recoverable injury	207	357	172
Fish eggs and larvae	Mortality	207	357	172

[3] Predicted injury ranges modelled for the west of the offshore wind farm area and those associated with the installation of monopiles are presented in appendix 10-2: Subsea Noise Technical Report.

Table 9-17: Summary of cumulative SEL injury ranges for fish due to installation of one 9.6 m diameter monopile at the east of the offshore wind farm area (N/E = threshold not exceeded).

Fish Type	Injury Type	Threshold (SEL_{cum}, dB re 1 µPa^2s)	Range, m
No swim bladder (particle motion detection)	Mortality	219	N/E
	Recoverable injury	216	N/E
Swim bladder not involved in hearing (particle motion detection)	Mortality	210	N/E
	Recoverable injury	203	19
Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	<10
	Recoverable injury	203	19
Fish eggs and larvae	Mortality	210	362
All fish types	Temporary threshold shift	186	690

Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. Normal hearing ability returns following cessation of the noise causing TTS, though the recovery period is variable. When experiencing TTS, fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment. Table 9-18 presents the ranges at which TTS in fish may occur as a result of piling for one 9.6 m diameter monopile. This indicates that effects of TTS may occur to maximum ranges of up to 690 m.

Of the key shellfish species of the Fish and Shellfish Ecology Study Area, decapod crustaceans (e.g. lobster and crab) are believed to be physiologically resilient to noise as they lack gas filled spaces within their bodies (Popper *et al*., 2001). To date no lethal effects of underwater noise have been described for *C. pagurus* (edible crab), *H. gammarus* (European lobster) *or N. norvegicus* (Norway lobster), however a number of sub-lethal physiological effects have been reported among *N. norvegicus* and related species. In a report by Christian *et al*. (2003), no significant difference was found between acute effects of seismic airgun exposure (a similar impulsive high amplitude noise source to piling; >189 dB re 1 µPa (peak–peak) at 1 m) upon adult snow crabs *Chionoecetes opilio* in comparison with control crabs. Another study investigated whether there was a link between seismic surveys and changes in commercial rock lobster (*Panulirus cygnus*) based on rates associated with acute to mid-term mortality over a 26-year period. This found no statistically significant correlative link (Parry and Gason, 2006).

Sub-lethal physiological effects have been identified from impulsive noise sources including bruised hepatopancreas' and ovaries in *C. opilio* exposed to seismic survey noise emissions (at unspecified SPLs) (DFO, 2004). Changes in serum biochemistry and hepatopancreatic cells (Payne *et al*., 2007), increase in respiration in brown shrimp *Crangon crangon* (Solan *et al*., 2016) and metabolic rate changes in *Carcinus maenas* have also been identified.

In terms of shellfish eggs and larvae there is no direct evidence to suggest they are at risk of direct harm from high amplitude anthropogenic underwater noise such as piling (Edmonds *et al.,* 2016). Of the few studies that have focussed on the eggs and larvae of shellfish species evidence of impaired embryonic development and mortality has been found to arise from playback of seismic survey noise among Gastropoda sp. and Bivalvia sp. (De Soto *et al*., 2013, Nedelec *et al*., 2014). There is limited information on the effect of impulsive sound upon crustacean eggs, and no research has been conducted on commercially exploited UK/ Irish decapod species. Of the evidence that is available all studies focus on the impact of seismic noise. Preliminary findings show that seismic exposure could be implicated in delayed hatching of *C. opilio* eggs, causing resultant larvae to be smaller than controls (DFO, 2004). Pearson *et al*. (1994) found no statistically significant difference between the mortality and development rates of stage II Dungeness crab (*Metacarcinus magister*) larvae exposed to single field-based discharges (231 dB re 1 µPa (zero-peak) at 1 m) from a seismic airgun.

While the evidence described above from species specific studies and primarily laboratory-based experiments have shown some effects on shellfish species (although lower-level effects compared to fish species), another recent study examined the effects on catch rates of European lobster of a temporary closure of lobster fishing grounds during offshore wind farm construction (including piling). Monitoring data at the Westernmost Rough Offshore Wind Farm located on the northeast coast of England found that the size and abundance of lobster increased following temporary closure or the area while construction was undertaken. This study shows that the activities associated with construction of the wind farm, which included piling of foundations for 80 turbines, did not impact on the resident lobster populations and instead allowed some respite from fishing activities for a short period time before reopening following construction (Roach *et al.,* 2018). The results of this study strongly suggest that population level injury effects on shellfish species will not occur due to piling operations.

Behaviour

Behavioural effects in response to construction related underwater noise include a wide variety of responses including startle responses (also known as C-turn responses), strong avoidance behaviour, changes in swimming or schooling behaviour or changes of position in the water column. The Popper *et al*. (2014) guidelines provide qualitative behavioural criteria for fish from a range of noise sources. These categorise the risks of effects in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. tens of metres), “intermediate” (i.e. hundreds of metres) or “far” (i.e. thousands of metres). The behavioural criteria for piling operations are summarised in Table 9-18 for the four fish groupings.

Table 9-18: Potential risk for the onset of behavioural effects in fish from piling (Popper *et al.*, 2014)[a].

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

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

Group 1 Fish (e.g. flatfish and elasmobranchs), Group 2 Fish (e.g. salmonids) and shellfish are less sensitive to sound pressure, with these species detecting sound in the environment through particle motion. However, sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al.,* 2010; Hawkins *et al*., 2014a). Group 3 (including gadoids such as cod and whiting) and Group 4 fish (sprat) are more sensitive to the sound pressure component of underwater noise and, as indicated in Table 9-18, the risk of behavioural effects in the intermediate and far fields are therefore greater for these species.

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

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

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

The authors did point out that any potential seismic effects on fish may not necessarily translate to population scale effect or disruption to fisheries and McCauley *et al*. (2000) show that caged fish experiments can lead to variable results. While these studies are informative to some degree, these, and other similar studies, do not provide an evidence base that is sufficiently robust to propose quantitative criteria for behavioural effects (Hawkins and Popper, 2016; Popper *et al.,* 2014) and as such the qualitative criteria outlined in Table 9-18 are proposed.

Figure 9-2 shows the modelled underwater noise levels based on the results from appendix 10-2: Subsea Noise Technical Report, relative to key fish spawning habitats in the vicinity of the offshore wind farm area. The modelled outputs show that noise attenuation is rapid with distance from foundation location. They also indicate that, based on a behavioural response occurring at levels in excess of 160 dB re 1 μPa SPL_{peak}, fish may exhibit behavioural responses within approximately 7 km from the source. It should be noted, however, that this noise level is lower than the levels reported by the existing studies on the effect of noise on fish behaviour outlined above. These results broadly align with qualitative thresholds for behavioural effects on fish as set out in Table 9-18, with moderate risk of behavioural effects in the range of hundreds to thousands of metres from the piling activity, depending on the species. Although spawning and nursery habitats are present within the Fish and Shellfish Ecology Study Area (e.g. for plaice, sole, herring and sandeel), these extend over a wide area across the Western Irish Sea Fish and Shellfish Ecology Study Area. The relative proportion of these habitats affected by piling operations at any one time will therefore be small in the context of the wider habitat available. Further, the duration of piling (i.e. piling being intermittent events occurring on up to 26 days during the construction phase) is also a relatively short term and temporary disturbance in the context of spawning seasons for these species.

As set out above, increased tolerance (and decreased sensitivity) to underwater sound may occur for some fish and shellfish during key life history stages, such as spawning or migration. This was demonstrated in an investigation into the impact of impulsive seismic air gun surveys on feeding herring schools, which found a slight but not significant reduction in swimming speed when exposed to the sound impact (Peña *et al.*, 2013). The findings of this survey indicated that feeding herring did not display avoidance responses to seismic sound sources, even when the vessel came into close proximity to herring, which indicated an awareness of and response to impulsive anthropogenic sound, which would be expected in response to piling, but not a significant response when fish were highly motivated to remain within an area – in this case during feeding, but potentially also in spawning. With regard to herring spawning, another example is from a spawning herring survey undertaken whilst piling was occurring at the Gunfleet Sands offshore wind farm within the relatively enclosed environment of the Thames estuary. Aggregations of spawning herring were caught within 10 to 15 km of active piling on the spawning grounds at Eagle Bank and Colne Bar, thus indicating that spawning was not entirely disrupted by piling at Gunfleet Sands offshore wind farm. This study suggests that herring's biological driver to use these grounds to spawn may have overridden the potential behavioural effects of percussive piling sound on herring (Brown and May Marine Ltd, 2009a).

With specific reference to herring spawning, while there is potential for piling activities to affect herring spawning activities in the Mourne spawning grounds, the proportion of spawning habitats affected would be relatively small in the context of the available spawning habitats in the wider western Irish Sea fish and shellfish study areas and any effects will temporary and reversible, with normal behaviour returning following cessation of piling. Furthermore, this disruption to herring spawning would only occur if piling occurs during the spawning season and would be limited in duration (i.e. up to 26 discreet piling events and up to 26 days piling).

The behavioural effects from the underwater noise, at the levels expected as a result of the pile driving for the Project, are likely to be limited for diadromous fish species. As noted in the paragraph above, Figure 9-2 indicates the noise contours associated with piling operations. Noise levels in excess of 160 dB re 1 μPa SPL_{peak} are expected to lead to behavioural effects on fish, including diadromous fish. Broadly, the range at which these behavioural responses are likely to occur is approximately 7 km from the noise source and as demonstrated in Figure 9-2, this does not extend to the coast, even at the greatest hammer energies. Therefore, there is a large area for fish to navigate along the coast, whilst avoiding the noise source, when migrating to and from rivers in which these species may spawn (e.g. River Boyne and River Blackwater SAC and other non-SAC rivers on the east coast of Ireland). As such, there is no potential for diadromous species to experience barriers to migration when moving from freshwater systems into and within the marine environment.

As set out in previous sections, information on the impact of underwater noise on marine invertebrates is scarce, and no attempt has been made to set exposure criteria (Hawkins *et al.,* 2014b). Studies on marine invertebrates have shown sensitivity of marine invertebrates to substrate borne vibration (Roberts *et al*., 2016). Aquatic decapod crustaceans are equipped with a number of receptor types potentially capable of responding to the particle motion component of underwater noise (e.g. the vibration of the water molecules which results in the pressure wave) and ground borne vibration (Popper *et al*., 2001). It is generally their hairs which provide the sensitivity, although these animals also have other sensor systems which could be capable of detecting vibration. It has also been reported that sound wave signature of piling noise can travel considerable distances through sediments (Hawkins and Popper, 2016), with implications for demersal and sediment dwelling fish (e.g. sandeel) and shellfish (e.g. *Nephrops*) in close proximity to piling operations. Sandeel may be particularly affected by vibration through the seabed during winter hibernation when they remain buried in sandy sediments.

N. norvegicus have been found to bury less deeply, flush their burrows less regularly and are considerably less active when exposed to impulsive anthropogenic noise (Solan *et al.*, 2016). *N. norvegicus* also showed reduced movement and burrowing behaviour in response to simulative shipping and construction noise (Solan *et al*., 2016). However, simulated shipping noise had no effect on the physiology of *N. norvegicus* (Solan *et al*., 2016). Another study on brown shrimp revealed elevated SPL are implicated in increased incidences of cannibalism and significantly delayed growth (Lagardère and Spérandio, 1981). Simulated shipping noise has been demonstrated to cause some individuals of common shore crab to cease feeding (Wale *et al*., 2013). The mud crab (*Scylla paramamosain*) and European spiny lobsters have been reported to have aspects of life history disrupted by anthropogenic noise e.g. movement and anti-predation behaviour. In contrast to *N. norvegicus*, increased movement has been seen in these species in response to simulated shipping noise and offshore activities (Filiciotto *et al*., 2016; Zhou *et al*., 2016). Such findings have implications with regard to species fitness, stress and compensatory foraging requirements, along with increased exposure to predators.

However as set out above, monitoring of lobster catch rates at the Westermost Rough offshore wind farm indicated that population level effects on shellfish species did not occur (Roach *et al.,* 2018). While there may be some residual uncertainty with regard to behavioural effects while piling operations are ongoing, the evidence suggests that long term effects will not occur and any effects will be reversible.

Scott *et al.* (2020) provide the most recent review of the existing published literature on the influence of anthropogenic noise and vibration on crustaceans. The review concluded that some literature sources identified behavioural and physiological effects on crustaceans from anthropogenic noise, however, there were several that showed no effect. The paper notes that to date no effect or influence of noise or vibrations has been reported on mortality rates, fisheries catch rates or yields. In addition, no studies have indicated a direct effect of anthropogenic noise on mortality, immediate or delayed (Scott *et al*., 2020). Group 1 Fish (e.g. flatfish, elasmobranchs, and lamprey), Group 2 Fish (e.g. salmonids) and aquatic decapod crustaceans are less sensitive to sound pressure, with these species typically detecting sound in the environment through particle motion. Group 1 elasmobranch species do not possess a swim bladder, and thus will be most impacted by particle motion. There is evidence of startle and fleeing responses to piling sounds at a minimum of 20-30 dB above background conditions due to increased particle motion (Casper *et al*., 2012). However, sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al*., 2010; Hawkins *et al*., 2014a). Particle motion is hard to quantify in the same way as sound pressure. It is likely that the designed-in soft start procedure will allow any individuals near the construction activities to avoid damage by fleeing the immediate area, suggesting low vulnerability overall to this impact. Furthermore, it is likely the area within which behavioural effects for sound pressure may occur is large enough and conservative enough to account for any potential behavioural responses and physical effects from particle motion as a result of piling.

Summary

In summary, proposed piling activities are unlikely to result in mortality of fish, as the implementation of the soft start procedure will result in fish swimming away from the noise source prior to piling noise reaching maximum energy levels. Some recoverable injury is possible within approximately 300 m of the piling works (monopile installation) particularly for fish groups 2, 3 and 4 (salmonids, scombridae, gadoids and eels, herring, sprat and shads) but less so for group 1 fish (elasmobranchs and flatfish). However again with the implementation of the soft start procedure, identified fish groups would be expected to swim out of the area of influence prior to maximum energy levels being reached. Behavioural responses are also more likely to be observed for gadoids and eels, herring, sprat and shads within hundreds to thousands of metres from the piling source during piling activity before returning to baseline conditions on completion of works.

Therefore, given the varying levels of sensitivity associated with identified fish IEFs, fish groups 2, 3 and 4, which include salmonids, scombridae, gadoids, eels, herring, sprat and shads, are deemed to be of medium to high vulnerability, medium recoverability and of local to international importance within the Fish and Shellfish Ecology Study Area. The sensitivity of these fish receptors is therefore considered to be medium.

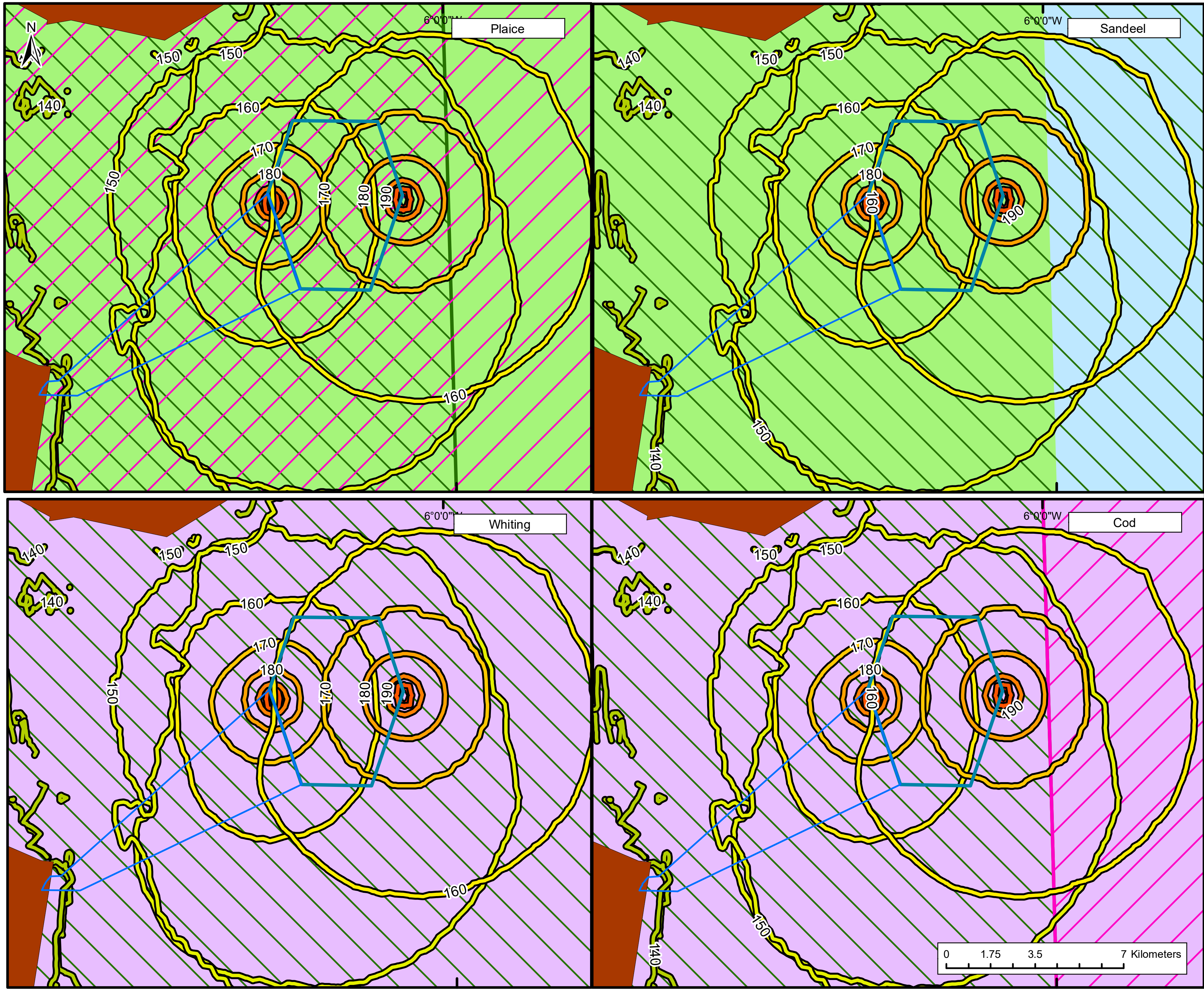
Fish group 1 (elasmobranchs and flatfish) are deemed to be of low vulnerability, medium recoverability and of local to regional importance within the Fish and Shellfish Ecology Study Area. The sensitivity of these fish receptors is therefore considered to be low.

Shellfish species are likely to experience short term localised, sub lethal physiological and behavioural effects from piling activities, although changes to population size and structure are considered unlikely.

All shellfish species are considered to have low vulnerability, high recoverability and of local to national importance within the Fish and Shellfish Ecology Study Area. The sensitivity of these shellfish receptors is therefore considered to be low.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low to medium. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.



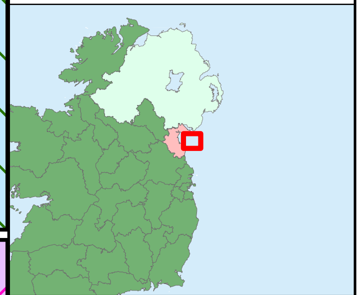
Offshore Wind Farm Area
Offshore Cable Corridor

Spawning Grounds (Ellis *et al*., 2012)
High Intensity
Low Intensity

Nursery Grounds (Ellis *et al*., 2012)
High Intensity (Ellis *et al*., 2012)
Low Intensity (Ellis *et al*., 2012)

Noise contours: dB re 1 µPa (SPLpeak)
100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210

Data Sources: Ellis et al 2012, Coull, K.A., Johnstone, R, and Rogers, S.I. (1998)



Client
ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project
Oriel Wind Farm Project

Title **Figure 9-2 Modelled underwater noise levels (peak pressure) associated with installation of monopiles within the offshore wind farm area and identified key fish spawning and nursery areas**

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Issue Details

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Date: 07/03/2024	

9.10.3 Increased suspended sediment concentrations and associated sediment deposition

Increases of suspended sediments and associated sediment deposition are predicted to occur during the construction and decommissioning phases as a result of the installation/removal of foundations and installation/removal of inter-array cables and offshore cable. Increases in suspended sediments and associated sediment deposition are also predicted to occur during the operational and maintenance phase due to inter-array and offshore cable repair and reburial events. Chapter 7: Marine Processes provides a full description of the physical assessment, including numerical modelling used to inform the predictions made with respect to increases in suspended sediment and subsequent deposition.

Construction Phase

Magnitude of impact

The installation of infrastructure within the offshore wind farm area and offshore cable corridor may lead to increases in suspended sediment concentrations (SSC) and associated sediment deposition. The project design parameter for foundation installation assumes all wind turbine and offshore substation foundations will be installed by drilling 9.6 m diameter piles (Table 9-9).

Modelling of suspended sediments associated with the foundation installation showed low levels of suspended sediments with peaks of 100 mg/l extending beyond the offshore wind farm area in all modelled events. The average SSC beyond the immediate vicinity of the offshore wind farm area are generally less than 30 mg/l with most of the sediment plume envelope having a suspended sediment concentration of less than 10 mg/l. Sediment deposition is predicted to be indiscernible from the background due to the limited quantity of material released, with the exception of directly at the drill site where cuttings fall to the seabed. Further detail can be found in chapter 7: Marine Processes.

Installation of inter-array cables through ploughing/jetting would involve disturbance of seabed material from trenches (of 1 m width and 3 m depth). Modelling of SSC associated with the installation of inter-array cables showed a peak concentration of 2,000 mg/l in the immediate vicinity of cable installation, with averages less than 3 mg/l. The sediment plume will only persist for a maximum of 2-3 hours in any location; following completion of the works, turbidity will return to normal within a couple of tidal cycles. Sedimentation will occur in the immediate vicinity of the inter-array cable installation activities, with no discernible levels of sedimentation modelled to occur beyond the offshore wind farm area. Further detail can be found in chapter 7: Marine Processes.

Installation of the offshore cable through ploughing/jetting would involve disturbance of seabed material from trenches (of 3 m width and 3 m depth). Modelling of suspended sediment associated with the installation of the offshore cable showed general peak concentrations of 300 mg/l which is equivalent to turbidity levels during storm conditions, although this level of increase would only be recorded in very localised areas towards the landfall, due to the shallow waters. Average concentrations were predicted to be less than 50 mg/l. The sediment plume will only persist for a maximum of 3-4 hours in any location. Sedimentation will occur in the immediate vicinity of the offshore cable installation activities. The distribution of the sediment which is released during the operation is typically less than 20 mm in depth. The final settled depth being 10 mm. Further detail can be found in chapter 7: Marine Processes.

Modelling of the inter-array cables and offshore cable was carried out on the basis of a number of trenching techniques. Sand wave clearance activities would use ploughing techniques. The volume of material relocated per metre of bed preparation is of the same order of magnitude as the trenching, however the mobilisation into suspension would be less significant as the trenching lifts material off the bed whilst plough would move material along it. The sand wave clearance constitutes up to 10% of the cable lengths therefore the operations would be less extensive than cable burial. It may therefore be concluded that the magnitude of impacts arising from seabed clearance would be less than for cable trenching and therefore it was not modelled, and the conclusion for this impact is considered to be the same as for cable installation.

The increased SSC and associated sediment deposition is predicted to be of localised spatial extent, short term duration, intermittent and high reversibility due to site hydrodynamics. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

In terms of SSC, adult fish species are more mobile than many of the other fish and shellfish receptors, and therefore may show avoidance behaviour within areas affected by increased SSC (EMU, 2004), making them less susceptible to physiological effects of this impact. Juvenile fish are more likely to be affected by habitat disturbances such as increased SSC than adult fish. This is due to the decreased mobility of juvenile fish and these animals are therefore less able to avoid impacts. Juvenile fish are likely to occur throughout the Fish and Shellfish Ecology Study Area, with some species using offshore areas as nursery habitats while inshore areas are more important for other species (see section 9.7). Due to the temporary increases in SSC associated with winter storm events and the occurrence of juveniles in inshore areas (where SSCs are typically higher), it can be expected that most fish juveniles expected to occur in the Fish and Shellfish Ecology Study Area (e.g. whiting, cod, herring and spurdog) will be largely unaffected by the low level temporary increases in SSC, as the concentrations are likely to be within the range of natural variability for these species and will reduce to background concentrations within a very short period (approximately two tidal cycles).

A study by Appleby and Scarratt (1989) found that the development of eggs and larvae has the potential to be affected by suspended sediments at concentrations of thousands of mg/l. Modelling undertaken of SSC associated with the Project construction phase identified peak maximum concentrations of 500 mg/l observed immediately adjacent to the source of disturbance. It is therefore unlikely that the development of eggs and larvae will be affected by SSC during the construction phase.

Migratory fish species known to occur in the area are also expected to have some tolerance to naturally high SSC, given their migration routes typically pass through estuarine habitats for which background SSC are considerably higher than those expected in the offshore areas of the Western Irish Sea Fish and Shellfish Ecology Study Area. It is predicted that construction activities associated with the Project will produce temporary and short-lived increases in SSC, with levels below those experienced in estuarine environments. Therefore, it would be expected that any migratory species should only be temporarily affected (if they are affected at all). Any adverse effects on these species are likely to be short-term behavioural effects (i.e. avoidance) and are not expected to create a barrier to migration to rivers or estuaries used by these species in the Western Irish Sea Fish and Shellfish Ecology Study Area.

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

The species likely to be affected by sediment deposition are those which either feed or spawn on or near the seabed. The majority of species which have known spawning grounds within the Fish and Shellfish Ecology Study Area are pelagic spawners and so it is likely that these species will not be affected. Demersal spawners within the Fish and Shellfish Ecology Study Area include sandeel and herring. Sandeel eggs are likely to be tolerant to sediment deposition due to the nature of re-suspension and deposition within their natural high energy environment. Low intensity spawning sites for sandeel occur within the Fish and Shellfish Ecology Study Area, therefore effects on sandeel spawning populations are predicted to be limited. Sandeel populations are also sensitive to sediment type within their habitat, preferring coarse to medium sands and showing reduced selection or avoidance of gravel and fine sediments (Holland *et al*., 2005). Therefore, any increase in the fine sediment fraction of their habitat may cause avoidance behaviour until such time that currents remove fine sediments from the seabed, although modelled sediment deposition levels are expected to be highly localised and at very low levels (<10 mm).

Herring occur mostly in entirely pelagic habitats, but utilise benthic environments for spawning, and are known to prefer rock, gravelly or coarse sand environments for this purpose, specifically within the Mourne herring spawning grounds (appendix 9-1: Fish and Shellfish Ecology Technical Report). With respect to the effects of sediment deposition on herring spawning activity, it has been shown that herring eggs may have some tolerance to very high levels of SSC (Messieh *et al*., 1981; Kiorbe *et al.*, 1981). Detrimental effects may be seen if smothering occurs and the deposited sediment is not removed by the currents (Birklund and Wijsmam, 2005), however this would be expected to occur quickly in this case (i.e. within a couple of tidal cycles), given the low levels of deposition expected. However, there is suitable alternative spawning grounds available and therefore will likely limit the potential for effects of SSC and deposition on herring spawning. This is supported by the mapping of spawning grounds (appendix 9-2: Herring Spawning - Technical Report), which shows herring spawning extending north-easterly along the Northern Ireland coast, and the extent of plumes and sedimentation from the physical processes modelling at piling location and trenching (Chapter 7: Marine Processes) were found to be localised and to dissipate quickly (within two to three hours), thereby reducing any potential for impacts of SSC and deposition on herring spawning.

All fish and shellfish receptors (with the exception of lobster) within the Fish and Shellfish Ecology Study Area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of the receptor is therefore, considered to be low.

Lobster are deemed to be of medium vulnerability, high recoverability and regional importance in the Fish and Shellfish Ecology Study Area. The sensitivity of the receptor is therefore, considered to be low.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Operational and maintenance phase

Magnitude of impact

Operational and maintenance activities within the offshore wind farm area and offshore cable corridor may lead to increases in suspended sediment concentrations and associated sediment deposition. The project design parameter is for seven inter-array cable repair, seven reburial events, three offshore cable repair events and three reburial events over the Project lifetime (Table 9-9

Table 9-9), using similar methods as those for cable installation activities (i.e. trenching/jetting).

Any suspended sediments and associated deposition will be of the same magnitude, or lower as for construction. For the purposes of this assessment, the impacts of the operational and maintenance activities are predicted to be similar to those for construction, as set out above.

The increased suspended sediment concentrations and associated sediment deposition is predicted to be of localised spatial extent, short term duration, intermittent and high reversibility due to site hydrodynamics. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

The sensitivity of the fish and shellfish receptors can be found in the construction phase assessment above.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Decommissioning Phase

Magnitude of impact

Decommissioning of Project infrastructure within the offshore wind farm area and offshore cable corridor may lead to increases in suspended sediment concentrations and associated sediment deposition. The project design parameter is represented by the cutting and removal of monopile foundations to approximately 2 m below seabed, and the removal of inter-array cables and offshore cable.

Decommissioning of the foundations, inter-array cables and offshore cable are assumed to result in similar increases in suspended sediments and associated deposition as that during construction. For the purposes of this assessment, the impacts of decommissioning activities are therefore predicted to be similar to those for construction, as set out above.

The increased suspended sediment concentrations and associated sediment deposition are predicted to be of localised spatial extent, short term duration, intermittent and high reversibility due to site hydrodynamics. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

The sensitivity of the fish and shellfish receptors can be found in the construction phase assessment above.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

9.10.4 Long-term subtidal habitat loss

Long term habitat loss will occur directly under all foundation structures, associated scour protection and cable protection, where this is required. This impact considers only the habitat loss occurring during the operational phase of the Project, because while these structures may be placed during the construction phase, the effect on fish and shellfish receptors (i.e. habitat loss effects) will be experienced throughout the 40-year operational and maintenance phase of the Project.

Operational and maintenance phase

Magnitude of impact

The presence of Project infrastructure within the offshore wind farm area and offshore cable corridor may result in long-term habitat loss. The project design parameter includes for 332,060 m^2 of long-term habitat loss due to the installation of monopile foundations and associated scour protection and cable protection associated with inter-array cables and offshore cable. This equates to 0.4% of the offshore wind farm area and offshore cable corridor combined and therefore represents a very small proportion of the offshore wind farm area and offshore cable corridor combined. Monitoring at Belgian offshore wind farms has reported that fish assemblages undergo no drastic changes due to the presence of offshore wind farms (Degraer *et al*., 2020). They reported slight, but significant increases in the density of some common soft sediment-associated fish species (common dragonet *C. lyra*, solenette, lesser weever and plaice) within the offshore wind farm (Degraer *et al*., 2020). There was also some evidence of increases in numbers of species associated with hard substrates, including crustaceans (including edible crab), sea bass and common squid (potentially an indication that foundations were being used for egg deposition; Degraer *et al*., 2020). The author noted that these effects were site specific and therefore may not necessarily be extrapolated to other offshore wind farms, although this does indicate the presence of offshore wind farm infrastructure does not lead to adverse, population wide effects.

Long-term subtidal habitat loss impacts will be continuous throughout the 40-year operational and maintenance phase.

The long-term habitat loss/disturbance is predicted to be of highly localised spatial extent (restricted to discrete areas within the offshore wind farm area and offshore cable corridor), long-term duration, continuous and high reversibility (once decommissioning phase has been completed, and infrastructure is removed). It is predicted that the impact will affect fish and shellfish receptors directly or indirectly depending on species life strategy. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

Fish and shellfish species that are reliant upon the presence of suitable sediment/habitat for their survival are considered to be more vulnerable to change depending on the availability of habitat within the wider geographical region. The seabed habitats removed by the installation of infrastructure will reduce the amount of available food resource for fish and shellfish species however this area represents a very low percentage compared with the area of habitats located within the Western Irish Sea Fish and Shellfish Ecology Study Area.

The Fish and Shellfish Ecology Study Area coincides with fish spawning and nursery habitats including anglerfish, plaice, lemon sole, common sole, herring, sprat, whiting, cod, sandeel, mackerel, sprat and elasmobranchs (Coull *et al.*, 1998, Ellis *et al.*, 2012; see section 9.7). The fish species most vulnerable to habitat loss include sandeel and herring which are demersal spawning species (i.e. eggs are laid on the seabed), as these have specific habitat requirements for spawning (i.e. sandy sediments). As well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history and loss of this specific type of habitat could represent an impact on this species. However, monitoring at other offshore wind farm sites has indicated that the presence of operational wind farm structures has not led to significant negative effects on sandeel populations in the long term (van Deurs *et al*., 2012). For herring, the presence of hard structures, such as monopiles, cable and scour protection is likely to increase the availability of suitable egg laying substrate. Thereby, the presence of the offshore wind farm may increase the spawning ground area, albeit this would be a very minor increase in area in the context of the wider habitats available.

The Fish and Shellfish Ecology Study Area also coincides with low intensity sandeel spawning habitat. The presence of infrastructure will result in direct impacts on this habitat, though as detailed above the proportion of habitat affected within the offshore wind farm area and offshore cable corridor is small and this area is smaller still in the context of the known sandeel habitats and the potential sandeel habitats in the wider Western Irish Sea Fish and Shellfish Ecology Study Area (appendix 9-1: Fish and Shellfish Ecology Technical Report).

The Project is located in the vicinity of known *Nephrops* spawning habitat in the Fish and Shellfish Ecology Study Area. Long term habitat loss is predicted to affect a small proportion of this habitat, particularly where structures are placed in deep water areas within the offshore wind farm area. Lobster spawning and nursery habitats have the potential to occur within the Fish and Shellfish Ecology Study Area. The proportion of lobster spawning and overwintering habitats affected is, however, likely to be small in the context of the available habitats in this part of the Fish and Shellfish Ecology Study Area.

Most fish and shellfish receptors in the Fish and Shellfish Ecology Study Area are deemed to be of low vulnerability and of local to national importance (recoverability is possible following completion of decommissioning). Given the widespread nature of spawning and nursery habitat in the wider Western Irish Sea Fish and Shellfish Ecology Study Area, the sensitivity of these fish and shellfish receptors is therefore, considered to be low.

European lobster and *Nephrops* are deemed to be of high vulnerability and of regional importance within the Western Irish Sea Fish and Shellfish Ecology Study Area. The sensitivity of these shellfish receptors is therefore, considered to be medium.

Sandeel are deemed to be of high vulnerability and of regional importance within the Western Irish Sea Fish and Shellfish Ecology Study Area. Due to the specific habitat requirement of these species, the sensitivity of these fish receptors is considered to be medium.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptors is considered to be low to medium. The effect will, therefore, be of **imperceptible or slight adverse significance**, which is not significant in EIA terms.

9.10.5 Electromagnetic fields (EMF) from subsea electrical cabling

The installation of inter-array cables and offshore cable will conduct an AC current (see Table 9-9). The conduction of electricity through subsea power cables has the potential to emit a localised EMF which could potentially affect the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species (including elasmobranchs) and migratory fish species (CMACS, 2003).

Operational and maintenance phase

Magnitude of impact

The presence and operation of inter-array cables and offshore cable within the offshore wind farm area and offshore cable corridor may lead to a localised EMF affecting fish and shellfish receptors. EMF comprise both the electrical (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in microtesla (μT) or milligauss (mG). Background measurements of the magnetic field are approximately 50 μT in the North Sea, and the naturally occurring electric field in the North Sea is approximately 25 μV/m (Tasker *et al*., 2010). It is common practice to block the direct electrical field (E) using conductive sheathing, meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resultant induced electrical field (iE). It is generally considered impractical to assume that cables can be buried at depths that will reduce the magnitude of the B field, and hence the sediment-sea water interface iE field, to below that at which these fields could be detected by certain marine organisms on or close to the seabed (Gill *et al.,* 2005, Gill *et al*., 2009). By burying a cable, the magnetic field at the seabed is reduced due to the distance between the cable and the seabed surface as a result of field decay with distance from the cable (CSA, 2019).

A variety of design and installation factors affect EMF levels in the vicinity of the cables. These include current flow, distance between cables, cable insulation, number of conductors, configuration of cable and burial depth. The flow of electricity associated with an AC cable (proposed for the Project) changes direction (as per the frequency of the AC transmission) and creates a constantly varying electric field in the surrounding marine environment (Huang, 2005).

The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source.

A recent study conducted by CSA (2019) found that inter-array and export cables buried between depths of 1 m to 2 m reduces the magnetic field at the seabed surface four-fold. For cables that are unburied and instead protected by thick concrete mattresses or rock berms, the field levels were found to be similar to buried cables.

CSA (2019) found EMF levels directly over live AC undersea power cables associated with offshore wind energy projects range between 65 mG and 5 mG for inter-array cables respectively and 165 mG and 10 mG for export cables, at heights of 1 m above the seabed and at the seabed surface, respectively. At lateral distances of between 3 m and 7.5 m from the cable, magnetic fields greatly reduced to between 10 mG and <0.1 mG for inter-array cables, and 15 mG and <0.1 mG for export cables, at heights of 1 m above the seabed and at the seabed surface, respectively.

The induced electric fields directly over live AC undersea power cables ranged between 1.7 mV/m and 0.1 mV/m for inter-array cables and 3.7 mV/m and 0.2 mV/m for export cables, at heights of 1 m above the seabed and at the seabed surface, respectively. At lateral distances of between 3 m and 7.5 m electric fields reduced to between 0.01 mV/m and 1.1 mV/m for inter-array cables and 0.02 mV/m and 1.3 mV/m for export cables at heights of 1 m above the seabed and at the seabed surface respectively.

The impact therefore is predicted to be of local spatial extent (i.e. restricted to within Fish and Shellfish Ecology Study Area), long term duration (i.e. the lifetime of the Project), continuous and irreversible during the operational and maintenance phase (recoverability is possible following completion of decommissioning). It is predicted that the impact has the potential to affect both fish and shellfish receptors directly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

Molluscs, crustaceans and fish (particularly elasmobranchs) are able to detect applied or modified magnetic fields. Species for which there is evidence of a response to E and/or B fields include elasmobranchs (sharks, skates and rays), river lamprey, sea lamprey, European eel, plaice, American plaice and Atlantic salmon (Gill *et al*., 2005; CSA, 2019). It can be inferred that the life functions supported by an electric sense may include detection of prey, predators or conspecifics to assist with feeding, predator avoidance, and social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*., 2005; Normandeau *et al*., 2011).

Studies examining the effects of EMF from AC undersea power cables on fish behaviours have been conducted to determine the thresholds for detection and response to EMF. Table 9-19 provides a summary of the scientific studies conducted to assess sensitivity of EMF on varying fish species.

Table 9-19: Relationship between geomagnetic field detection, electrosensitivity, and the ability to detect 50/60-Hz AC fields in common marine fish and shellfish species (adapted from CSA, 2019).

Species Group	Detect Geomagnetic Field	Detect Electric Fields	Evidence from Laboratory Studies of 50/60-Hz EMF from AC Power Cables	Evidence from Field Studies of AC Power Cables
Skates	Yes, multiple species (Normandeau *et al.,* 2011)	Yes, multiple species (Normandeau *et al.,* 2011)	No responses expected at 60 Hz (Kempster *et al*., 2013)	No attraction at California AC cable sites operating at up to 914 mG (Love *et al*., 2016).
Flounders	Potentially, due to observed orientation behaviours (Metcalf *et al*., 1993)	Not tested	Not tested	No population-level effects, but some evidence of delayed cable crossing. It is unclear whether effect was due to cable EMF or prior sediment disturbance (Vattenfall and Skov-og, 2006).
Tunas and mackerels	Yes, for some species (Walker, 1984)	Not tested (Normandeau *et al*., 2011)	Not tested	Some evidence of attraction of mackerel to monopile structure, but no effect from cables (Bouma, 2008).
American/European Eels	Yes, for multiple species (Normandeau *et al*., 2011)	Mixed evidence (Normandeau *et al*., 2011)	No effect of 950 mG magnetic field at 50 Hz on swim behaviour or orientation (Orpwood *et al.,* 2015)	Unburied AC cable did not prevent migration of eels (Westerberg *et al.,* 2008).

Species Group	Detect Geomagnetic Field	Detect Electric Fields	Evidence from Laboratory Studies of 50/60-Hz EMF from AC Power Cables	Evidence from Field Studies of AC Power Cables
Salmon	Yes, for multiple species (Yano *et al.*, 1997; Putman *et al.*, 2014)	Not tested (Normandeau *et al.,* 2011)	No effect of 950 mG magnetic field at 50 Hz on swim behaviour (Armstrong *et al.*, 2015)	Not surveyed.
Lobsters and crabs	Yes, for some lobster species (Lohmann *et al.*, 1995; Hutchison *et al.,* 2018)	Not tested (Normandeau *et al.,* 2011)	No effect at 800,000 µT (Ueno *et al.,* 1986)	Distribution unaffected by 60-Hz AC cable operating up to 800 mG (Love *et al.*, 2017).

A number of field studies have observed behaviours of fish and other species around AC submarine cables in the U.S.A. Observations at three energized 35-kV AC undersea power cable sites off the coast of California that run from three offshore platforms to shore, which are unburied along much of the route, did not show that fish were repelled by or attracted to the cables (Love *et al.,* 2016).

Elasmobranchs (i.e. sharks, skates and rays) are known to be the most electro-receptive of all fish. These species possess specialised electro-receptors which enable them to detect very weak voltage gradients (down to 0.5 µV/m) in the environment naturally emitted from their prey (Gill *et al.*, 2005). Both attraction and repulsion reactions to E-fields have been observed in elasmobranch species. Spurdog, one of the elasmobranch species known to occur within the Fish and Shellfish Ecology Study Area, avoided electrical fields at 10 µV/cm (Gill and Taylor, 2001). A COWRIE-sponsored mesocosm study demonstrated that the lesser spotted dogfish and thornback ray were able to respond to EMF of the type and intensity associated with subsea cables; the responses of some ray individuals suggested a greater searching effort when the cables were switched on. However, the responses were not predictable and did not always occur (Gill *et al.*, 2009). In another study, EMF from 50/60-Hz AC sources appears undetectable in elasmobranchs. Kempster *et al.* (2013) reported that small sharks could not detect EMF produced at 20 Hz and above, and a magnetic field of 14,300 mG produced by a 50 Hz source had no effect on bamboo shark (Scyliorhinidae, a group that includes catsharks and dogfish) behaviour.

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

Atlantic salmon and European eel have both been found to possess magnetic material of a size suitable for magnetoreception, and these species can use the earth's magnetic field for orientation and direction-finding during migration (Gill and Bartlett, 2010; CSA, 2019). Mark and recapture experiments undertaken at the Nysted operational offshore wind farm showed that eel did cross the export cable (Hvidt *et al*., 2003) but studies on European eel in the Baltic Sea have highlighted some limited effects of subsea cables. The swimming speed during migration was shown to change in the short term (tens of minutes) with exposure to AC electric subsea cables, even though the overall direction remained unaffected (Westerberg and Langenfelt, 2008). The authors concluded that any delaying effect (i.e. on average 40 minutes) would not be likely to influence fitness in a 7,000 km migration. Research in Sweden on the effects of a high-voltage direct current (HVDC) cable on the migration patterns of a range of fish species, including salmonids, failed to find any effect (Westerberg *et al*., 2007; Wilhelmsson *et al*., 2010). Research conducted at the Trans Bay cable, a DC undersea cable near San Francisco, California, found that migration success and survival of chinook salmon (*Oncorhynchus tshawytscha*) was not impacted by the cable. However, as with the Hutchison *et al.* (2018) study, behavioural changes were noted when these fish were near the cable (Kavet *et al.,* 2016) with salmon appearing to remain around the cable for longer periods. These studies demonstrate that while DC undersea power cables can result in altered patterns of fish behaviour, these changes are temporary and do not interfere with migration success or population health.

Crustacea, including lobster and crab, have been shown to demonstrate a response to B fields, with the Caribbean spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (CSA, 2019). EMF exposure has been shown to result in varying egg volumes for edible crabs compared to controls. Exposed larvae were significantly smaller, but there were no statistically significant differences in hatched larval numbers, deformities, mortalities, or fitness (Scott, 2019). Exposure to EMF has also been shown to affect a variety of physiological processes within crustaceans. For example, Lee and Weis demonstrated that EMF exposure affected moulting in fiddler crabs (*Uca pugilator* and *Uca pugnax*) (Lee and Weis, 1980). Several studies have also suggested that EMF effect serotonin regulation which may affect the internal physiology of crustaceans which may potentially result in behavioural changes although this has not been reported (Atema and Cobb, 1980; Scrivener, 1971). Crab movement and location inside large cages has been reported to be unaffected by proximity to energized alternating current (AC) undersea power cables off southern California and in Puget Sound, indicating crabs also were not attracted to or repelled by energized AC undersea power cables that were either buried or unburied (Love *et al.,* 2016). However, studies on the Dungeness crab and edible crab have reported behavioural changes during exposure to increased EMF. Both species showed increased activity when compared to crabs that were not exposed (Scott *et al*., 2018, Woodruff *et al*., 2012). Crabs may also spend less time buried, a natural predator avoidance behaviour (Rosaria and Martin, 2010).

It is uncertain if other crustaceans including commercially important European lobster and *Nephrops* are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*., 2011; Ueno *et al*., 1986). A field study by Hutchison *et al.* (2018) observed the behaviour of American lobster (a magneto-sensitive species) to DC and AC fields from a buried cable and found that it did not cause a barrier to movement or migration, as both species were able to freely cross the cable route. However, lobsters were observed to make more turns when near the energized cable. Adult lobsters have been shown to spend a higher percentage of time within shelter when exposed to EMF. European lobsters exposed to EMF have also been found to have a significant decrease in egg volume at later stages of egg development and mare larval deformities (Scott, 2020).

Scott *et al*., 2020 is a recent review of the existing papers on the impact of EMF on crustacean species. Of the papers reviewed by Scott *et al*., three studied EMF effect on fauna in the field, the rest were laboratory experiments which directly exposed the target fauna to EMF (Scott *et al.,* 2020). These laboratory experiments, while giving us an indication of crustacean behaviour to EMF, may be less applicable in the context of subsea cables in the marine environment. Of the field experiments, one demonstrated that lobsters have a magnetic compass by tethering lobsters inside a magnetic coil (Lohmann *et al.,* 1995), one focused on freshwater crayfish and put magnets within the crayfish hideouts (Tański *et al*., 2005), and the last one looked at shore crabs at an offshore wind farm and found no negative impact on the population. The two former papers are not applicable offshore wind farm subsea cables and the latter found no negative impact on the population of shore crabs from the offshore wind farm (Langhamer *et al*., 2016).

The range over which these species can detect electric fields is limited to metres (CSA, 2019). Pelagic species generally swim well above the seafloor and can be expected to rarely be exposed to the EMF at the lowest levels from AC undersea power cables buried in the seafloor, resulting in impacts that would therefore be localised and transient. Demersal species (e.g. skates) that dwell on the bottom will be closer to the undersea power cables and thus encounter higher EMF levels when near the cable. Demersal species are also likely to be exposed for longer periods of time and may be largely constrained in terms of location. However, the rapid decay of the EMF minimises potential impacts. Finally, fish that can detect the Earth’s magnetic field are unlikely to be able to detect magnetic fields produced by 50/60-Hz AC power cables and therefore these species are unlikely to be affected in the field (CSA, 2019).

Elasmobranch species are deemed to be of medium vulnerability and of local importance in the Fish and Shellfish Ecology Study Area. The sensitivity of the receptor is therefore, considered to be low.

Migratory fish species are deemed to be of medium vulnerability and of regional to international importance in the Fish and Shellfish Ecology Study Area. The sensitivity of the receptor is therefore, considered to be low to medium.

All other fish and shellfish receptors are deemed to be of low vulnerability and of local to regional importance in the Western Irish Sea Fish and Shellfish Ecology Study Area. The sensitivity of these fish and shellfish receptors is therefore, considered to be low.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of fish and shellfish including migratory fish receptors is considered to be low to medium. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

9.10.6 Mitigation and residual effects

The assessment of impacts has concluded that there are no significant effects and therefore it is considered that no further measures over those included in the Project (as outlined in section 9.8.2) are required.

Residual effects

With the implementation of the measures included in the Project (section 9.8.2), the residual effects are as outlined in the assessment provided in section 9.10.

9.10.7 Future monitoring

No monitoring to test the predictions made within the impact assessment is considered necessary. However, as herring spawning grounds have been identified as a feature of a potential MPA and raised in pre-application consultation with An Bord Pleanála, the applicant is proposing to undertake the following initiatives:

- Baseline, construction and post construction monitoring of egg/larval activity. Surveys to include either trawl surveys for adult herring (to see if they are spawning) or egg/larvae surveys to detect recent spawning activity;
- Potential initiatives which could aid herring spawning population, such as oyster beds (shells are used for laying eggs on) within final design of cable protection and scour protection.

It is proposed that these initiatives are to be discussed with the relevant stakeholders and agreed prior to the pre-construction phase of the Project so that measures can be incorporated into the final design.

9.11 Cumulative Impact Assessment (CIA)

9.11.1 Methodology

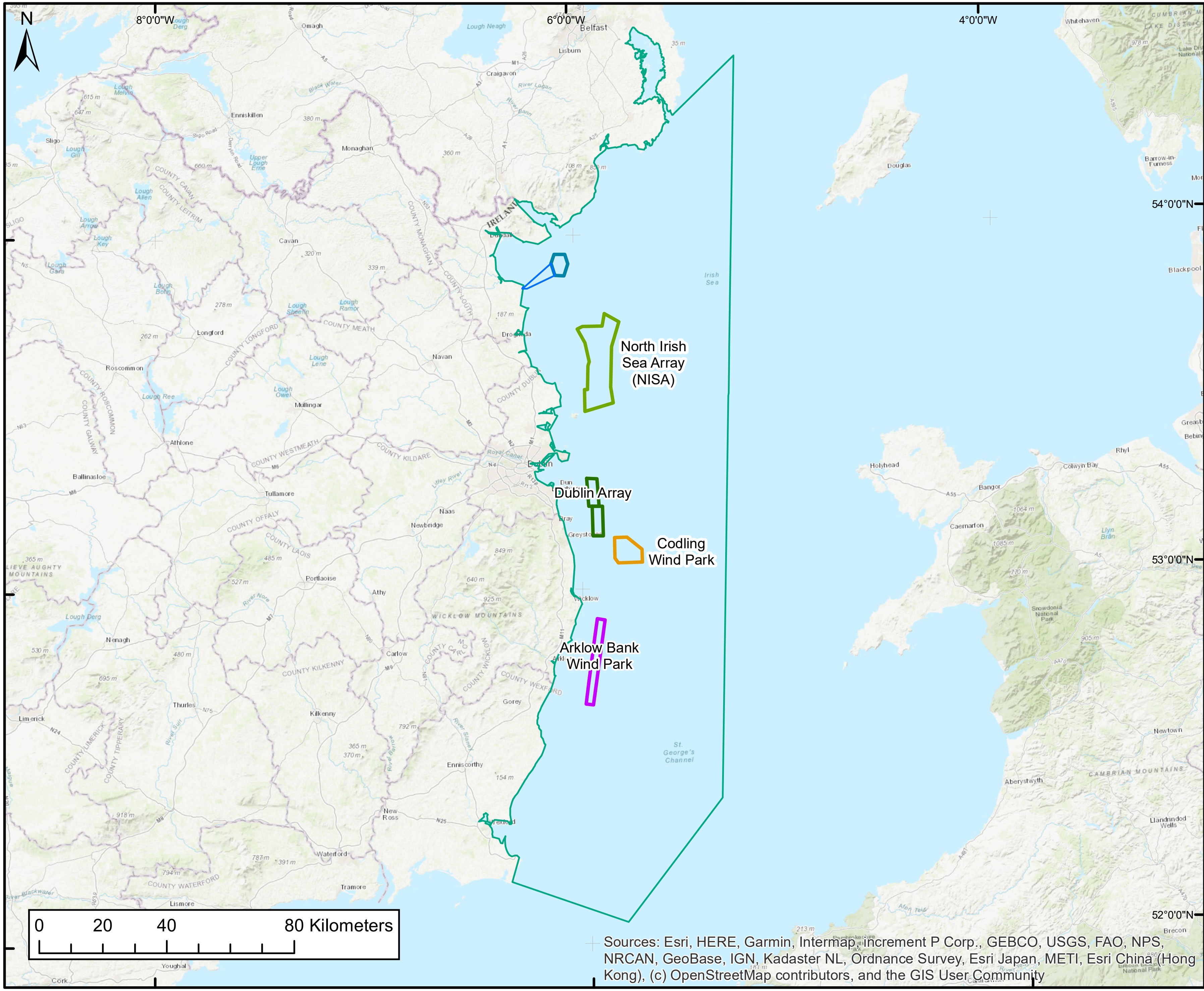
The Cumulative Impact Assessment (CIA) takes into account the impact associated with the Project together with other projects. The projects selected as relevant to the CIA presented within this chapter are based upon the results of a screening exercise (see volume 2A, appendix 3-1: CIA Screening Annex). Each project has been considered on a case-by-case basis for screening in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

The approach to CIA examines the effects of the Project alongside the following projects if they fall within the ZoI for fish and shellfish ecology (further details on the ZoI are provided in volume 2A, appendix 3-1: CIA Screening Annex):

- Other projects with consent but not yet constructed/construction not completed;
- Other projects in the planning process;
- Other projects currently operational that were not operational when baseline data were collected, and/or those that are operational but have an ongoing impact; and
- Projects that have a Maritime Area Consent under the Maritime Area Planning Act (2021) (i.e. wind farm projects designated as 'Relevant Projects' or 'Phase 1 Projects').

The specific projects scoped into this CIA, are outlined in Table 9-20 and Figure 9-3.

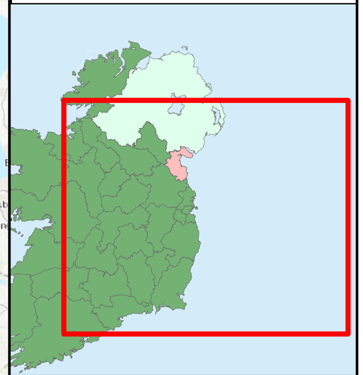
Collaboration with the other Phase 1 projects has informed the CIA. This included discussions amongst the project teams on the approach and methodologies regarding alignment of sensitivities and magnitudes and key receptor species.



Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- Dublin Array
- Arklow Bank Wind Park
- Codling Offshore Wind Farm
- North Irish Sea Array (NISA)
- Western Irish Sea Fish and Shellfish Ecology Study Area

Data Sources: Client



Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title

Figure 9-3
Offshore projects screened into the cumulative impact assessment

rps
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Issue Details

Drawn By:	NG	Project No.	EOR0822 (MDR1520B)
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Approved By:	AOS		EOR0822_FAS_E_1203_FINAL
Scale:	1:1,592,230@ A4	Projection:	ITM (IRENET95)
Date:	07/03/2024		Geographic Co-ordinates: ETRS89

Table 9-20: List of other projects and plans considered within the CIA.

Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction	Dates of operation	Overlap with the Project
Offshore Wind Farms							
North Irish Sea Array (NISA)	Maritime Area Consent	16.2	18.1	EIA Scoping Report (2021) refers to the construction of an offshore wind farm of up to 500 MW, consisting of 36 turbines with a maximum height of 320 m and rotor diameter of up to 290 m. Offshore substation platforms may be required.[4]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.
Dublin Array	Maritime Area Consent	61.2	56.9	EIA Scoping report (2020) refers to the construction of Bray and Kish offshore wind farm of up to 900 MW, consisting of up to 61 turbines with a max. height of 308 m and rotor diameter of up to 285 m and up to three offshore substation platforms.[5]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.
Codling Wind Park	Maritime Area Consent	61.4	57.1	EIA Scoping report (2020) refers to the construction of up to 140 turbines with a maximum height of 320 m and rotor diameter of up to 288 m (up to 1500 MW). The project will also contain up to five offshore substation platforms.[6]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.
Arklow Bank Wind Park	Maritime Area Consent	107.1	104.6	EIA Scoping Report (2023): The project will include between 37 & 56 turbines and up to two OSS and foundation substructures. The area in which the proposed wind turbines, inter-array cables and OSS will be located on Arklow Bank covers an area of seabed approximately $64km^2$.[7]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.

[4] Project website https://northirishseaarray.ie/: states that wind farm will consist of 35 to 46 turbines.

[5] Project website: https://dublinarray.com/project-information/key-facts/: states between 39 and 50 turbines (total project capacity 824 MW) individual tip heights between approx. 270 m and 310 m.

[6] Project website: https://codlingwindpark.ie/the-project/: states max energy output 1300 MW, 100 turbines, turbine tip height max 320 m.

[7] Project website https://www.sserenewables.com/: states between 36 and 60 turbines (up to 800MW) along with one to two OSS and foundation substructures, a network of inter-array cabling and two offshore export cables.

Table 9-21 presents the relevant project design parameters from Table 9-9, which are used to assess the potential cumulative impact of the Project with the other projects identified in Table 9-20 (where information is available).

For the purposes of this chapter, cumulative underwater noise emissions have been assessed within the Western Irish Sea Fish and Shellfish Ecology Study Area. Cumulative impacts associated with temporary and permanent habitat loss, suspended sediments and generation of electrical magnetic fields have not been assessed, given the small areas of seabed substrates that will be disturbed/removed as a consequence of the construction, operational and maintenance and/or decommissioning phases of the identified projects screened into the cumulative assessment, and the localised impacts associated with the electrical magnetic fields generated by operational subsea cables respectively (particularly given the large distances between the Project and other projects).

Table 9-21: Project design parameters considered for the assessment of potential cumulative impacts on fish and shellfish ecology.

Potential impact	Phase			Project design parameter	Justification
	C	O	D		
Injury and/or disturbance to fish from underwater noise during pile-driving	✓	x	x	Project design parameter as described for the Project (Table 9-9) assessed cumulatively with the following other projects/plans: • NISA; • Codling Wind Park; • Dublin Array (Bray Bank and Kish Banks); and • Arklow Bank Wind Park.	Maximum potential for cumulative effects from underwater noise from construction operations within the Western Irish Sea Fish and Shellfish Ecology Study Area.

9.11.2 Assessment of significance

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

Injury and/or disturbance to fish from underwater noise during pile-driving

Construction Phase

Magnitude of impact

The installation of foundations within the offshore wind farm area, together with the projects identified in Table 9-21, may lead to injury and/or disturbance to fish from underwater noise during pile driving. Other projects screened into the assessment within the Western Irish Sea Fish and Shellfish Ecology Study Area include the NISA, Codling Wind Park, Dublin Array and Arklow Bank Wind Park offshore wind farms.

Injury or mortality of fish from piling noise would not be expected to occur cumulatively, due to the small range within which potential injury effects would be expected (i.e. predicted to occur within tens to hundreds of metres of piling activity within each of the identified projects) and the large distances between identified projects. Cumulative effects of underwater noise are therefore discussed in the context of behavioural effects, particularly on spawning or nursery habitats.

Piling operations will represent intermittent occurrences at these offshore wind farm sites, with each individual piling event likely to be similar in duration to those proposed for the Project. The project design parameter (temporal) for piling duration for the Project is for monopile foundations with on average five hours piling per pile (up to a maximum of eight hours per pile) (see Table 9-9). For other offshore wind farm projects monopile foundations have been assumed to represent the maximum design parameter. Therefore given the intermittent nature of identified piling events the potential for temporal overlap is therefore minimised even when construction phases overlap which, as outlined in Table 9-21 is subject to change as construction phases are indicative.

No publicly available information was available to determine the level of impact associated with underwater noise emissions on fish for these four offshore wind farm projects. However, it is assumed that a similar level of impact to the Project is likely based on the Project locations and geographic area. Also due to a lack of data or information regarding piling timescales for these projects for the purposes of this assessment it is assumed that construction periods could overlap.

The NISA Offshore Wind Farm, Codling Wind Park, Dublin Array and Arklow Bank Wind Park are assumed to contribute to the cumulative disturbance resulting underwater noise as a result of piling activities from the installation of wind turbines (NISA – 46 WTGs, Dublin Array – 61, Codling – 140 WTGs and Arklow Bank Wind Park – between 36 and 60 WTGs). Currently these projects have only published EIA scoping reports or information on their project websites, which have limited information on the impact of underwater noise expected from the projects. Given the importance of this impact, the projects have committed to providing an assessment of noise effects as part of their EIAR. The scoping information, however, is not sufficient enough to undertake a detailed assessment however the contribution of these four wind farms to underwater noise is likely to be similar to other offshore wind farms in the Fish and Shellfish Ecology Study Area.

Based on the distance to the other offshore wind farm projects (16 km to the closet offshore wind farm) and disturbance ranges predicted for the Project (approximately 300 m) and assuming similar levels of effects from the other projects for fish receptors, it is not expected that there will be a spatial overlap of underwater noise emissions associated with each project in the event that construction timeframes coincide.

The impact is predicted to be of local/regional spatial extent, short term duration, intermittent and high reversibility It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

Sensitivities of fish and shellfish receptors to underwater noise are fully detailed in section 9.10.2. Fish injury as a result of piling noise would only be expected in the immediate vicinity of piling operations, and the area within which effects on fish larvae would be expected is similarly small. However, it is unclear whether effects on fish larvae would include injury or mortality. Effects on shellfish species are also predicted to be limited as these species are considered to be less sensitive to noise than fish species or would only be affected at ranges much less than those predicted for fish.

Behavioural effects on fish species as a result of piling noise are predicted to be dependent on the nature of the fish and shellfish receptors, with larger impact ranges predicted for pelagic fish than for demersal fish species. A detailed description of sensitivity of fish to underwater noise emissions is described in section 9.10.2.

The proportions of fish spawning and nursery habitats predicted to be affected by underwater noise from piling operations are expected to be small, particularly in the context of available spawning and nursery habitats within the Western Irish Sea Fish and Shellfish Ecology Study Area. The spread of behavioural impact ranges predicted for the identified projects reflects some of the uncertainty associated with behavioural effects criteria, with any behavioural effects also dependent on factors such as type of fish, its sex, age and condition, stressors to which the fish is or has been exposed or the reasons and drivers for the fish being in the area.

Effects on migratory species are likely to be limited to behavioural effects within the ranges discussed for the projects listed above. Shad, being more sensitive to the acoustic pressure component of piling noise, would be expected to be affected according to the ranges presented for herring, while European eel, lamprey species, sea trout and Atlantic salmon are likely to be affected to relatively smaller ranges. Due to the distance between the offshore wind projects (at least 60 km) and the distance of these projects from the coast (approximately 5 km), there is minimal potential for cumulative effects from piling noise to represent a barrier to migratory species for the projects identified, particularly taking into account the intermittency of piling activities.

Therefore, given the varying levels of sensitivity associated with identified fish IEFs, salmonids, scombridae, gadoids, eels, herring, sprat and shads are deemed to be of medium to high vulnerability, medium recoverability and of local to international importance within the Western Irish Sea Fish and Shellfish Ecology Study Area. The sensitivity of these fish receptors is therefore considered to be medium.

Elasmobranchs and flatfish are deemed to be of low vulnerability, medium recoverability and of local to regional importance within the Western Irish Sea Fish and Shellfish Ecology Study Area. The sensitivity of these fish receptors is therefore considered to be low.

All shellfish species are deemed to be of low vulnerability, high recoverability and of local to national importance within the Western Irish Sea Fish and Shellfish Ecology Study Area. The sensitivity of these shellfish receptors is therefore considered to be low.

Significance of effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the fish and shellfish receptor is considered to be low to medium. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

9.12 Transboundary effects

The Western Irish Sea Fish and Shellfish Ecology Study Area in the western portion of the Irish Sea extends from Ballyquintin Point in Co. Down (Northern Ireland) to Carnsore Point (see Figure 9-1). This area was defined to assess the likely significant effects which may extend beyond the project boundary (e.g. injury and/or disturbance to fish from underwater noise during pile-driving) and also to account for the highly mobile nature of some fish and shellfish species, in particular diadromous fish species. These impacts are examined in section 9.10 and as no significant effects are predicted, there is no potential for significant transboundary effects with regard to fish and shellfish ecology from the Project upon the interests of the UK or other EEA States.

9.13 Interactions

A description of the likely interactions arising from the Project on fish and shellfish ecology is provided in volume 2C, chapter 32: Interactions.

9.14 Summary of impacts, mitigation measures and residual effects

Information on fish and shellfish ecology within the Fish and Shellfish Ecology Study Area was collected through a detailed desktop review of existing datasets and studies (appendix 9-1: Fish and Shellfish Ecology Technical Report).

The desktop review found the species assemblage of the Fish and Shellfish Ecology Study Area to be typical for this region of the western Irish Sea. The key characterising fish species consisted of a mix of both pelagic and demersal species, including plaice, American plaice, cod, haddock, whiting, sprat, mackerel, herring and sandeel. Many of these species are fished commercially within the Western Irish Sea Fish and Shellfish Ecology Study Area, as are shellfish species such as European lobster and *Nephrops*. Low intensity spawning and nursery grounds were identified within the Fish and Shellfish Ecology Study Area. A number of migratory fish species have the potential to occur in the Western Irish Sea Fish and Shellfish Ecology Study Area, including six species listed as qualifying features of SACs/SCIs in the UK and other EEA states.

Table 9-22 presents a summary of the potential impacts, mitigation measures and residual effects in respect to fish and shellfish ecology. The impacts assessed include: temporary/long-term habitat loss, underwater noise, increased SSC and deposition and EMF. Overall, it is concluded that there will be no significant effects arising from the Project during the construction, operational and maintenance or decommissioning phases.

In light of the concern raised for the herring Mourne spawning grounds, the Project will implement initiatives to monitor and aid herring spawning population, which will be discussed with stakeholders prior to construction.

Table 9-23 presents a summary of the potential cumulative impacts, mitigation measures and residual effects. The cumulative impacts assessed include: Injury and/or disturbance to fish from underwater noise during pile-driving. Overall, it is concluded that there will be no significant cumulative effects from the Project alongside other projects/plans.

No potential transboundary impacts have been identified in regard to effects of the Project.

Table 9-22: Summary of potential environment effects, mitigation and monitoring.

Description of impact	Phase C	Phase O	Phase D	Measures included in the Project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Temporary subtidal habitat loss/disturbance	✓	✓	✓	None	C: Low O: Negligible D: Low	Low to medium	C: Slight adverse O: Imperceptible adverse D: Slight adverse	None	C: Slight adverse O: Imperceptible adverse D: Slight adverse	None
Injury and/or disturbance to fish from underwater noise during pile-driving	✓	✗	✗	During piling operations, soft starts will be used, with lower hammer energies used at the beginning of the piling sequence before increasing energies to the higher levels.	Low	Low to medium	Slight adverse	None	Slight adverse	None
Increased suspended sediment concentrations and associated sediment deposition	✓	✓	✓	None	C: Low O: Low D: Low	Low	C: Imperceptible adverse O: Imperceptible adverse D: Imperceptible adverse	None	C: Imperceptible adverse O: Imperceptible adverse D: Imperceptible adverse	None
Long-term subtidal habitat loss	✗	✓	✗	None	Low	Low to medium	Imperceptible or slight adverse	None	Imperceptible or slight adverse	None
Electromagnetic Fields (EMF) from subsea electrical cabling	✗	✓	✗	Burial and protections of cables.	Low	Low to medium	Slight adverse	None	Slight adverse	None

Table 9-23: Summary of potential cumulative environment effects, mitigation and monitoring.

Description of impact	Phase C	Phase O	Phase D	Measures included in the Project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Further measures	Residual effect	Proposed monitoring
Injury and/or disturbance to fish from underwater noise during pile-driving	✓	✗	✗	During piling operations, soft starts will be used, with lower hammer energies used at the beginning of the piling sequence before increasing energies to the higher levels.	Low	Low to medium	Slight adverse	None	Slight adverse	None

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