Environmental Impact
Assessment Report

NISA

North Irish Sea Array

Volume 3: Offshore Chapters

Chapter 13
Fish and Shellfish Ecology

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13.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) presents an assessment of the likely significant effects from the North Irish Sea Array (NISA) Offshore Wind Farm (hereafter referred to as the 'proposed development') in relation to fish and shellfish during the construction, operation and decommissioning phases.

This chapter sets out the methodology followed (Section 13.2), describes the baseline environment (Section 13.3) and summarises the main characteristics of the proposed development which are of relevance to fish and shellfish (Section 13.4) including any embedded mitigation. Potential impacts and relevant receptors are identified, and an assessment of likely significant effects on fish and shellfish ecology is undertaken, details of which are provided (Section 13.5).

Additional mitigation measures are proposed to mitigate and monitor these effects if required (Section 13.6) and any residual likely significant effects are then described (Section 13.7). Transboundary effects are considered (Section 13.8), and cumulative effects are considered in Section 13.9 and are summarised in Volume 6, Chapter 38: Cumulative and Inter-Related Effects (hereafter referred to as the 'Cumulative and Inter-Related Effects Chapter'). The chapter then provides a reference section (Section 31.10).

The EIAR also includes the following:

- Detail on the competent experts that have prepared this chapter is provided in Appendix 1.1 in Volume 8;
- Detail on the consultation that has been undertaken with a range of stakeholders during the development of the EIAR is set out in Appendix 1.2;
- A glossary of terminology, abbreviations and acronyms is provided at the beginning of Volume 2 of the EIAR; and
- A detailed description of the proposed development including construction, operation and decommissioning is provided in Volume 2, Chapter 6: Description of the Proposed Development - Offshore (hereafter referred to as the 'Offshore Description Chapter'), and Volume 2, Chapter 8: Construction Strategy - Offshore (hereafter referred to as the 'Offshore Construction Chapter').

The assessment should be read in conjunction with the following linked EIAR chapters within Volume 3:

- Chapter 10: Marine Geology, Oceanography and Physical Processes (hereafter referred to as the Physical Processes Chapter);
- Chapter 11: Marine Water and Sediment Quality (hereafter referred to as the Marine Water and Sediment Quality Chapter);
- Chapter 12: Benthic Subtidal and Intertidal Ecology (hereafter referred to as the Benthic Ecology Chapter); and
- Chapter 16: Commercial Fisheries (hereafter referred to as the Commercial Fisheries Chapter).

This chapter should also be read alongside the following appendices:

- Volume 9, Appendix 10.2: Marine Physical Processes Numerical Modelling;
- Volume 9, Appendix 12.1: Array Area Benthic Survey Report;
- Volume 9, Appendix 12.2: Cable Route Benthic Survey Report;
- Volume 9, Appendix 13.1: Fish and Shellfish Ecology Baseline Characterisation (hereafter referred to as the Fish and Shellfish Technical Baseline);

- Volume 9, Appendix 14.1: Underwater Noise Modelling Report (hereafter referred to as the Underwater Noise Report); and
- Volume 9, Appendix 16.1: Commercial Fisheries Technical Report (hereafter referred to as the Commercial Fisheries Technical Baseline).

All figures within this chapter are provided in Volume 7a.

13.2 Methodology

13.2.1 Introduction

The assessments of fish and shellfish ecology are consistent with the EIA methodology presented in Volume 2, Chapter 2: EIA and Methodology for the preparation of an EIAR (hereafter referred to as the EIAR Methodology chapter).

The assessments presented in the Fish and Shellfish Ecology Chapter consider impacts on fish (demersal, pelagic and elasmobranch species), shellfish (molluscs and crustaceans), and marine turtles within the offshore development area and potential Zones of Influence (ZoIs) (as defined in Section 13.2.2). Marine turtles were included in the fish and shellfish assessment as they possess hearing mechanisms comparable to those used by marine fishes. For ease of reference, all receptors considered in this report are collectively referred to as fish and shellfish receptors.

13.2.2 Study Area

The fish and shellfish ecology study area was initially identified at the proposed development scoping stage, in line with Department of Communications, Climate Action and Environment (DCCAE) (now the Department of the Environment, Climate and Communications; DECC) Guidance (DCCAE, 2017) (See Appendix 2.1: Scoping Report). The extent of the fish and shellfish ecology study area has been set to capture the greatest extent of potential direct and indirect effects[1] on fish and shellfish receptors that may arise from the proposed development. The study area incorporates the proposed development boundary seaward of the high water mark[2] (HWM), consisting of the array area and the offshore Export Cable Corridor (ECC), collectively referred to as 'the offshore development area'. In addition to the offshore development area, the study area also consists of the surrounding ZoIs (Figure 13.1). The actual extent of the ZoI will vary according to the nature of the impact being studied; to assess the effects on fish and shellfish receptors, the ZoI has been defined by the following spatial scales:

- For impacts related to seabed disturbance events, a sedimentary ZoI of 12km (Figure 13.1) buffering the offshore development area was selected, which has been determined by reference to the modelled spread of sediment plumes that may locally elevate background levels of turbidity. The results of the modelling indicate that suspended sediments at concentrations above background levels may be displaced up to about 12km during construction activities (Physical Processes Chapter). The 12km buffer zone has been set with reference to these modelled plume dispersal distances, resulting in a ZoI that is likely to cover the extent over which suspended sediment concentrations (SSC) above natural background levels might occur.
- An additional underwater noise ZoI of 70km buffering the offshore development area was defined to assess the effects from underwater noise, based on predictions that underwater noise may have a larger effect range than that associated with sedimentary impacts. The largest impact range of underwater noise is anticipated from piling of foundations in the array area during the construction phase. The spatial extents over which effects on sensitive fish and shellfish receptors may arise have been determined through project-specific underwater noise modelling (see the Underwater Noise Report).

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[1] For the purpose of this assessment, impacts that occur within the footprint of an activity are termed direct impacts (e.g., physical disturbance to the seabed), while those impacts occurring away from an activity are termed indirect impacts (e.g., dispersal of sediment plumes and associated sediment deposition following the disturbance of the seabed).

[2] As defined by Ordnance Survey Ireland mapping.

The 70km buffer zone has been set to fully encapsulate the modelled maximum impact ranges for the 186dB re 1µPa^{2}s Sound Exposure Level (SEL) during pile driving, as the recommended threshold for the onset of temporary threshold shifts (TTS) in sensitive fish receptors (Popper et al., 2014).

Collectively, the area covered by the offshore development area and the two ZoIs defined for fish and shellfish receptors is referred to throughout this report as the fish and shellfish study area (or as the study area).

13.2.3 Relevant Guidance, Legislation and Policy

This section outlines the guidance, legislation and policy used to inform the assessment of fish and shellfish ecology. Overarching guidance on EIA is presented in the EIAR Methodology Chapter. Furthermore, policy applicable to the proposed development is detailed in Volume 2, Chapter 3: Legal and Policy Framework. The assessment of likely significant effects upon fish and shellfish ecology has been made with specific reference to the following identified relevant guidelines and guidance:

- Guidance on Environmental Impact Statement (EIS) and Natura Impact Statement (NIS) Preparation for Offshore Renewable Energy Projects (Prepared for the Environmental Working Group of the Offshore Renewable Energy Steering Group and the DCCAE, 2017) (hereafter referred to as the DCCAE Guidance)
- Guidance on Marine Baseline Ecological Assessments & Monitoring Activities for Offshore Renewable Energy Projects (Department for Communications, Climate Action & Environment (DCCAE), 2018)
- Guidelines on the Information to be contained in Environmental Impact Assessment Reports (Environmental Protection Agency (EPA), 2022)
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Centre for Environment, Fisheries and Aquaculture (Cefas), 2012)
- Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by American National Standards Institute (ANSI) Accredited Standards Committee S3/SC1 and registered with ANSI (Popper et al., 2014)
- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater, Coastal and Marine (Chartered Institute of Ecology and Environmental Management (CIEEM), 2018); and
- Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008).

Consideration of fish and shellfish ecology in Natura 2000 sites is required under The European Communities (Birds and Natural Habitats Regulations 2011 (S.I. No. 477 of 2011)), which transpose the EU Habitat and Birds Directives.

An assessment of the impacts of the proposed development on Natura 2000 sites and their qualifying features is presented in the NIS (North Irish Sea Array Windfarm Ltd, 2024).

The key National Marine Policy Framework (NMPF) that is applicable to the assessment of fish and shellfish ecology is summarised in Table 13.1. NMPF policies are addressed in their entirety in Appendix 3.1: NMPF Compliance Report.

Table 13.1 Key NMPF policies relevant to the assessment

Policy Name	Policy Description	Where addressed
National Marine Planning Framework	**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 significance of effects relevant to Biodiversity Policy 1 are addressed in: Sections 13.5.2.1 Impact 1, 13.5.3.1 Impact 5, and 13.5.4.1 Impact 11: Temporary increase in SSC and sediment deposition during construction, maintenance and decommissioning activities, respectively; Section 13.5.3.3 Impact 7: Long-term and permanent loss of benthic habitat due to the placement of subsea infrastructure; Section 13.5.2.4 Impact 4 and Section 13.5.4.4 Impact 14: Introduction of underwater noise and vibration leading to mortality, injury and behavioural impacts; and Section 13.5.3.6 Impact 10: Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables. No significant adverse residual effects on fish and shellfish receptors are predicted as a result of the assessed impacts. Embedded mitigation measures in respect to likely effects are detailed in Section 13.4.5 and include soft-start procedures during piling, the adoption of a UXO specific management plan, the implementation of marine pollution prevention and contingency measures, and cable burial and cable protection measures.
	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 significance of effects relevant to Biodiversity Policy 2 are addressed in: Sections 13.5.2.1 Impact 1, 13.5.3.1 Impact 5, and 13.5.4.1 Impact 11: Temporary increase in SSC and sediment deposition during construction, maintenance and decommissioning activities, respectively; Sections 13.5.2.2 Impact 2, 13.5.3.2 Impact 6, and 13.5.4.2 Impact 12: Temporary habitat damage and disturbance of the seabed during construction, maintenance and decommissioning activities, respectively; and Section 13.5.3.3 Impact 7: Long-term and permanent loss of benthic habitat due to the placement of subsea infrastructure. No significant adverse residual effects on fish and shellfish receptors are predicted as a result of the assessed impacts. Embedded mitigation measures in respect to likely effects are detailed in Section 13.4.5 and include the implementation of marine pollution prevention and contingency measures.
	Biodiversity Policy 4 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 significance of effects relevant to Biodiversity Policy 4 are addressed in: Section 13.5.2.4 Impact 4 and Section 13.5.4.4 Impact 14: Introduction of underwater noise and vibration leading to mortality, injury and behavioural impacts; and Section 13.5.3.6 Impact 10: Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables.

Policy Name	Policy Description	Where addressed
		No significant adverse residual effects on fish and shellfish receptors are predicted as a result of the assessed impacts. Embedded mitigation measures in respect to likely effects are detailed in Section 13.4.5 and include soft-start procedures during piling, the adoption of a UXO specific management plan, and the use of cable burial and cable protection measures.
	Water Quality Policy 1 Proposals that may have significant adverse impacts upon water quality, including upon habitats and species beneficial to water quality, 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	The significance of effects relevant to Water Quality Policy 1 are addressed in: Sections 13.5.2.1 Impact 1, 13.5.3.1 Impact 5, and 13.5.4.1 Impact 11: Temporary increase in SSC and sediment deposition during construction, maintenance and decommissioning activities, respectively; and Sections 13.5.2.3 Impact 3, 13.5.3.4 Impact 8, and 13.5.4.3 Impact 13: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental pollution during construction, maintenance and decommissioning activities, respectively. No significant adverse residual effects on fish and shellfish receptors are predicted as a result of the assessed impacts. Embedded mitigation measures in respect to likely effects are detailed in Section 13.4.5 and include the implementation of marine pollution prevention and contingency measures.
	Sea Floor and Water Column Integrity Policy 2 Proposals, including those that increase access to the maritime area, must demonstrate that they will, in order of preference and in accordance with legal requirements: a. avoid, b. minimise, or c. mitigate adverse impacts on important habitats and species.	The significance of effects relevant to Sea Floor and Water Column Integrity Policy 2 are addressed in: Sections 13.5.2.1 Impact 1, 13.5.3.1 Impact 5, and 13.5.4.1 Impact 11: Temporary increase in SSC and sediment deposition during construction, maintenance and decommissioning activities, respectively; Sections 13.5.2.2 Impact 2, 13.5.3.2 Impact 6, and 13.5.4.2 Impact 12: Temporary habitat damage and disturbance of the seabed during construction, maintenance and decommissioning activities, respectively; Section 13.5.2.4 Impact 4 and 13.5.4.4: Introduction of underwater noise and vibration leading to mortality, injury, TTS and/or behavioural effects during construction and decommissioning; Section 13.5.3.3 Impact 7: Long-term and permanent loss of benthic habitat due to the placement of subsea infrastructure; and Section 13.5.3.6 Impact 10: Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables. No significant adverse residual effects on fish and shellfish receptors are predicted as a result of the assessed impacts. Embedded mitigation measures in respect to likely effects are detailed in Section 13.4.5 and include soft-start procedures during piling, the adoption of a UXO specific management plan, and the use of cable burial and cable protection measures.
	Fisheries Policy 5 Proposals, regardless of the type of activity they relate to, enhancing essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes should be supported.	The significance of effects relevant to Fisheries Policy 5 are addressed in: Sections 13.5.2.1 Impact 1, 13.5.3.1 Impact 5, and 13.5.4.1 Impact 11: Temporary increase in SSC and sediment deposition during construction,

Policy Name	Policy Description	Where addressed
	If proposals cannot enhance essential fish habitat, they must demonstrate that they will, in order of preference: a. avoid, b. minimise, c. mitigate significant adverse impact on essential fish habitat, including spawning, nursery and feeding grounds, and migration routes. d. if it is not possible to mitigate significant adverse impact on essential fish habitat, proposals must set out the reasons for proceeding.	maintenance and decommissioning activities, respectively; Sections 13.5.2.2 Impact 2, 13.5.3.2 Impact 6, and 13.5.4.2 Impact 12: Temporary habitat damage and disturbance of the seabed during construction, maintenance and decommissioning activities, respectively; Section 13.5.3.3 Impact 7: Long-term and permanent loss of benthic habitat due to the placement of subsea infrastructure; and Section 13.5.3.5 Impact 9: Increase in hard substrate and structural complexity due to the placement of subsea infrastructure. No significant adverse residual effects on fish and shellfish receptors are predicted as a result of the assessed impacts. Embedded mitigation measures in respect to likely effects are detailed in Section 13.4.5 and include the implementation of marine pollution prevention and contingency measures.
	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 significance of effects relevant to Underwater Noise Policy 1 are addressed in: Section 13.5.2.4 Impact 4 and 13.5.4.4 Impact 14: Introduction of underwater noise and vibration leading to mortality, injury, TTS and/or behavioural effects during construction and decommissioning. The assessment describes the noise sources associated with construction and decommissioning activities. A detailed assessment of underwater noise effects on potentially sensitive fish and shellfish species is provided. No significant adverse residual effects on fish and shellfish receptors are predicted as a result of underwater noise. Embedded mitigation measures in respect to likely effects from underwater noise are detailed in Section 13.4.5 and include soft-start procedures during piling and the adoption of a UXO specific management plan.

13.2.4 Data Collection and Collation

A detailed desktop review has been carried out to inform the baseline characterisation of fish and shellfish resources within the study area. Information was sought on fish and shellfish ecology in general and on spawning and nursery behaviour and habitats of key species. The baseline characterisation utilises a broad combination of existing literature and site-specific and regional monitoring datasets. Regional monitoring datasets were used to describe the distribution of fish and shellfish assemblages within the wider western Irish Sea and to characterise the receiving seabed environment. In addition, regional datasets were used to identify spawning and nursery grounds within the study area. Data collected during site-specific benthic ecology surveys undertaken across the offshore development area were used to complement the characterisation of the fish and shellfish resources in the study area and to identify potential suitable spawning grounds for sandeel and herring. These surveys collected sediment samples for particle size analysis (PSA) and drop-down video (DDV) data.

Key data and information sources used to inform the fish and shellfish ecology baseline characterisation are listed in Table 13.2. Full details on these data sources and the utilisation of each are provided in the Fish and Shellfish Technical Baseline.

The data available from existing literature and relevant surveys provide a comprehensive evidence base for the distribution and ecology of fish and shellfish populations within the fish and shellfish study area, sufficient to inform the EIAR. Therefore, additional site-specific fish and shellfish trawl surveys have not been deemed necessary. The use of available survey data and information from peer-reviewed literature over site-specific trawl survey data is an accepted and tested approach for offshore wind developments in UK waters.

It is considered that standard epibenthic trawls (and other traditional fish surveys) have limited value as they provide solely a snapshot of species in time and sampling is highly gear specific. Moreover, such surveys are highly invasive, and it would be highly unlikely that they would identify any additional receptor species that are not already recorded in the extensive (both spatially and temporally) data that is available and which has been used to inform the EIA of the proposed development. Rather, the baseline description draws upon wider scientific literature and publicly available datasets, as this provides a more thorough, robust, and longer evidence base, which therefore ensures a more comprehensive and precautionary baseline, identifying all fish and shellfish species that are likely to be present within the study area.

Table 13.2 Data sources used to inform the fish and shellfish ecology baseline characterisation and assessment

Data source	Data utilisation
Site-specific Surveys	
• Site-specific benthic ecology baseline surveys across the array (Volume 9, Appendix 12.1: Array Area Benthic Survey Report) and ECC (Volume 9, Appendix 12.2: Cable Route Benthic Survey Report).	• Site-specific survey data inclusive of benthic grabs, DDV, PSA, sediment total carbon content and contaminant analysis. DDV data used to inform the fish and shellfish baseline; PSA data used to determine potential for herring and sandeel spawning grounds.
Existing Data Sources	
• Coull et al. (1998) Fisheries Sensitivity Maps in British Waters.	• Used to provide information on likely spawning grounds or nursery areas for commercially important species.
• Ellis et al. (2010) Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (MPAs).	• Provided information on spawning and nursery grounds for elasmobranchs and commercially important fish species.
• Ellis et al. (2012) Spawning and nursery grounds of selected fish species in UK waters.	
• Marine Institute (2016) Species spawning and nursery areas – Ireland’s Marine Atlas.	• Provided information on spawning and nursery grounds, and observations of common commercially important fish species in Ireland.
• Marine Institute (2009) Irish Sea Marine Assessment (ISMA) (2009) Survey CV0926.	• Irish Sea marine habitat data presented to provide an indication on the location of suitable habitat and spawning grounds for herring and sandeel.
• Integrated Mapping for the Sustainable Development of Ireland’s Marine Resources (INFOMAR) (2023) Marine broadscale habitat data.	• Broadscale marine habitat data presented to provide an indication on the location of suitable habitat and spawning grounds for herring and sandeel.
• Broad-scale seabed habitat map of Europe (EUSeaMap) (2021). European Marine Observation and Data Network (EMODnet)	• Broadscale seabed habitat map presented to characterise the seabed environment.
• Cefas (2000) Irish Sea Annual Egg Production Method (AEPM) Plankton Survey.	• Used to provide information on numbers of fish eggs, larvae and zooplankton.
• ICES (2023a) Northern Irish Ground Fish Survey (NIGFS) (2012-2022).	• Provided distribution data on ground fish in the western Irish Sea (ICES statistical rectangles 36E3, 36E4, 35E3, 35E4, 37E3, and 37E4)
• ICES (2023b) Offshore Beam Trawl Survey (BTS) (2012-2022)	• Provided distribution data on ground fish in the western Irish Sea (ICES statistical rectangles 36E3, 36E4, 35E3, 35E4, 37E3, and 37E4)
• Marine Institute (2023) The Stock Book 2023: Annual Review of Fish Stocks in 2023 with Management Advice for 2024.	• Commercial fisheries data used to provide data related to fisheries landings and fishing effort within the study area.
• Gerritsen and Kelly (2019) Atlas of Commercial Fisheries around Ireland.	
• Marine Institute and Bord Iascaigh Mhara (2024) Shellfish Stocks and Fisheries Review 2023.	• Commercial fisheries data used to provide data related to shellfish fisheries within the study area.
• Tully (2017) Atlas of Commercial Fisheries for Shellfish around Ireland.	
• Celtic Sea Trout Project (CSTP) (2016)	• Used to provide information on the status, distribution, and ecology of sea trout populations.

Data source	Data utilisation
• ICES (2022a) ICES Ecosystem Overviews. Celtic Seas ecoregion – Ecosystem Overview	• Overview of the state of the ecosystem in the region.
• ICES (2022b) ICES Fisheries Overviews. Celtic Seas ecoregion – fisheries overview.	• Overview of all common commercially important fish and shellfish species in the region.
• O'Sullivan et al. (2013) An Inventory of Irish Spawning Herring Grounds	• Inventory of key herring spawning and fishing grounds around the coast of Ireland based on data from the fishing industry and seabed surveys.
• King et al. (2011) Ireland Red List No. 5: Amphibians, Reptiles and Freshwater Fish	• Details most up-to-date list of amphibians, reptiles and freshwater fish native and non-native to Ireland, listed from least concern to extinct.
• Clarke et al. (2016) Ireland Red List No. 11: Cartilaginous fish (sharks, skates, rays and chimaeras)	• Details most up-to-date list of cartilaginous fish native and non-native to Ireland, listed from least concern to extinct.
• Inland Fisheries Ireland (IFI) publications on the status of migrating fish populations (2018-2023).	• Findings of a monitoring programme designed to assess the status of salmon populations in river catchments throughout Ireland.
• Marine Institute (2013) Article 6 Assessment of Fisheries, including a Fishery Natura Plan for Seed Mussel (2013-2017), in the Irish Sea.	• Assessment of the potential ecological impact of fishing activity on Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) in the Irish Sea.
• Aquatic Services Unit (2020) Dublin Port Maintenance Dredging 2022 – 2029 Benthic and Fisheries Assessment	• Trawl survey data from Dublin Bay used to support the fish and shellfish baseline characterisation.
• Saorgus Energy Limited, 2013. Dublin Array An Offshore Wind Farm on the Kish and Bray Banks. Environmental Impact Statement.	• Environmental and ecological data collected from the Kish and Bray banks and along the ECC of the proposed Dublin Array wind farm development. Data used to support the fish and shellfish baseline characterisation.
• Department of Communications, Energy and Natural Resources (DCENR), 2010. Strategic Environmental Assessment (SEA) of the Offshore Renewable Energy Development Plan (OREDP) in the Republic of Ireland: Environmental Report Volume 2: Main Report and Appendix F – Commercial Fisheries in Environmental Report Volume 4: Appendices.	• Includes data on common commercially important fish and shellfish species in Irish waters.
• Department of the Environment, Climate and Communications, 2023. Draft OREDP II: Draft SEA Report and Appendix 3 – Updated Baseline Summary Report.	

13.2.5 Methodology for Assessment of Effects

EIA significance criteria for fish and shellfish ecology follows Environmental Protection Agency (EPA) guidance:

- EPA (2022) Guidelines on the information to be contained within Environmental Impact Assessment Reports.

The impact assessment for fish and shellfish species has taken a Valued Ecological Receptor (VER) approach to determine which species to take forward to the impact assessment stage. This allows the assessment to focus on important ecological features that might be affected by the proposed development (CIEEM, 2018). The importance of a fish or shellfish species is dependent upon a range of factors, including their conservation, social, and economic value.

Other factors used to identify VERs for the proposed development include the potential for migratory species to transit the study area and the importance of the study area to support key life stages, such as spawning and nursery periods. The list of factors considered during the selection of VERs and the VER species list are included in Section 13.3.10.

The impact assessment for the fish and shellfish VERs evaluates the significance of effects during the construction, operation and decommissioning phases of the proposed development (Section 13.5). The potential for significant transboundary (Section 13.8) and cumulative (Section 13.9) effects to arise are also considered. The assessment also considers likely naturally occurring variability in fish and shellfish receptors within the lifetime of the proposed development due to natural cycles and/or climate change. This is important as it enables a reference baseline level to be established against which the potentially modified fish and shellfish baseline can be compared throughout the lifecycle of the proposed development. The baseline conditions of the receiving environment are described in Section 13.3.1 to Section 13.3.9, and the future receiving environment is detailed in Section 13.5.1.

The criteria for determining the sensitivity of the receiving environment and the magnitude of impacts for the fish and shellfish ecology assessment are defined in Table 13.4 and Table 13.5 respectively. A matrix was used for the determination of significance in EIA terms (Table 13.6). The combination of the magnitude of the predicted impact with the sensitivity of the receptor helps to determine the assessment of significance of effect.

13.2.5.1 Sensitivity criteria

The determination of a receptor's sensitivity to an impact is based on the receptor's adaptability, tolerance, and recoverability together with its assigned value. Adaptability relates to a receptor's capacity to avoid or adapt to an impact, while tolerance refers to a receptor's ability to absorb environmental changes arising from an impact. For example, when regarding fish and shellfish receptors, consideration is given to several factors, including the mobility of the receptor. Receptors that can move away from an impact are considered more adaptable than those that are sedentary or less mobile. When applying this consideration to a fish and shellfish assessment, less adaptable receptors typically include shellfish of limited mobility, fish that will potentially be engaging in spawning behaviours, substrate dependent receptors, and eggs and larvae.

The determination of tolerance takes account of a receptor's ability to absorb temporary or permanent changes without altering its character (Holling, 1973). This may relate to a receptor's ability to resist damage or death or the likelihood of behavioural and physiological changes or changes in reproductive success. When applying this consideration to a fish and shellfish assessment, less tolerant receptors may include less mobile shellfish species that are susceptible to damage from physical disturbances, fish and shellfish unable to tolerate changes in substratum type, and fish that will be affected by underwater noise, for example, by experiencing physical injuries. The determination of tolerance will also consider the likelihood of damage to, or loss of early life stages.

The recoverability of a receptor relates to the degree to which the receptor can recover after an impact has stopped. It takes account of the rate of recovery, which for the purpose of this assessment is evaluated against the time periods proposed in the EPA Guidelines (EPA, 2022). For fish and shellfish receptors, recoverability can relate to the ability of a receptor to recolonise an area after an impact has occurred, for normal behaviour to resume, or the time needed for recovery from a reduction in population levels or recruitment success due to injury or mortality.

The determination of receptor adaptability, tolerance and recoverability for fish and shellfish receptors is informed by reference to available peer-reviewed scientific literature, relevant Marine Evidence-Based Sensitivity Assessments (MarESA) from the Marine Life Information Network (MarLIN) database[3], and expert judgement. The different categories used to describe adaptability, tolerance and recoverability of fish and shellfish receptors and their respective definitions are presented in Table 13.3.

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

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[3] The MarLIN database (https://www.marlin.ac.uk) holds the largest review of potential sensitivities of North-East Atlantic marine and coastal habitats to human activities (Tyler-Walters et al., 2023). This includes historic (MarLIN approach) and more recent (MarESA approach) sensitivity assessments for some fish and shellfish receptors, which have been used to inform the impact assessment.

Full details about the determination of value of fish and shellfish receptors are given in the Fish and Shellfish Technical Baseline. The commercial importance of individual receptors is fully described in the Commercial Fisheries Chapter and Commercial Fisheries Technical Baseline.

The overall sensitivity is derived by considering a receptor's ability to adapt, tolerate and recover from an impact in relation to its value. The criteria are considered in-combination on a receptor-by-receptor basis, as outlined in Table 13.4. For example, if a receptor is considered of high value/importance, or has rapid recovery rates, these criteria may be given greater weighting in defining the sensitivity of the receptor. Where a receptor could reasonably be assigned more than one level of sensitivity, professional judgement is used to determine which level is applicable, in line with the CIEEM 2018 Guidance (CIEEM, 2018).

Table 13.3 Definitions of adaptability, tolerance and recoverability applied to determine receptor sensitivity

Criteria	Definition
Adaptability	
• High	• Receptor has high capacity to avoid or adapt to impact.
• Medium	• Receptor has a reasonable capacity to avoid or adapt to impact.
• Low	• Receptor has a limited capacity to avoid or adapt to impact.
• None	• Receptor cannot avoid or adapt to impact.
Tolerance	
• High	• Receptor is considered tolerant to impact (i.e., receptor has a high capacity to accommodate change).
• Medium	• Receptor has some tolerance to impact (i.e., receptor has a moderate capacity to accommodate change).
• Low	• Receptor has limited tolerance to impact (i.e., receptor has a low capacity to accommodate change).
• Very low to none	• Receptor has very limited to no tolerance to impact (i.e., receptor has no or very low capacity to accommodate change).
Recoverability	
• High	• Effects are anticipated to be temporary (i.e., lasting less than one year).[4]
• Medium	• The receptor is anticipated to recover fully withing the short-term (i.e., 1-7 years).
• Low	• The receptor is anticipated to recover fully within the medium-term (i.e., 7-15 years).
• Very low	• The receptor is anticipated to recover fully within the long-term (i.e., 15-60 years).
• No recoverability	• The effect on the receptor is anticipated to be permanent (i.e., over 60 years).

Table 13.4 Sensitivity criteria used to assess impacts on fish and shellfish receptors

Receptor sensitivity	Definition
• High	• Nationally and internationally important receptors with no adaptability, no or very low tolerance and no or very low ability for recovery.
• Medium	• Nationally and internationally important receptors with low adaptability, medium to low tolerance, and medium to low recoverability; • Regionally important receptors with low to no adaptability, no or very low tolerance and no or very low ability for recovery; or • Regionally important receptors with low tolerance and medium to low recoverability.
• Low	• Nationally and internationally important receptors with medium adaptability, medium tolerance and high recoverability; • Regionally important receptors with medium to low adaptability, medium tolerance and medium to low recoverability; • Regional important receptor with low tolerance and high recoverability; or

[4] The potential time for recovery and the duration of impacts are assessed against the definitions proposed within the EPA EIA guidelines (EPA, 2022).

Receptor sensitivity	Definition
	• Locally important receptors with low adaptability, low to very low tolerance and low recoverability.
• Negligible	• Receptors are considered tolerant to the impact regardless of value/importance; or • Locally important receptors with medium adaptability, medium tolerance and medium to high recoverability.

13.2.5.2 Magnitude of impact criteria

It is noted here that a distinction is made throughout the assessment between the magnitude of impact, as defined by the extent, duration, frequency and consequences of the impact, and the resulting significance of the 'effects' upon fish and shellfish receptors. The magnitude of impacts is evaluated based on the potential consequences of impacts on fish and shellfish VERs, as defined in Table 13.5. Four levels of impact magnitude are used: high, medium, low, and negligible. It should be noted that individual determinations of impact magnitude may be based on criteria belonging to different levels. For example, whilst an impact may occur constantly throughout the operational period, the effects on particular receptors may be indiscernible from baseline conditions. Therefore, the impact would be concluded to be of a negligible magnitude despite its frequent occurrence. Conversely, an impact may occur infrequently or only once, but the effects on sensitive receptors may be severe, resulting in fundamental changes to the receptor's key characteristics. In this instance, the impact would be concluded to be of high magnitude. Where an impact could reasonably be assigned more than one level of magnitude, professional judgement is used to determine which level is most appropriate for the impact. All impacts have been considered in terms of whether they lead to adverse or beneficial effects on fish and shellfish receptors.

For the purposes of the definitions below, near-field has been defined as within the offshore development area. Far-field has been defined as extending beyond these boundaries, within the sedimentary and underwater noise ZoIs as defined in Section 13.2.2. To describe the duration of impacts, the categories and time periods recommended in the EPA guidelines were applied (EPA, 2022).

Table 13.5 Magnitude of the impact

Magnitude	Definition
High	**Extent:** The impact occurs across the near-field and far-field areas (i.e., across the whole study area). **Duration:** The impact is anticipated to be permanent. **Frequency:** The impact will occur constantly throughout the relevant project phase. **Consequences (adverse):** Permanent and fundamental adverse changes to key characteristics or features of the receptor's character or distinctiveness. **Consequence (beneficial):** Large scale or major improvement to key characteristics or features of the receptor's character or distinctiveness.
Medium	**Extent:** The maximum extent of the impact is restricted to the near-field and adjacent far-field (i.e., covering parts of the ZoIs). **Duration:** The impact is anticipated to be medium-term (i.e., seven to 15 years) to long-term (15-60 years). **Frequency:** The impact will occur constantly throughout a relevant project phase. **Consequences (adverse):** Noticeable change to key characteristics or features of the receptor's character or distinctiveness. **Consequences (beneficial):** Benefit to, or addition of, key characteristics or features of the receptor's character or distinctiveness.
Low	**Extent:** The maximum extent of the impact is restricted to the near-field (i.e., within the offshore development area). **Duration**: The impact is anticipated to be temporary (i.e., lasting less than one year) to short-term (i.e., one to seven years). **Frequency:** The impact will occur frequently and intermittent throughout a relevant project phase. **Consequences (adverse):** Barely discernible to noticeable change to key characteristics or features of the receptor's character or distinctiveness. **Consequences (beneficial):** Minor benefit to, or addition of, some key characteristics or features of the receptor's character or distinctiveness.
Negligible	**Extent:** The maximum extent of the impact is restricted to the immediate vicinity of subsea infrastructure (i.e., within about 0-10m).

Magnitude	Definition
	Duration: The impact is anticipated to be momentary (seconds to minutes) to brief (lasting less than one day). **Frequency:** The impact will occur once or infrequently throughout a relevant project phase. **Consequences:** No discernible to barely discernible change to key characteristics or features of the receptor's character or distinctiveness.

13.2.5.3 Defining the significance of effect

The significance of effect associated with an impact will be dependent upon the sensitivity of the receptor and the magnitude of the impact. The assessment methodology for determining the significance of likely significant effects is described in Table 13.6. Effects defined as significant, very significant or profound are considered significant in EIA terms. An effect that has a significance of moderate, slight, not significant or imperceptible is not considered to be significant in EIA terms.

With respect to fish and shellfish populations, an effect is concluded to be significant in EIA terms when it may affect the behaviour, survival and/or distribution of sufficient numbers of individuals, with sufficient severity, to affect the long-term viability of the population. Where more than one receptor (e.g., multiple fish species) has been considered for a given impact that vary in their sensitivity to that impact due to different life histories for example, the greatest level of significance has been assigned to the impact.

Table 13.6 Significance of likely significant effects upon fish and shellfish ecology

			Existing Environment–- Sensitivity			
			High	**Medium**	**Low**	**Negligible**
Description of Impact Magnitude	**Adverse impact**	**High**	Profound or very significant (significant)	Significant	Moderate	Imperceptible
		Medium	Significant	Moderate	Slight	Imperceptible
		Low	Moderate	Slight	Slight	Imperceptible
		Negligible	Not significant	Not significant	Not significant	Imperceptible
	Beneficial impact	**Negligible**	Not significant	Not significant	Not significant	Imperceptible
		Low	Moderate	Slight	Slight	Imperceptible
		Medium	Significant	Moderate	Slight	Imperceptible
		High	Profound or very significant (significant)	Significant	Moderate	Imperceptible

Where relevant, mitigation measures that are incorporated as part of the proposed development design process and/ or can be considered to be industry standard practice (referred to as ‘‘embedded mitigation’’) are considered throughout the chapter and are reflected in the outcome of the assessment of effects, described in Section 13.5. Additional mitigation measures that are not embedded and are considered as part of the residual effects assessment and are described separately (Section 13.7).

13.3 Baseline Environment

13.3.1 Introduction

A detailed characterisation of the fish and shellfish baseline environment is provided in the Fish and Shellfish Technical Baseline (Volume 9, Appendix 13.1). This characterisation draws on regional datasets, published literature, site-specific data collected within the array area and ECC, and industry specific data collections undertaken for nearby infrastructure projects (Table 13.2). A summary of the key findings from the baseline study is provided in the following sections. This summary is not intended to repeat or to carry out any additional reviews or analysis of ecological data and should therefore be read alongside the Fish and Shellfish Technical Baseline report.

13.3.2 Receiving Environment

13.3.3 Marine Fishes and Elasmobranchs

Data collected during the Northern Irish Ground Fish Surveys (NIGFS) (ICES, 2023a) and Offshore Beam Trawl Surveys (BTS) (ICES, 2023b) between 2012 and 2022 suggest that the ground fish assemblages within the study area are dominated by whiting *Merlangius merlangus*, haddock *Melanogrammus aeglefinus*, common dab *Limanda limanda*, and plaice *Pleuronectes platessa*. Other species caught in high numbers were Norway pout *Trisopterus esmarkii*, grey gurnard *Eutrigla gurnardus*, common dragonet *Callionymus lyra*, poor cod *Trisopterus minutus*, witch flounder *Glyptocephalus cynoglossus*, American plaice *Hippoglossoides platessoides*, sand gobies *Pomatoschistus*, and scaldfish *Arnoglossus laterna*. Species that were typically caught during the trawl surveys albeit in lower numbers included Atlantic cod *Gadus morhua*, spotted dragonet *Callionymus maculatus*, the white anglerfish *Lophius piscatorius*, and various species of sole.

The most abundant pelagic fish species caught during the NIGFS were Atlantic herring *Clupea harengus* and European sprat *Sprattus sprattus* followed by Atlantic mackerel *Scomber scombrus* and Atlantic horse mackerel *Trachurus trachurus*.

Among the elasmobranch species recorded within the study area, small-spotted catshark *Scyliorhinus canicula* was typically the most abundant (ICES, 2023a,b). Other elasmobranch species recorded in these surveys included nursehound *Scyliorhinus stellaris*, spiny dogfish *Squalus acanthias*, starry smooth-hound *Mustelus asterias*, tope *Galeorhinus galeus*, thornback ray *Raja clavata*, spotted ray *Raja montagui*, blonde ray *Raja brachyura*, and cuckoo ray *Leucoraja naevus*. Notable demersal elasmobranch species recorded on the Kish and Bray banks in the southern part of the study area (Saorgus Energy Limited, 2013) and across Dublin Bay (Aquatic Services Unit, 2020) included small-spotted catshark and thornback ray. Moreover, basking shark *Cetorhinus maximus* are known to migrate through the Irish Sea (e.g. Berrow and Heardman, 1994). Opportunistic public sightings and satellite tracking indicate that basking shark hotspots are located across the central Irish Sea, around the Isle of Man; however, there are also records of basking sharks across the western Irish Sea, including the study area (e.g., Dolton et al., 2020; Irish Whale and Dolphin Group, 2023). Monthly site-specific digital aerial surveys (DAS)[5] conducted across the array area (plus a 4km buffer area) between May 2020 and October 2022 recorded one basking shark each in September and November 2020 . Five sightings were recorded in October 2022, though it is unclear if these records captured different individuals or constitute repeat sightings.

DDVs taken across the array area and the ECC during the site-specific benthic ecology baseline surveys (Volume 9, Appendix 12.1 and Appendix 12.2) recorded flatfishes (Pleuronectiformes), dragonets (*Callionymidae*), cod fishes (*Gadidae*) and gurnards (*Triglidae*). Beam trawl samples from Kish and Bray banks located in the southern part of the underwater noise ZoI (Saorgus Energy Limited, 2013) also included flatfishes (e.g., plaice, dab, witch flounder and lemon sole *Microstomus kitt*) and cod fishes (e.g., haddock, whiting, cod, and poor cod *Trisopterus minutus*) as well as gurnards, lesser weaver *Echiichthys vipera*, butterfish *Pholis gunnellus*, herring, two-spotted clingfish *Diplecogaster bimaculata*, lesser sandeel *Ammodytes tobianus*, and greater sandeel *Hyperoplus lanceolatus*.

Flatfishes (e.g., dab, plaice, and flounder *Plathichtys flesus*) have also been frequently caught in beam trawls taken across Dublin Bay and the Dublin shipping channel (Aquatic Services Unit, 2020). Other groundfish species recorded were cod, whiting as well as butterfish, dragonet, sand gobies, short-spined sea scorpion *Myxocephalus scorpius* , sandeel (*Ammodytes* spp.) and thornback ray.

[5] DAS surveys were conducted by APEM Ltd. on a monthly basis between May 2020 and October 2022 to inform the assessment of marine mammal and ornithology receptors. A total of 16 transects per month were surveyed with 2.3km spacing totalling 15% coverage of the survey area. Further information about the DAS programme including transect lines and data collection methods is provided in Volume 9, Appendix 15.1: Offshore Ornithology Baseline Characterisation.

13.3.4 Shellfish Ecology

Site-specific DDVs identified the presence of Norway lobster *Nephrops norvegicus* burrows in the fish and shellfish study area, particularly in the finer sediments within the northern section of the array area (Volume 9, Appendix 12.1) and along the ECC (Volume 9, Appendix 12.2). *Nephrops* inhabiting these burrows are part of the western Irish Sea *Nephrops* population, which is found in the fine sediments of the Western Irish Sea Mud Belt from about 54.5°N in the north to 53.5°N in the south (Figure 13.2). The western Irish Sea stock supports one of the most productive *Nephrops* fisheries in Irish waters, with fishing effort concentrated in ICES rectangle 36E4 (Commercial Fisheries Technical Baseline), which overlaps the array area and the deeper areas of the ZoIs (Figure 13.2).

Other shellfish observed on the seabed imagery collected during the site-specific surveys were limited to sporadic sightings of bivalves (*Pectinidae*), sea snails (*Buccinidae*) and decapod crustaceans (hermit crabs *Paguridae*, and Brachyura including brown crab *Cancer pagurus*.

The areas surrounding the proposed development boundary are known to host several shellfish species. Beam trawl surveys undertaken across the Dublin shipping channel and inner Dublin Bay recorded common whelk *Buccinum undatum*, shrimp spp. and several species of crab, including hermit crab *Pagurus bernhardus*, green crab, brown crab, velvet crab *Necora puber*, harbour crab *Liocarcinus* sp. and spider crabs *Majidae* (Aquatic Services Unit, 2020). The substrates on Kish and Bray banks supported crabs, common whelk and blue mussel *Mytilus edulis* (Saorgus Energy Limited, 2013).

Decapod crustaceans and epibenthic molluscs commonly recorded during the regional BTS within the study area (ICES, 2023b) also included whelk, queen scallop, brown shrimp, hermit crabs, brown crab, *Nephrops*, and velvet crabs, king scallop *Pecten maxiumus*, and spider crabs *Inachus* spp.

13.3.5 Marine Turtles

Five species of marine turtles have been recorded in Irish waters, including leatherback turtle *Dermochelys coriacea*, loggerhead turtle *Caretta caretta* and Kemp's Ridley turtle *Lepidochelys kempii*. The leatherback turtle is the most regularly reported around the coast of Ireland, accounting for just over 80% of all records. Rare vagrant species to southern Irish waters include hawksbill turtle *Eretmochelys imbricata* and green turtle *Chelonia mydas* (King and Berrow, 2009). No turtles were recorded during the site-specific DAS or benthic ecology surveys.

Further detail on marine turtles can be found in Fish and Shellfish Technical Baseline (Volume 9, Appendix 13.1).

13.3.6 Spawning and Nursery Grounds

The locations of spawning and nursery grounds of fish and elasmobranch receptors were identified using information from Coull et al. (1998), Ellis et al. (2010, 2012) and Ireland's Marine Atlas (Marine Institute, 2016) and data from the Irish Sea AEPM plankton surveys (Cefas, 2000). The Coull et al. (1998) dataset shows spawning and nursery grounds for commercially important fish species in waters surrounding the UK and Ireland. Ellis et al. (2010, 2012) provides an update to these maps and extends the identification of spawning and nursery locations to ecologically important species, including elasmobranchs.

Spawning and nursery areas are categorised by Ellis et al. (2010, 2012) as either 'high' or 'low' intensity dependent on the level of spawning activity or presence of juveniles recorded in these areas. Coull et al. (1998) does not always provide this level of detail, although the authors define more refined areas of potential spawning and nursery grounds. The spatial extent of the mapped spawning grounds is considered to represent the widest known distribution within which spawning will occur, while the duration of spawning periods indicated in these studies is considered likely to represent the maximum duration of spawning (Coull et al., 1998). Therefore, these maps provide a precautionary basis for assessing impacts on spawning activity.

Due to the demersal spawning nature of sandeel and herring, and therefore their increased sensitivity to potential impacts from the development, sandeel and herring have been addressed separately below. The spawning and nursery grounds (Coull et al., 1998; Ellis et al., 2010; Marine Institute, 2016) discussed and illustrated below are considered robust sources of information, as the physical drivers such as sediment type remain the same and are supplemented by project specific PSA data.

‘High intensity’ spawning grounds for Atlantic cod and plaice overlap the study area (Figure 13.3), with ‘low intensity’ spawning grounds for these species evident across the wider region (Coull et al, 1998; Ellis, et al, 2010, 2012; Marine Institute, 2016). Low intensity spawning grounds for sole (Ellis et al., 2010, 2012; Coull et al., 1998) and whiting (Ellis et al., 2010, 2012; Coull et al., 1998; Marine Institute, 2016) overlap the study area (Figure 13.3). Low intensity spawning grounds for mackerel, horse mackerel, hake, and common ling *Molva molva* also overlap the study area (Ellis et al., 2010, 2012) (Figure 13.4). Furthermore, spawning grounds of unidentified intensity are present for lemon sole and sprat (Coull et al, 1998), and for haddock (Marine Institute, 2016) (Figure 13.3). For the commonly observed cod, plaice and whiting, larval densities recorded during the Irish Sea AEPM plankton surveys (Cefas, 2000) indicate areas of high intensity spawning to be present within the study area and across the Irish Sea (Figure 13.6**)**.

The fish and shellfish study area overlaps with ‘high intensity’ nursery grounds for herring and Atlantic cod (Figure 13.7), and whiting (Figure 13.8) (Coull et al., 1998; Ellis et al., 2010, 2012; Marine Institute, 2016). ‘Low intensity’ nursery grounds are present across the study area for plaice (Coull et al., 1998; Ellis et al., 2010, 2012; Figure 13.7), Atlantic mackerel (Ellis et al., 2010, 2012; Marine Institute, 2016; Figure 13.8), and anglerfish (Ellis et al., 2010, 2012; Figure 13.7). There are also nursery grounds present across the study area for haddock (Coull et al., 1998; Marine Institute, 2016; Figure 13.7), lemon sole (Coull et al., 1998; Figure 13.7), and Atlantic horse mackerel (Marine Institute, 2016; Figure 13.8). Furthermore, the study area also likely acts as a ‘high intensity’ nursery ground for spiny dogfish and ‘low intensity’ nursery grounds for tope, thornback ray, and spotted ray (Ellis et al., 2010, 2012; Figure 13.8).

Table 13.7 Summary of spawning times in the Irish Sea for fish and shellfish species known to have spawning grounds in the study area (medium red indicates spawning period, dark red indicates approximate peak spawning period, light red indicates potential spawning period). Spawning periods data sources: 1–- Coull et al. (1998); 2–- ICES (2005); 3–- Nichols et al. (1993); 4–- Campanella and van der Kooij (2021); 5–- ICES (1994) 6–- Farmer (1974)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
• Atlantic cod[2]												
• Whiting[1,4]												
• Common ling[3]												
• Horse mackerel[4]												
• Atlantic mackerel[1]												
• Plaice[1,2]												
• Witch flounder[3]												
• Common sole[1,3]												
• Lemon sole[1]												
• Sprat[1]												
• Haddock[1]												
• Sandeel[3]												
• Herring[5]												
• Nephrops[6]												

13.3.6.1 *Sandeel*

Sandeel show a high degree of site fidelity, and the settled distribution of adult sandeel is largely reflective of preferred spawning sediments (Jensen et al., 2011). Therefore, the distribution of potential sandeel habitats discussed below equally refers to suitable spawning habitats.

Data analysed by Ellis et al. (2010) suggest that the study area overlaps with ‘low intensity’ sandeel spawning grounds (Figure 13.5). Sandeels are demersal spawners with a preference for sandy and gravelly sandy sediments with low mud content (Holland et al., 2005; Wright et al., 2000). Broadscale sediment maps (EUSeaMap, 2021) indicate mainly homogenous substrates across the array area and ECC with sediments predominantly composed of Sandy muds to Muddy sands and Sands (Figure 13.9). Sediments across the ZoI also contain large areas of Mud to muddy sand and Mixed sediments. To further refine the understanding of potential sandeel spawning grounds within the study area, site-specific PSA data collected across the array area (Volume 9, Appendix 12.1), ECC (Volume 9, Appendix 12.2) and ZoI (INFOMAR, 2023) were classified according to the methodology described in Latto et al. (2013). The Latto et al. (2013) approach classes sediments as either ‘Unsuitable’, ‘Suitable’ or ‘Sub-Prime’ for sandeel spawning based on the proportions of mud, sands and gravels within the sediments.

Sediments collected from within the array area were classified as sandy Muds and muddy Sands, indicating ‘Unsuitable’ conditions for sandeel, including sandeel spawning. ‘Unsuitable’ sediments for sandeel are also located in the north-eastern corner of the ECC where muddy Sands and Mixed sediments with mud concentrations greater than 10% were recorded. Sediments within the remaining ECC sampling area were categorised as mainly ‘Suitable’ Sands for sandeel with some locations classed as ‘Sub-Prime’ sandeel substrate (Figure 13.9). Within the sedimentary and underwater noise ZoIs, INFOMAR (2023) seabed substrate data indicate localised ‘Suitable’ areas for sandeel spawning to the north and south of the ECC between the proposed windfarm array and the coastline. The INFOMAR data also indicate the presence of ‘Preferred’ (‘Prime’ and ‘Sub-Prime’) and ‘Marginal’ (‘Suitable’) sandeel habitats to the south of the offshore development area within the southern part of the underwater noise ZoI (Figure 13.9).

13.3.6.2 Herring

Herring were recorded in relatively high abundances across the study area and western Irish Sea in the NIGFS (ICES, 2023a). Herring nursery grounds are located inshore, overlapping the array area, ECC and the northern sections of the ZoI (Figure 13.7). The nearest known active herring spawning ground (the Mourne ground) is located off County Down and the northern sections of County Louth about 20km to the north of the array area (Dickey-Collas et al., 2001), with potential suitable spawning substrate known to also be present across the outer sections of Dundalk Bay (MPA Advisory Group, 2023) (Figure 13.5).

Potential suitable substrate for herring spawning were also defined using site-specific and publicly available PSA data, following the methodology described by Reach et al. (2013). The results of this analysis suggest that sediments within the array area and ECC are unsuitable for herring spawning, based on the analysis of substrate type, being dominated by Sands and Muds (Figure 13.10). Besides potential suitable substrates across Dundalk Bay (Figures 13.5 and 13.10), sediments suitable (‘Suitable’ to ‘Prime’) for herring spawning may be present across the coarser grounds along nearshore areas within the southern portion of the study area, including the coastal areas off Howth. Whether such areas are ultimately used by herring for spawning depends on additional factors, including small-scale seabed geomorphology and local wind and flow conditions (Frost and Diele, 2022). Larval data taken across the Irish Sea suggests that these areas are not used as key spawning sites (Dickey-Collas et al., 2001; ICES, 1994).

13.3.7 Species of Commercial importance

As described in the Commercial Fisheries Technical Baseline, the study area supports a variety of commercial fisheries for fish and shellfish. The array area and its surrounding areas to the north and west are dominated by landings of *Nephrops* caught with demersal otter trawls. Demersal fish and elasmobranch species caught in conjunction with the *Nephrops* fishery include haddock, plaice, monkfish, cod, lesser-spotted dogfish, and thornback ray. A low intensity beam trawl fishery mainly targeting sole, plaice and thornback ray also occurs within the study area, with notable grounds located approximately 50km south-east of the array area. Pelagic species commercially targeted within the study area are Atlantic herring and European sprat, with fishing grounds mainly located inshore in Dublin Bay and off Howth.

The inshore areas overlapping the ECC are dominated by landings of shellfish including sword razorshell *Ensis siliqua*, brown crab, common cockle *Cerastoderma edule*, and common whelk, as well as some catches of *Nephrops* (Figure 13.11). Fishing grounds for razor clams are located close to the coast from Howth to Dundalk Bay in water depths of about 4-14m (Figure 13.11), while cockles are currently commercially harvested across the inshore areas in Dundalk Bay (Marine Institute and Bord Iascaigh Mhara, 2022).

Brown crab are currently targeted across the ECC right up to the array area, and potting activity for whelk is understood to be concentrated further south towards the array area. Other shellfish commercially fished within the study area are king scallop and European lobster *Hommarus gammarus*. The lobster fishery is located inshore along the coast from Howth to Dundalk Bay (Tully, 2017). King scallop is commercially fished further offshore from several scallop beds, which are located predominantly to the south of the array area.

13.3.8 Diadromous Species

Diadromous fish are fish that spend part of their life cycle in freshwater and part in seawater, such species are termed catadromous (born in marine habitats then migrate to freshwater areas) and anadromous (born in freshwater then migrate to, and mature in, the ocean). Such species are not generally present in the vicinity of the study area for much of their life cycle. However, they may pass through the study area when migrating to and from rivers and other freshwater bodies in the area.

Diadromous fish species that have the potential to occur in the fish and shellfish study area are Atlantic salmon *Salmo salar*, sea trout *Salmo trutta*, European eel, twaite shad *Alosa fallax*, sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluviatilis*. The nearest rivers designated as salmonid waters under the Salmonid River Regulations are the river Boyne and the river Dargle, the latter entering the Irish Sea at Bray to the south of the offshore development area. Atlantic salmon are also present in the Rivers Varty, Liffey, Dodder, Tolka, Fane, Glyde, Dee and Castletown (IFI, 2018, 2022; Millane et al., 2023; O'Connor, 2006). The marine phase of Atlantic salmon begins between spring and early summer when large numbers of young salmon (smolts) leave Irish rivers to migrate northward towards the rich feeding grounds of the Norwegian Sea (e.g., Gilbey et al., 2020; Holm et al., 2000). The return migration of salmon into rivers peaks during spring and summer, and spawning occurs during the following autumn and winter (Finstad et al., 2005). Acoustic telemetry data showed that salmon smolts from east coast rivers in Ireland move north upon leaving their home rivers (Barry et al., 2020). The tracking data further suggest that on leaving their natal rivers, smolts move rapidly away from the coast towards the deep waters of the Irish Sea, possibly to take advantage of the northwards flowing currents, which can assist their journey to the oceanic feeding grounds in the north-east Atlantic (Barry et al., 2020).

Sea trout are widespread in all major river and lake systems of Ireland. On the east coast of Ireland, they have been recorded in the Rivers Boyne, Nanny, Dargle, Tolka, Liffey and Dodder, Avoca, Castletown, Fane, Glyde and Dee, with the Dodder being an important angling river (IFI, 2022). European eel are also found in many Irish rivers, including the Rivers Boyne, Fane, Tolka, Liffey and Dodder (IFI, 2018; Technical Expert Group on Eel, 2021). Tagging studies suggests that European eels begin their oceanic migration from their home rivers to the spawning grounds in the Sargasso Sea between August and December (Righton et al., 2016).

The Boyne and Lower Liffey are a known migratory corridor for river lamprey. Little is known about the movements of river and sea lampreys at sea. River lamprey are reported to typically remain in estuarine areas during their marine stage (Maitland, 2003), while adult sea lamprey have been recorded in both shallow coastal and deep offshore waters, with sightings as deep as 4,000m (Kelly and King, 2001; Maitland, 2003). In northwest Europe, adult sea lamprey typically migrate into rivers throughout spring and early summer, while the seaward movement of newly metamorphosed young adults takes place during autumn and early winter (Kelly and King, 2001; Maitland, 2003). The upstream migration of mature river lampreys from the sea to freshwater spawning streams typically begins in late summer and autumn (Kelly and King, 2001), and young adults migrate downstream into estuaries between summer and late autumn/early winter (Kelly and King, 2001; Maitland, 2003). The distribution and habitat requirements of twaite shad while at sea are also poorly documented. The species is reported to prefer shallow waters at depths of 10-20 m, although it has also been recorded in deeper waters of up to 300 m (Maitland and Hatton-Ellis, 2003).

13.3.9 Species of Conservation Importance and Designated Sites

The desk-based review identified a number of marine and estuarine fish and elasmobranch species protected under national and international legislation and commitments that have potential to be present within the study area. These are discussed in full in the Fish and Shellfish Technical Baseline (Volume 9, Appendix 13.1).

Among the species of conservation importance, four are listed as Annex II species under the EU Habitats Directive: river lamprey, sea lamprey, twaite shad and Atlantic salmon. All four species are diadromous species and have been afforded protection in SACs under the EU Habitats Directive. The nearest SAC designated for these species to the study area is the River Boyne and River Blackwater SAC, which lies inland approximately 21km to the north-west of the array area. The SAC is designated for river lamprey and Atlantic salmon (Figure 13.12). Along the south-east coast of Ireland, migrating fish species are afforded protection in the Slaney River Valley SAC, which is located approximately 149km from the array area (measured to the Slaney estuary). The site is designated for salmon, sea lamprey, brook lamprey, river lamprey, and twaite shad, as well as for the freshwater pearl mussel *Margaritifera margaritifera*, which is closely linked with salmon populations, with pearl mussel larvae depending on juvenile Atlantic salmon as hosts (Skinner et al., 2003; Taeubert and Geist, 2017).

Another SAC relevant to the protection of fish species is the Rockabill to Dalkey Island SAC, whose northern boundary is located about 2.4km south of the array area. The Conservation Objectives (COs) for this site include to provision to maintain the favourable conservation condition of harbour porpoise *Phocoena phocoena*. Any human activities should occur at levels that do not adversely affect the harbour porpoise community at the site. This target also includes any activities or operations that may result in the deterioration of key resources (e.g. water quality, feeding, etc.) upon which harbour porpoises depend, such as key prey stocks for feeding. Similarly, the Rockabill SPA and the North-west Irish Sea candidate SPA (cSPA), which are designated for ornithology features, include COs that provide for the protection of key foraging grounds and prey species.

Table 13.8 summarises the Natura sites that were identified to be of relevance to fish and shellfish ecology. The likely significant effects of the proposed development on the integrity of these sites are assessed in full within the NIS.

Elasmobranch species listed under the Ireland Red List No. 11 (Clarke et al., 2016) with the potential to occur within the study area include basking shark, tope, spiny dogfish, cuckoo ray, blonde ray, nursehound, small-eyed ray, spotted ray, thornback ray, starry smooth-hound, and small-spotted catshark. Since 2021, basking sharks are also protected under Irish law by the Wildlife Act (1976) (as amended). European eel, listed on the Ireland Red List as Critically Endangered (King et al., 2011), also have the potential to occur within the study area. Eel populations in European waters are strictly managed under the European Eel Regulations, with an Irish Eel Management Plans in place since 2009 (Technical Expert Group on Eel, 2021).

Table 13.8 Natura 2000 sites relevant to fish and shellfish receptors

Site code	Site name	Relative location to the proposed development	Qualifying/supporting fish and shellfish features	Relevance for fish and shellfish receptors
SACs				
002299	River Boyne and River Blackwater SAC	Located 20.9km from the array area and 13.0km from the ECC	River lamprey and Atlantic salmon	COs provide protection of features.
000781	Slaney River Valley SAC	Located 79.1km from the array area and 71.7km from the ECC	Twaite shad, river lamprey, Brook lamprey, sea lamprey, Atlantic salmon, freshwater pearl mussel	COs provide protection of features.
002162	River Barrow and River Nore SAC	Located 87.9km from the array area and 76.1km from the ECC	Twaite shad, river lamprey, Brook lamprey, sea lamprey, Atlantic salmon, freshwater pearl mussel	COs provide protection of features.
003000	Rockabill to Dalkey Island SAC	Located 2.4km from the array area and 2.9km from the ECC	Harbour porpoise	COs provide for the protection against activities that have the potential to adversely affect the harbour porpoise community at the site, which includes activities that may affect key prey resources.

Site code	Site name	Relative location to the proposed development	Qualifying/supporting fish and shellfish features	Relevance for fish and shellfish receptors
SPAs				
004014	Rockabill SPA	Located 0.2km from the array area and 0.1km from the ECC	Designated for ornithology features, including roseate tern Sterna dougallii, common tern S. hirundo, and Arctic tern S. paradisaea	COs provide for the protection of prey biomass, with key prey items including crustaceans and small fish, mainly clupeids, sandeel and gadoids.
004236	North-west Irish Sea cSPA	Overlapping with the array area and ECC	Designated for ornithology features	COs provide for the protection of foraging grounds and forage biomass of species the protected bird species rely on as prey, which include fish and crustaceans.

13.3.10 Valued Ecological Receptors

Based on the baseline characterisation summarised above, VERs within the fish and shellfish study area were selected to include:

- Species showing spawning, nursery and migratory behaviour within the fish and shellfish study area
- Species of commercial, conservation and ecological interest, including species import in supporting species of high trophic levels (e.g., prey species for bird and marine mammal species); and
- Species potentially sensitive to specific impacts of offshore wind farm development (e.g., Electro-Magnetic Fields (EMF) and underwater noise).

The VERs identified and included in the impact assessments are listed in Table 13.9 below. A detailed justification for their selection is given in the Fish and Shellfish Technical Baseline.

Table 13.9 Valued Ecological Receptors included in the impact assessment

VER Group	VERs
• Demersal VERs	• Atlantic cod, plaice, lemon sole, common sole, common dab, whiting, American plaice, witch flounder, common haddock, anglerfish
• Pelagic VERs	• Atlantic mackerel, sprat, Atlantic horse mackerel
• Substrate-spawning VERs	• Atlantic herring, sandeel
• Diadromous VERs	• Sea trout, European eel, Atlantic salmon, sea lamprey, river lamprey, twaite shad
• Shellfish VERs	• Nephrops, European lobster, brown crab, razor clam, common cockle, king scallop, common whelk, blue mussel
• Elasmobranch VERs	• Thornback ray, blonde ray, spotted ray, cuckoo ray, small-eyed ray, tope, nursehound, small-spotted catshark, spiny dogfish, starry smooth-hound, basking shark
• Marine turtle VERs	• Leatherback turtle, loggerhead turtle, Kemp's Ridley turtle, hawksbill turtle, green turtle

13.4 Characteristics of the Proposed Development

This section outlines the characteristics of the proposed development that are relevant to the identification and assessment of effects on Fish and Shellfish Ecology during each phase of the proposed development. The impact assessments presented in this chapter are limited to effects on fish and shellfish VERs occurring in the offshore environment and it considers both Project Options 1 and Project Option 2 (the key characteristics of which are provided in Table 13.10 and are detailed in full in the Offshore Description Chapter). Impacts arising from activities within the onshore development area that have the potential to impact marine features (including landfall works and onshore cabling) have been considered but have been scoped out of the assessment (further detail is provided in Section 13.5.2.1).

Table 13.10 Key characteristics of Project Option 1 and Project Option 2

Key Offshore Characteristics	Project Option 1	Project Option 2
• Array area	• 88.5km^2	• 88.5km^2
• ECC	• 36.45km^2	• 36.45km^2
• Landfall	• One landfall site, immediately south of Bremore Point, which includes two subtidal exit pits within the ECC	• One landfall site, immediately south of Bremore Point, which includes two subtidal exit pits within the ECC
• Wind Turbine Generator (WTG) •	• 49 WTGs with 250m rotor diameter	• 35 WTGs with 276m rotor diameter
• WTG Foundations •	• 49 monopiles of 12.5m diameter requiring seabed preparation	• 35 monopiles of 12.5m diameter or jacket foundations (three or four leg configurations, with 6m diameter pin piles) requiring seabed preparation
• Offshore Substation Platform (OSP) Foundations (array area) •	• One OSP, with either a four-legged jacket foundation with pin piles, or one monopile; or two monopiles	• One OSP, with either a four-legged jacket foundation with pin piles, or one monopile; or two monopiles
• Cables	• Installation of 111km of array cables within the array area and installation of two 18km export cables within the ECC	• Installation of 91km of array cables within the array area and installation of two 18km export cables within the ECC

A presentation of the potential impacts in relation to Project Option 1 and Project Option 2 is provided, and the magnitude of those impacts in relation to the size and scale of the proposed development parameters is presented in 13.12. This enables the identification of the project option that will result in the greatest magnitude of impact on receptors and will therefore present the greatest potential for a likely significant effect.

To determine the magnitude of the impact level, modelling, calculations and mapping have been undertaken for the project option with the greatest magnitude of impact, for all impacts for the relevant receptor/s.

The significance of effect assessment is then undertaken for both project options, which considers both receptor sensitivity and the magnitude of the impact and is detailed in Section 13.5. Given the similarity of the project options, in all instances the conclusions of impact significance are the same.

13.4.1 Parameters for Assessment

The below activities, infrastructure and key design parameters have been considered within this chapter when determining the potential impacts. Further detail on the offshore elements of the proposed development is provided in the Offshore Description Chapter and Offshore Construction Chapter.

These parameters apply to both project options and any differences in values that may require consideration have been identified in Table 13.12.

13.4.2 Construction

During construction the following activities and infrastructure have the potential to impact on fish and shellfish ecology:

- Pre-construction geotechnical and geophysical surveys
- Seabed preparation in advance of foundation installation and cable laying
- WTG foundation installation and OSP foundation installation
- Installation of WTGs and OSP topside
- Installation of scour protection
- Installation of inter-array cables and cable protection

- Installation of export cables and cable protection; and
- Landfall Horizontal Directional Drilling (HDD) for export cables.

13.4.3 Operational Phase

During operation, the following activities and infrastructure have the potential to impact on fish and shellfish ecology:

- Presence of WTG and OSP foundations and scour and cable protection material
- Repair and replacement of WTG and OSP components; and
- Repair and replacement of inter-array and export cables.

13.4.4 Decommissioning

During decommissioning, the following activities and infrastructure have the potential to impact on fish and shellfish ecology:

- Removal of foundations and associated subsurface infrastructure; and
- Removal of inter-array and export cables and associated protection measures.

13.4.5 Embedded Mitigation Measures

The following embedded mitigation measures in Table 13.11 have been identified through the design and consultation process and are incorporated as part of the proposed development. The embedded mitigation measures will not be considered again at the residual effect stage.

Table 13.11 Embedded mitigation measures relating to fish and shellfish ecology

Measure	Mitigation detail
Construction	
• Marine Pollution Contingency Procedure (MPCP)	• Marine pollution prevention and contingency measures will be implemented as part of Volume 8, Appendix 6.1: Offshore Environmental Management Plan (EMP; hereafter the Offshore EMP) to manage the risk of accidental pollution from offshore operations relating to the proposed development (Appendix 2A and 2B in Offshore EMP). The MPCP will include the following control measures and procedures: – A chemical risk review with information regarding how and when chemicals (including vessel fuels) are to be used, stored and transported in accordance with recognised best practice guidance and national and international regulations and commitments. – Navigational safety measures (e.g., guard vessels, safety buoys, lighting of active working zones) to reduce the likelihood of collision events; and – Emergency response methods and procedures to deal with any spills and collision incidents. • Implementation of these measures would reduce the likelihood of potentially harmful pollutants to be released into the marine environment, thereby reducing the likelihood of pollution impacts on sensitive fish and shellfish receptors.
• Offshore Waste Management Procedure	• An Offshore Waste Management Procedure setting out waste management and disposal procedures will be implemented as part of the Offshore EMP (Appendix 6 in Offshore EMP).The Waste Management Procedure will include the following measures: – Application of the waste hierarchy (prevention, re-use, recycle, recovery, and disposal) to minimise the amount of waste produced, and reduce, as far as possible, the amount of waste that is disposed of in landfill; – Waste disposal procedures, ensuring all waste that cannot be reused, recycled or recovered will be kept onboard vessels and safely disposed of onshore in a suitable licensed waste facility; and – Code of conduct for vessel operators with respect to the discharge of wastewater and handling and storing of hazardous materials. • Implementation of these measures will reduce the likelihood of potentially harmful pollutants to be released into the marine environment, thereby reducing the likelihood of pollution impacts on potentially sensitive migratory fish species.

Measure	Mitigation detail
• Environmental Vessel Management Plan (EVMP)	• An EVMP will be implemented to minimise the risk of collision, injury and disturbance to marine wildlife during construction activities, which will include a code of conduct for vessel operators when encountering marine species (Volume 9, Appendix 14.5). In addition, vessel movements to and from construction sites and ports will, where feasible, follow existing routes. While the measures are targeted towards marine mammals and birds at sea, they would equally reduce the risk of injury and disturbance to marine turtles and larger mobile receptors, such as basking sharks.
• Soft-start procedures during pile driving	• During the piling of foundations, each piling event will commence with a soft-start at low hammer energy, followed by gradual ramp-up to the maximum hammer energy required (Section 8.3.4.1 in the Offshore Construction Strategy). This would allow sensitive fish and shellfish receptors to vacate the area before sound energy levels reach levels where lethal or sublethal effects may occur.
• UXO Management Measures	• The clearance of UXO will follow a mitigation hierarchy, with micro-siting of subsea infrastructure around UXO where practicable. Where avoidance is not possible, relocating the UXO to a safe place and leaving in situ will be considered. Where clearance of UXO is required (i.e. avoidance or relocation is not practicable), removal of the UXO from the site or low order clearance at the UXO location will be adopted where feasible. However, removal of the UXO or low order deflagration of the UXO are not always possible and are dependent upon the individual situations surrounding each UXO. Therefore, a high order detonation of the UXO may be required. A case-by-case risk assessment will be undertaken following dedicated geophysical and ROV surveys during the construction phase (Volume 9, Appendix 14.4: Marine Mammal Mitigation Protocol (MMMP), and Offshore EMP).
• Noise Abatement System (NAS) during high order UXO clearance	• Where auditory injury impact ranges for marine mammals from the use of high order detonations are greater than what can be mitigated using Marine Mammal Observers (MMO), Passive Acoustic Monitoring (PAM) and Acoustic Deterrent Devices (ADD) (e.g., > 7.5 km; e.g. 120kg UXO charge weight plus donor weight), noise abatement will be used to reduce the noise propagated through the water column during detonations (MMMP). This would reduce the impact of UXO clearance noise on sensitive fish and shellfish species.
• UXO detonation strategy	• If UXO detonations are required for clearance, detonations will not occur within the same 24-hour window as piling operations. Where there may be clusters of UXO requiring detonation, these UXO will not be detonated at the same time (Offshore EMP).
• Pre-construction profile survey	• Where necessary, before works commence and following reinstatement, a topographical survey of the nearshore subtidal area will be carried out to identify and map the contours of the subtidal HDD exit pit to ensure a profile similar in nature to the profile recorded during the pre-construction survey is reinstated, as far as practicable.
Operation	
• Cable burial and cable protection measures	• Export and inter-array cables will be buried where practicable to ensure they are not exposed by sediment movements (Section 8.3.10 in the Offshore Construction Strategy). Where cables cannot be buried, additional cable protection measures such as rock placement or mattressing will be applied to achieve adequate cable protection. Up to 20% of cable length is expected to need protection either during initial installation, or throughout the operational phase of the proposed development (Volume 3, Chapter 8). Cable burial or cable protection increases the distance between the cables and electro- and magneto-sensitive receptors, thereby reducing the received EMF (from attenuation of the EMF).
• MPCP, Offshore Waste Management Procedure, EVMP	• Marine pollution and waste management control measures and vessel operating procedures will be implemented throughout the operational phase of the proposed development, following the same measures and procedures that were implemented during the construction phase.
Decommissioning	
• Assessment of impacts and best practice environmental management	• Prior to decommissioning a study of the potential environmental impacts to fish and shellfish receptors from the proposed decommissioning activities will be undertaken, considering the baseline environment at the pre-decommissioning stage. All mitigation measures to be captured will be captured within the Rehabilitation Schedule and decommissioning strategy within the Offshore EMP. Any licences or authorisations that might be required will be identified and obtained prior to decommissioning, including any validation, updating or new submission of an EIAR, as required.

13.4.6 Potential Impacts

The identification of potential impacts has been undertaken by considering the relevant characteristics from both project options (refer to Section 13.4.1) and the potential for a pathway for direct and indirect effects on known receptors (as identified in Section 13.3). Each identified impact relevant to fish and shellfish ecology is presented in Table 13.12.

For each impact, the relevant characteristics of Project Option 1 and Project Option 2 are presented to determine the magnitude (size or extent) of the potential impact, defined by the proposed development parameters in the Offshore Description Chapter and in consideration of the WTG Limits of Deviation (LoD[6]), in line with the approach detailed in the EIAR Methodology chapter. A comparison of the project options has then been undertaken to determine which project option has the greatest magnitude of impact.

[6] Both Project Option 1 and Project Option 2 layouts have a 500m Limit of Deviation (LoD)

Table 13.12 Potential impacts and magnitude of impact per project option. The project option that has the greatest magnitude of impact is identified in blue

Potential impact	Project Option 1 (49 WTG)	Project Option 2 (35 WTG)	Rationale for the project option with the greatest magnitude of impact
Construction			
Impact 1: Temporary increase in SSC and sediment deposition arising during the construction phase	**Total volume of suspended sediment and sediment deposition 805,292m^3.** **WTG foundation drill cuttings:** 49 turbines foundations with 75% requiring drilling = 338,243m^3. **OSP foundations (array):** One OSP foundation requiring seabed preparation and drilling = 22,089m^3. **Cable trenching:** Installation of 111km of array cables = 333,000m^3. Installation of two export cables = 108,000m^3 (excluding the part of the export cable within the array area). **Subtidal HDD:** Exit pits total volume = 3,960m^3. Release of drilling muds (i.e. bentonite) during exit pit punch-out = 30 tonnes.	**Total volume of suspended sediment and sediment deposition 897,061m^3.** **WTG foundation preparatory dredging:** Dredging at the seabed in preparation for foundation placement (jacket foundations only) at 50% of locations = 133,755m^3. **WTG foundation drill cuttings:** 35 turbines foundations with 100% requiring drilling = 356,257m^3. **OSP Foundations (array):** One OSP foundation requiring seabed preparation and drilling = 22,089m^3 of sediment. **Cable trenching:** Installation of 91km of array cables = 273,000m^3 Installation of two export cables = 108,000m^3 (excluding the part of the export cable within the array). **Subtidal HDD:** Exit pits total volume = 3,960m^3. Release of drilling muds (i.e. bentonite) during exit pit punch-out = 30 tonnes.	**Project Option 2 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest volume of sediments released during construction activities including seabed preparation activities, cable installation and the drilling of foundations. The greatest magnitude of impact for foundation installation results from the largest volume suspended relating to jacket foundation seabed preparation and installation. For cable installation, the greatest magnitude of impact results from the greatest volume installation using energetic means (CFE). This also assumes the largest number of cables and the greatest burial depth. One OSP will be constructed within the order limits. Project Option 2 has a higher total volume than Project Option 1 (91,769m^3 more volume of materials) and presents the greatest magnitude of impact.
Impact 2: Temporary habitat damage and disturbance of the seabed during construction activities	**Temporary habitat disturbance of 6,269,549m^2.** **Array area** Seabed preparation (dredging) at one OSP foundation (jacket only) = 1,304m^2. Jack up vessel spud can footprint, anchoring operations, construction buoys (assumed 12) = 374,271m^2. Cable seabed preparation and installation in the array trench area affected: 111km length, 40m width (including preparatory seabed measures) = 4,440,000m^2.	**Temporary habitat disturbance of 5,391,017m^2.** **Array area** seabed preparation (dredging) at WTG foundation (jacket only) = 23,185m^2. Seabed preparation (dredging) at one OSP foundation (jacket only) = 1,304m^2. Jack up vessel spud can footprint, anchoring operations, construction buoys (assumed 12) = 275,303m^2. Cable seabed preparation and installation in the array trench width affected: 91km length, 40m width (including preparatory seabed measures) = 3,640,000m^2.	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the total area of seabed temporarily disturbed or damaged during the construction phase. It includes areas affected by seabed preparation works conducted prior to the installation of foundations and cables including boulder clearance and Pre-Lay Grapnel Runs (PLGR). Note that the loss of benthic habitat due to the placement of subsea infrastructure (e.g., WTG foundations, scour and cable protection) is considered an operational impact and has been assessed under Impact 7.

Potential impact	Project Option 1 (49 WTG)	Project Option 2 (35 WTG)	Rationale for the project option with the greatest magnitude of impact
	ECC Cable seabed preparation and installation in the ECC trench area affected: 18km length, 40m width (including preparatory seabed measures) = 1,440,000m^2. **Subtidal HDD:** Total footprint of disturbance (exit pits, transition zone, temporary sidecast/ deposited material & JUV footprint) = 4,156m^2. Boulders required to be cleared across array area (IAC routes, WTG & OSP locations) & ECC = 9,817m^2.	**ECC** Cable seabed preparation and installation in the ECC trench area affected: 18km length, 40m width (including preparatory seabed measures) = 1,440,000m^2. **Subtidal HDD:** Total footprint of disturbance (exit pits, transition zone, temporary sidecast/ deposited material & JUV footprint) = 4,156m^2. Boulders required to be cleared across array area (IAC routes, WTG & OSP locations) & ECC = 7,069m^2.	The footprint of seabed disturbance at the WTG and OSP foundations in this impact only relates to jacket foundations and is just the area dredged that goes beyond the footprint of the infrastructure.
Impact 3: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination	The magnitude of the impact represents the largest volume of sediments released during the construction phase, as listed under Impact 1 (Temporary increase in SSC and sediment deposition arising during the construction phase). **Total volume of sediment released 805,292 m^3.**	The magnitude of the impact represents the largest volume of sediments released during the construction phase, as listed under Impact 1 (Temporary increase in SSC and sediment deposition arising during the construction phase). **Total volume of sediment released 897,061m^3.**	**Project Option 2 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest volume of sediments that may be released into the water column during construction activities. The risk of accidental contamination as a result of spillages or collisions will be managed through the implementation of an Offshore EMP, and therefore no design scenarios are presented for accidental contamination.
Impact 4: Introduction of underwater noise and vibration leading to mortality, injury, TTS and/or behavioural effects during construction	**Installation of WTG foundations** Indicative total duration = up to 9 months 49 monopile WTG foundations (12.5m pile diameter, 5,500kJ hammer energy) One monopile foundation installed in a 24-hour period, **Installation of one OSP** One OSP on monopile foundation with two monopiles per foundation (12.5m diameter, 5,500kJ hammer energy). One monopile foundation installed in a 24-hour period. OR	**Installation of WTG foundations** Indicative total duration = Up to 9 months 35 monopile WTG foundations (12.5m pile diameter, 5,500kJ hammer energy) One monopile foundation installed in a 24- hour period. OR 35 jacket WTG foundations (6m pile diameter, 3,000kJ hammer energy) Two pin piles installed in a 24-hour period. **Installation of one OSP** One OSP on monopile foundation with two monopiles per foundations (12.5m diameter, 5,500kJ hammer energy). One monopile foundation installed in a 24-hour period.	**Project Option 1 and Project Option 2 both represent the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by spatial and temporal extents of noise propagation resulting from the installation of turbine and OSP foundations during the construction phase. Project Option 1 has the greatest spatial extent due to the larger hammer energy whereas Project Option 2 (jacket foundations only) has the greatest temporal extent as there are more active piling hours in a 24-hour period and more total active days of piling. For the array area, the spatial scenario with the greatest potential magnitude of impact results from the pile driving of a single monopile foundation in a 24-hour period. The temporal scenario with the greatest

Potential impact	Project Option 1 (49 WTG)	Project Option 2 (35 WTG)	Rationale for the project option with the greatest magnitude of impact
	One OSP on jacket foundations with 4 pin piles per foundation (6m pile diameter, 3,000 kJ hammer energy). Two pin piles installed in a 24-hour period. **UXO clearance** Pre-construction surveys have not yet been completed; therefore, it is not possible at this time to determine how many items of UXO will require clearance. **Other construction noise** Noise emitted from construction vessels and arising during construction activities (e.g., placement of scour and cable protection, drilling of foundations).	OR One OSP on jacket foundations with 4 pin piles per foundation (6m pile diameter, 3,000kJ hammer energy). Two pin piles installed in a 24-hour period. **UXO clearance** Pre-construction surveys have not yet been completed; therefore, it is not possible at this time to determine how many items of UXO will require clearance. **Other construction noise** Noise emitted from construction vessels and arising during construction activities (e.g., placement of scour and cable protection, drilling of foundations).	magnitude of impact results from the sequential piling of up to two pin piles in a 24-hour period. As a precautionary approach, it has been assumed that all foundations would be installed by impact pile driving. No simultaneous piling is expected. Note the programme is indicative at this stage as it is dependent on the contractor selected at construction stage.
Operational Phase			
Impact 5: Temporary increase in SSC and sediment deposition arising during maintenance activities	The volume of sediment released during the operational phase and associated bed level changes would be less to those experienced during the construction phase (as listed under Impact 1). **Repair and maintenance of scour protection for WTG and OSP foundations** Once every 5 years **Inter-array cable replacement, repair and reburial** Once every 5 years **Export cable repair and reburial** Once every 5 years	The volume of sediment released during the operational phase and associated bed level changes would be less to those experienced during the construction phase (as listed under Impact 1). **Repair and maintenance of scour protection for WTG and OSP foundations** Once every 5 years **Inter-array cable replacement, repair and reburial** Once every 5 years **Export cable repair and reburial** Once every 5 years	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest volume of sediments released into the water column during maintenance activities. The volume of sediment that could be suspended has not been calculated but will be of much smaller quantity compared with that generated by construction and decommissioning activities. There is more infrastructure to maintain in Project Option 1; therefore, the increase of SSC from operational activities will be greater from Project Option 1.
Impact 6: Temporary damage and disturbance of the seabed during maintenance activities	**Total temporary habitat disturbance: 675,134m^2**. **Array area:** JUV operations–- Major WTG component repair/replacement = 646,540m^2. JUV–- Major OSP component replacement = 13,195m^2.	**Total temporary habitat disturbance: 490,409m^2**. **Array area:** JUV operations–- Major WTG component repair/replacement = 461,814m^2. JUV–- Major OSP component replacement = 13,195m^2. Inter array cable repair and/or replacement of cabling = 7,000m^2.	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the area of seabed temporarily disturbed or damaged during maintenance activities. It includes areas affected by cable maintenance activities and jack-up vessel operations during the maintenance of WTG and OSP foundations.

Potential impact	Project Option 1 (49 WTG)	Project Option 2 (35 WTG)	Rationale for the project option with the greatest magnitude of impact
	Inter array cable repair and/or replacement of cabling = 7,000m^2. Inter array cable reburial of any section of the offshore export cable which has become exposed = 700m^2. **ECC** Export Cable–- Repair and/or replacement of cabling = 7,000m^2. Export Cable–- Reburial of any section of the offshore export cable which has become exposed = 700m^2.	Inter array cable reburial of any section of the offshore export cable which has become exposed = 700m^2. **ECC** Export Cable–- Repair and/or replacement of cabling = 7,000m^2. Export Cable–- Reburial of any section of the offshore export cable which has become exposed = 700m^2.	Note that the loss of benthic habitat due to the potential placement of cable protection material during the operational phase is included under Impact 7.
Impact 7: Long-term/permanent loss of benthic habitat due to the placement of subsea infrastructure	**Habitat change of 276,296m^2**. **Array are**a: WTG footprint with scour protection, based on 49 WTG = 121,767m2. One OSP foundations footprint = 4,788m^2. Pre- and post-lay rock berm area within array area (5 cable crossings) = 2750m^2. Inter array cable protection assuming 20% of cable will require additional cable protection = 111,000m^2. **ECC:** Cable protection assuming 20% of cable will require additional cable protection = 36,000m^2.	**Habitat change of 297,510m^2**. **Array are**a: Turbine footprint with scour protection, based on 35 WTG = 162,982m2. One OSP foundations footprint = 4,778m^2. Pre- and post-lay rock berm area within array area (5 cable crossings) = 2,750m^2. Inter array cable protection assuming 20% of cable will require additional cable protection = 91,000m^2. **ECC:** Cable protection assuming 20% of cable will require additional cable protection = 36,000m^2.	**Project Option 2 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest area of seabed lost or changed as a result of the installation of offshore infrastructure and associated protection measures. The greatest loss/change of benthic habitat would result from the installation of 35 multi-leg jacket foundations and associated scour protection material (Project Option 2).
Impact 8: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination	The magnitude of the impact represents the largest volume of sediments released during the operational phase Temporary increases in SSC will result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities (activities listed under Impact 5).	The magnitude of the impact represents the largest volume of sediments released during the operational phase, as listed under Impact 5 (Temporary increase in SSC and sediment deposition arising during maintenance activities). Temporary increases in SSC will result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities (activities listed under Impact 5).	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest volume of sediment that are predicted to be released into the water column during the operational phase. There is more infrastructure to maintain in Project Option 1; therefore, the increase of SSC from operational activities will be greater from Project Option 1. The risk of accidental contamination as a result of spillages or collisions will be managed through the implementation of an Offshore EMP, and therefore no design scenarios are presented for accidental contamination.

Potential impact	Project Option 1 (49 WTG)	Project Option 2 (35 WTG)	Rationale for the project option with the greatest magnitude of impact
Impact 9: Increase in hard substrate and structural complexity due to the placement of subsea infrastructure	**Total surface area of introduced hard substrate in the water column: 414,766m^2.** Scour protection 49 WTGs, 1 OSP = 120,533m^2. Cable protection = 196,980m^2. Post-lay rock berm = 4,125m^2. Total surface area of subsea portions of WTG foundation piles in contact with the water column = 89,476m^2. Total surface area of subsea portions of OSP foundation piles in contact with the water column = 3,652m^2.	**Total surface area of introduced hard substrate in the water column: 388,128m^2.** Scour protection 49 WTGs, 1 OSP = 87,460m^2. Cable protection = 170,180m^2. Post-lay rock berm (cable crossings) = 4,125m^2. Total surface area of subsea portions of WTG foundation piles in contact with the water column = 122,711m^2. Total surface area of subsea portions of OSP foundation piles in contact with the water column = 3,652m^2.	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest area of hard surfaces introduced by subsea infrastructure that are accessible to receptors. This includes the surface area of scour protection around foundations, the surface area covered with cable protection material, and the lateral surface area of vertical structures within the water column (e.g., WTG foundations).
Impact 10: Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables	**Inter-array cables** Total length = 111km Nominal operating voltage 66kV or 132kV **Export cables** Two export cables, each with a length of 18km Nominal voltage of 220kV with High Voltage Alternating Current (HVAC) Target burial depth of all cables = 1m-3m	**Inter-array cables** Total length = 91km Nominal operating voltage 66kV or 132kV **Export cables** Two export cables, each with a length of 18km Nominal voltage of 220kV with High Voltage Alternating Current (HVAC) Target burial depth of all cables = 1m-3m	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the number and largest length of cables and the type and strength of currents to be applied.
Decommissioning			
Impact 11: Temporary increase in SSC and sediment deposition arising during decommissioning activities	It is anticipated that the activities resulting in the impact will be similar to the construction phase (Impact 1) apart from seabed preparation works and excluding the removal of structures that may remain. Therefore, it is expected that the volume of sediments released during decommissioning activities and associated bed level changes would be comparable or less to the amounts released during the construction phase.	It is anticipated that the activities resulting in the impact will be similar to the construction phase (Impact 1) apart from seabed preparation works and excluding the removal of structures that may remain. Therefore, it is expected that the volume of sediments released during decommissioning activities and associated bed level changes would be comparable or less to the amounts released during the construction phase.	**Project Option 2 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest volume of sediments released into the water column during the removal of offshore infrastructure including foundations, cables, and scour and cable protection. The project option with the greatest magnitude of impact is assumed to be as per the construction phase, with all infrastructure removed in reverse-construction order.

Potential impact	Project Option 1 (49 WTG)	Project Option 2 (35 WTG)	Rationale for the project option with the greatest magnitude of impact
Impact 12: Temporary habitat damage or disturbance of the seabed during decommissioning activities	Removal of all foundations, cables and rock protection leading to a temporary damage or disturbance of the seabed equivalent to Impact 2 (Temporary habitat damage or disturbance of the seabed during decommissioning activities).	Removal of all foundations, cables and rock protection leading to a temporary damage or disturbance of the seabed equivalent to Impact 2 (Temporary habitat damage or disturbance of the seabed during decommissioning activities).	**Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the area of seabed temporarily disturbed or damaged during the removal of foundations, cables, and scour and cable protection material. The largest area to be disturbed is assumed to be similar to the construction phase (Impact 2), with all infrastructure removed in reverse construction order. The greatest magnitude of impacts considers the removal of cables and rock protection; however, the necessity to remove cables and rock protection will be reviewed at the time of decommissioning.
Impact 13: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination	The magnitude of the impact represents the largest volume of sediments released during the decommissioning phase, as listed under Impact 11 (Temporary increase in SSC and sediment deposition arising during decommissioning activities).	The magnitude of the impact represents the largest volume of sediments released during the decommissioning phase, as listed under Impact 11 (Temporary increase in SSC and sediment deposition arising during decommissioning activities).	**Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by the largest volume of contaminated sediments that may be released into the water column during the decommissioning phase. The risk of accidental contamination as a result of spillages or collisions will be managed through the implementation of an Offshore EMP, and therefore no design scenarios are presented for accidental contamination.
Impact 14: Introduction of underwater noise and vibration leading to mortality, recoverable injury, TTS and/or behavioural effects during decommissioning	It is anticipated that the activities resulting in the impact will be similar to the construction phase (Impact 4) apart from piling for foundations and excluding the removal of UXO. Therefore, it is expected that the magnitude of the impact would be no greater or less than that during construction (Impact 4).	It is anticipated that the activities resulting in the impact will be similar to the construction phase (Impact 4) apart from piling for foundations and excluding the removal of UXO. Therefore, it is expected that the magnitude of the impact would be no greater or less than that during construction (Impact 4).	**Project Option 1 represents the greatest magnitude of impact in relation to this impact.** The magnitude of the impact is defined by spatial and temporal extents of noise propagation resulting from the decommissioning of infrastructure. Project Option 1 has more turbines and inter array cables; therefore, the temporal extent will be greater. It is not expected the spatial extents will vary as the activities will be similar.

13.5 Potential Effects

The likely significant effects, both beneficial and adverse, on fish and shellfish resources for each stage of the proposed development are considered, specifically, the likely significant effects of the proposed development during its construction, operational, and decommissioning phases associated with the offshore development area. The environment within the study area and associated fish and shellfish resources are naturally dynamic, and as such will exhibit some level of natural variation and change over time whether the proposed development proceeds or not.

Consequently, the identification and assessment of likely significant effects must be done in the context of natural change, both spatial and temporal.

The likely significant effects, both beneficial and adverse, on fish and shellfish ecology for each stage of the proposed development are considered. Specifically, the likely significant effects of the proposed development during its construction, operational, and decommissioning phases associated with the offshore development area. The environment in the vicinity of the proposed development is naturally dynamic, and as such will exhibit some level of natural variation and change over time whether the proposed development proceeds or not. Consequently, the identification and assessment of likely significant effects must be done in the context of natural change, both spatial and temporal.

The assessment of likely significant effects on the designated sites listed in Table 13.8 is an intrinsic part of the assessment of the regional population of fish and shellfish receptors assessed in this section, of which the citation population forms part of. An assessment of the indirect impacts on the fish and shellfish designated within these sites including impacts to supporting habitats and water quality is also included in this assessment.

A NIS has been prepared which is a standalone document independent of the findings of this EIAR, in compliance with the EU Habitat Directive and Birds Directive. The NIS assesses how the proposed development might affect the Natura 2000 conservation objectives, and the mitigation measures that will be implemented to ensure that adverse effects on site integrity do not arise, are considered. The conclusion of the NIS assessment was that the proposed development will not adversely affect the integrity of any European site, either alone or in-combination with other plans or projects.

13.5.1 Do-Nothing Scenario

Should the proposed development not be constructed, the baseline environment is unlikely to show future natural variations beyond that presented the future receiving environment, as follows.

Rising sea temperatures, ocean acidification, ocean deoxygenation and rising sea levels have been identified as four of the key stressors impacting the state of the world's oceans and coastal environments (EPA, 2020). Recent and future changes in the temperature and chemistry of marine waters around Ireland are having, and will have, effects on the phenology, productivity and distribution of marine fish and shellfish (Heath et al., 2012; Townhill et al., 2023).

Climate effects may influence fish and shellfish in a variety of ways, including changes in species distribution and community composition, growth rates, recruitment, behaviour, survival and alterations to food web dynamics and connectivity. For example, ocean warming has caused several fish species to move northward or into deeper, colder waters (Simpson et al., 2013), a trend that is predicted to continue in the future (e.g. Townhill et al., 2023). The Celtic Seas ecoregion (which incorporates the Irish Sea) is at the edge of the geographical range of several species, potentially making these species more susceptible to environmental variation (ICES, 2022a).

Additionally, overfishing subjects the populations of many fish and shellfish species to considerable pressure, reducing the biomass of commercially valuable species, and non-target species. Overfishing can also reduce the resilience of fish and shellfish populations to other pressures, including climate change and other anthropogenic impacts.

The baseline environment for fish and shellfish described in the preceding sections represents a 'snapshot' of the fish and shellfish assemblages of the study area, within a gradual and continuously changing environment. Any changes that may occur during the lifetime of the proposed development (i.e. construction, operation and decommissioning) should be considered in the context of both greater variability and sustained trends occurring on national and international scales in the marine environment, and the changes that would be expected to occur naturally in the absence of the proposed development.

13.5.2 Construction Phase

This section presents the assessment of impacts arising during the construction phase of the proposed development. The effects during construction activities have been assessed on fish, marine turtles, and shellfish VERs within the fish and shellfish study area as defined in Section 13.2.2. The environmental impacts arising from construction of the proposed development are listed in Table 13.12 along with the design options against which each construction phase impact has been assessed.

13.5.2.1 Impact 1: Temporary increase in SSC and sediment deposition arising during the construction phase

Temporary increases in SSCs and associated sediment deposition would be expected from construction activities that disturb the seabed and from the release of dredged material and drill cuttings. Understanding the potential changes in the physical environment is critical to inform the assessment for fish and shellfish resources as these may lead to smothering of receptors and key habitats, and barrier effects which can impede migration.

Activities that have the potential to increase SSC and sediment deposition during construction activities are listed in Table 13.12. These have provided the basis for site-specific modelling of sediment plumes and deposition resulting from seabed preparation and infrastructure installation activities (Physical Processes Modelling Report). The simulated release events have been designed to capture the full range of realistic outcomes as the largest:

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

Modelling has been undertaken based on project specific information for a range of tidal flow conditions and construction activities including dredging for seabed preparation and drilling of foundations. Full details of the scenarios modelled are given in Volume 9, Appendix 10.2: Marine Physical Processes Numerical Modelling. The results of the modelling study including the fate of sediment plumes and subsequent deposition under different tidal states are presented in the Physical Processes Chapter.

The numerical plume modelling study predicts increases to SSC and sediment deposition during the construction phase of the development to arise from the following activities:

- Seabed levelling prior to the installation of foundations via trailer suction hopper dredger (TSHD) and associated release of dredged material
- Drilling during the installation of piled foundations, which will release drill cuttings
- Cable installation using trenching, jetting and/or ploughing
- Excavation of HDD exit pits nearshore via mass flow excavator (MFE); and
- Release of drilling muds (with bentonite) following HDD.

There is also potential for material including disturbed soils produced by construction activities within the onshore development area (including the landfall works and onshore cabling) to enter the marine environment within surface runoff. With the inclusion of standard sediment and erosion control measures, pollution control measures and drainage and dewatering measures during construction (as indicated within Volume 8, Appendix 9.1 Onshore Construction Environmental Management Plan; CEMP) there is no pathway for impacts from onshore activities on marine and estuarine water quality, and therefore this impact pathway has not been considered further in this assessment.

Sensitivity of receptors

The increase in SSC and sediment deposition following seabed disturbances and the release of drill cuttings and dredged material could smother sedentary or less mobile receptors, potentially leading to injury or mortality. Receptors considered at higher risk from this impact include suspension feeding species (e.g., scallops), species that bury in the sediment (sandeel), and less mobile and burrowing shellfish species (e.g., *Nephrops*, brown crab). In addition, adverse effects on fish and shellfish populations may arise through direct damage or loss of early life stages (i.e., eggs and larvae) or indirectly through the disturbance of spawning and nursery grounds.

The sensitivity of fish, marine turtles and shellfish VERs to elevated levels of suspended sediments and associated changes in bed levels has been assessed in Table 13.13, based on the methodology outlined in Section 13.2.5. No specific embedded mitigation measures relevant the impact have been defined (see Table 13.11).

Table 13.13 Determination of receptor sensitivities to increased SSC and sediment deposition during construction activities

Receptor	Sensitivity
Marine turtles, basking shark	• Marine turtles and basking shark are highly mobile species and would be able to move away from intermittent, localised sediment plumes and associated sediment deposition (e.g., Wilson et al., 2020). In addition, these species show no dependence on the seabed for reproduction, with basking shark bearing live young (Wilson et al., 2020) and marine turtles nesting on tropical grounds (Rowley, 2005). Therefore, the receptors are considered to have a high capacity to avoid and accommodate sediment plumes and deposition (high adaptability and tolerance). Recoverability is assessed as high as any displacement of individuals is likely to be temporary, with individuals expected to return quickly after sediment plumes have dissipated. Taking this into consideration, the sensitivity of marine turtles and basking sharks to temporary increases in SSC and sediment deposition during the construction phase is deemed negligible. • Irrespective of the magnitude of the impact, the significance of the impact for these VERs is imperceptible as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Pelagic VERs (Atlantic mackerel, Atlantic horse mackerel, sprat	• Atlantic mackerel, Atlantic horse mackerel and sprat are deemed to be of regional importance. These species are mobile and expected to move away from localised sediment plumes (high adaptability). Any displacement is assessed to be temporary (high recoverability), with individuals expected to return shortly after sediment plumes have dissipated. In addition, these receptors are pelagic spawners, and therefore sediment deposition within the study area would not result in any potential disturbance or loss of available spawning locations. Consequently, these species are assessed to be broadly insensitive to sediment deposition. • However, high levels of suspended sediments in the water column may affect early life stages (pelagic eggs and larvae) as these would have no or only limited capacity to avoid the impact. Effects of high levels of suspended sediments on fish eggs and larvae may include abnormal development, delayed hatching, reduced foraging success, and increased mortality rates (e.g., Corell et al., 2023; Farkas et al., 2021; Westerberg et al., 1996), potentially lowering the species' recruitment success. On this basis, eggs and larvae of pelagic fish VERs are assessed as having a moderate capacity to accommodate increased concentrations of suspended sediments (medium tolerance). Sprat spawning areas are widely distributed across the Irish and North Sea (Coull et al., 1998), while low intensity spawning grounds for mackerel are found within the northern and central Irish Sea, and low intensity spawning areas of horse mackerel are widely spread across the outer continental shelf off western Ireland and within the northern Irish Sea (Ellis et al., 2010, 2012). Given the wide distribution of spawning locations, effects on early life stages are assessed to be temporary to short-term (high to medium recoverability), with recovery from any potential mortality of early life stages anticipated through the dispersal of eggs and larvae from surrounding unaffected areas or through recruitment in subsequent years.

Receptor	Sensitivity
	• Taking into consideration the regional importance of the receptors together with their overall high adaptability, medium tolerance, and medium to high recoverability, the sensitivity of Atlantic mackerel, Atlantic horse mackerel and sprat to increases in SSC and sediment deposition is deemed to be low.
Demersal VERs (Atlantic cod, plaice, lemon sole, common sole, common dab, American plaice, witch flounder, whiting, haddock, anglerfish)	• The demersal VER receptors typically depend on the seabed for feeding, but based on their mobile nature they would be able to relocate to nearby unimpacted areas (high adaptability and tolerance). Any potential displacement would likely be temporary (high recoverability), with individuals able to return shortly after construction activities have ceased. In addition, all receptors are pelagic spawners, and therefore sediment deposition would not result in any potential disturbance or loss of available spawning locations. Consequently, these receptors are assessed as being broadly insensitive to sediment deposition. • Juvenile and adult demersal fish are mobile and would be able to move away from disruptive sediment plumes, and as such they are assessed as having a high capacity to avoid the impact (high adaptability). Any potential displacement would likely be temporary, with individuals able to return shortly after sediment plumes have dissipated (high recoverability). However, high levels of suspended sediments during spawning periods may lead to injury or loss of early life stages, in particular pelagic eggs and larvae, which may be unable to avoid sediment plumes. Effects of suspended sediments on fish eggs and larvae may include abnormal development, delayed hatching, reduced foraging success, and increased mortality rates (e.g., Corell et al., 2023; Farkas et al., 2021; Westerberg et al., 1996), potentially lowering the species' recruitment success. On this basis, eggs and larvae of all demersal VERs are assessed as having a medium capacity to accommodate increased concentrations of suspended sediments (medium tolerance). The effects on early life stages are assessed to be temporary to short-term, with recovery from any potential mortality anticipated through the dispersal of eggs and larvae from surrounding unaffected areas or through recruitment in subsequent years (medium to high recoverability). Based on this, the sensitivity of the receptors to temporary increases in SSC is deemed to be low. • Taking into consideration the international (cod) or regional (remaining demersal VERs) importance of the receptors together with their overall medium tolerance and medium to high recoverability to elevated levels of SSCs, the overall sensitivity of demersal VERs to the impact is deemed to be low.
Tope, starry-smooth-hound, spiny dogfish	• Tope, starry smooth-hound and spiny dogfish are mobile species and expected to move away from sediment plumes (high adaptability). These receptors depend on the seabed for feeding, and based on their mobile nature they would be able to relocate to nearby unimpacted areas (high tolerance). Any potential displacement is expected to be temporary, with individuals able to return shortly after construction activities have ceased (high recoverability). In addition, these receptors bear live offspring, and therefore they show no dependence on the seabed for reproduction. Consequently, these species are assessed to be broadly insensitive to temporary increases in SSC and sediment deposition, and therefore the sensitivity of tope, starry smooth-hound and spiny dogfish to temporary increases in SSC and sediment deposition during the construction phase is deemed to be negligible. • Irrespective of the magnitude of the impact, the significance of the impact for these VERs is imperceptible as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further in this assessment.
Small-spotted catshark, nursehound and skate species (thornback ray, spotted ray, blonde ray, cuckoo ray, small-eyed ray)	• Small-spotted catshark, nursehound and skate species are mobile and expected to move away from sediment plumes (high adaptability). These receptors depend on the seabed for feeding and given their mobile nature they would be able to relocate to nearby unimpacted areas. However, these receptors are oviparous, attaching egg cases onto the seabed. Smothering of egg cases due to sediment plumes and deposition may disrupt the development of embryos and consequently may lower the recruitment to the receptor's populations. Therefore, these receptors are assessed as having a medium tolerance to the impact. Any potential displacement of individuals is expected to be temporary, with individuals able to return shortly after construction activities have ceased (high recoverability). Recovery from any potential decrease in recruitment success is assessed to occur within the short to medium-term (medium to low recoverability). • Taking into consideration the regional importance of the receptors (with the exception of spotted ray), together with their general high adaptability, medium tolerance and high to low recoverability, the sensitivity of the receptors to temporary increases in SSC and sediment deposition is deemed to be low. On a precautionary basis, the sensitivity of spotted ray to the impact is classed as medium, considering the international importance of the receptor.
Diadromous VERs (sea trout, Atlantic salmon, European eel, sea lamprey, river lamprey, twaite shad)	• Diadromous species are highly mobile and would be able to relocate to nearby unimpacted areas (high adaptability). Localised avoidance reactions might occur in areas of high SSC during the duration of the plumes (i.e., within a couple of tidal cycles). For example, a study by Carlson et al. (2001) documented the behavioural responses of salmonids to dredging activities and observed avoidance responses of migrating salmon upon encountering sediment plumes.

Receptor	Sensitivity
	However, given the localised and temporary nature of the predicted changes in SSC, any displacement would not result in a barrier effect to any upstream or outgoing migration preventing the receptors from accessing or leaving their freshwater habitats. The diadromous VERs are therefore considered to be of high tolerance to increases in SSC, with the recoverability of any potential behavioural changes also assessed as high. In addition, these receptors reproduced in freshwater habitats, and therefore they show no dependence on the seabed within the study area. • Based on the above, all diadromous VERs are assessed to be broadly insensitive to temporary increases in SSC and sediment deposition, and therefore their sensitivity to the impact is deemed to be negligible. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is imperceptible as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further in this assessment.
Sandeel	• Due to their burrowing habit and reliance on specific substrates, sandeel are susceptible to seabed disturbance impacts, inclusive of impacts from increased SSCs and sediment deposition. They are considered less able to avoid the impact during spawning when they are less mobile, with their demersal eggs also considered to be unable to avoid this impact (low to no adaptability). The capacity of juvenile and adult sandeel to accommodate increases in SSC and sediment deposition is assessed as high given the nature of resuspension and deposition within their natural high energy environments. Sandeel eggs are also likely to have some tolerance to increases in SSCs and smothering from sediment deposition (medium tolerance). Suspended particles may become attached to the adhesive egg membranes, and tidal currents can cover sandeel eggs with sand to a depth of a few centimetres. However, experiments have shown that the eggs can develop normally and hatch as soon as currents uncover them again (Winslade, 1971). Buried eggs experiencing reduced current flow, and therefore lower oxygen tension, can have delayed hatching periods, which is considered a necessary adaptation to survival in a dynamic environment (Hassel et al., 2004). Recruitment success could nevertheless be affected through the damage or loss of demersal eggs; recovery from such effects is considered to occur in the short-term (medium recoverability). • Considering the regional importance of sandeel and their medium tolerance and medium recoverability, the sensitivity of sandeel to temporary increases in SSCs and sediment deposition during the construction phase is deemed to be low.
Herring	• Impacts from increased SSC and sediment deposition are of greatest concern for herring eggs, which are attached on benthic substrates by an adhesive mucus (de Groot, 1980). The eggs rely on a high energy and well-ventilated environment (Frost and Diele., 2022). Smothering of the eggs by sediments may retard the growth of embryos when the eggs come in contact with high SSCs in the first few hours after laying. In addition, the development of embryos may be adversity affected through a reduction in oxygen availability around the eggs (Cohen and Strathman, 1996; von Nordheim et al., 2018, cited in Frost and Diele, 2022). However, herring spawn over coarser grounds and water currents in these areas will naturally be higher, which will aid in the re-suspension and re-distribution of any material deposited on the seabed, thereby reducing the duration and as such the severity of any potential adverse effects on herring eggs. Based on this, spawning herring are considered to have a low tolerance to accommodate increases in sediment plumes and deposition. Recovery from potential embryo mortality and reduction in recruitment success is anticipated to take place within the short-term (medium recoverability). Taking into account the regional importance of herring, and their low tolerance and medium recoverability, the sensitivity of herring to increases in SSC and sediment deposition from construction activities is deemed to be medium.
Nephrops	• Nephrops are of high commercial value to fisheries within the region (Commercial Fisheries Technical Report). The MarESA sensitivity review has assessed Nephrops as not being sensitive to increases in suspended sediments and smothering from sediment deposition, based on their active burrowing habit and ability to excavate any material deposited within their burrow systems (Durkin and Tyler-Walters, 2022). However, berried females may be considered more susceptible to smothering from sediment deposition, as the eggs require regular aeration. In addition, sediment deposition larger than the 30 cm considered by the MarESA assessment may occur locally during construction activities. Therefore, for the purpose of this assessment, Nephrops are considered to have a moderate capacity to accommodate the impact (medium tolerance) with medium to high recoverability. • Based on their medium tolerance and medium to high recoverability and taking into consideration their regional importance, the sensitivity of Nephrops to temporary increases in SSCs and sediment deposition is deemed to be low.
Brown crab	• Brown crab are of commercial value to fisheries within the region (Commercial Fisheries Technical Report). They may avoid areas of increased SSCs as they rely on visual cues during predation (Neal and Wilson, 2008), and consequently they are considered to have a medium tolerance to short-term increases in SSCs. Any potential displacement would likely be temporary (high recoverability), with individuals able to return shortly after sediment plumes have dissipated.

Receptor	Sensitivity
	Berried female edible crab exhibit a largely sedentary lifestyle during the overwintering period whilst brooding eggs. During this time, they are considered a stationary receptor, burying themselves into soft mud and sand, and are therefore unlikely to avoid disturbances (no adaptability). They will however be able to lift themselves clear of unfavourable sediment deposition (Neal and Wilson, 2008), and consequently they are considered to have a moderate capacity to accommodate the impact (medium tolerance). Recovery from any likely significant effects on the reproductive success of brooding females is assessed to occur within the short-term (medium recoverability). • Based on their overall medium tolerance and medium to high recoverability and taking into consideration their regional importance, the sensitivity of brown crab to temporary increases in SSCs and sediment deposition is deemed to be low.
European lobster	• European lobster are of commercial value to fisheries within the region (Commercial Fisheries Technical Report). Unlike brown crab, adult European lobster are not thought to exhibit a sedentary overwintering habitat (Pawson, 1995), being typically more mobile and are therefore considered able to move away from areas affected by increased SSC and sediment deposition (high adaptability and tolerance). Any potential displacement would likely be temporary (high recoverability), with individuals able to return shortly after sediment plumes have dissipated. However, berried females are likely to be more susceptible to increased SSCs and smothering impacts, as the eggs carried require regular aeration. Consequently, their tolerance to the impact is assessed as medium. In addition, juvenile lobsters are known to spend large amounts of time within their burrows (e.g., Smith et al., 1998), and therefore they may be considered a stationary receptor unlikely to move away from disturbances. They are however considered to be able to lift themselves clear of unfavourable sediment deposition, and consequently they are considered to have a moderate capacity to accommodate the impact (medium tolerance). Recovery from any likely significant effects on the reproductive success of brooding females is assessed to occur within the short-term (medium recoverability). • Based on their overall medium tolerance and medium to high recoverability and taking into consideration their regional importance, the sensitivity of European lobster to temporary increases in SSCs and sediment deposition is deemed to be low.
King scallop	• King scallop are of commercial value to fisheries within the region (Commercial Fisheries Technical Report). They can undertake limited swimming, although this is considered to be at a high energy cost and generally associated with predator avoidance (Marshall and Wilson, 2008). This species is therefore not expected to be able to travel large distances to avoid elevated SSCs and sediment deposition, and adaptability is consequently assessed as medium. The MarLIN sensitivity review has assessed king scallop as having a low intolerance (i.e., medium tolerance) to smothering and an increase in suspended sediments on the basis that they can lift themselves clear of sediment layers and areas of unfavourable SSCs (Marshall and Wilson, 2008). Larger increases in suspended solids may affect growth rates or increase the energetic costs for feeding (Marshall and Wilson, 2008). For example, Szostek et al. (2013) observed an increase in shell claps to remove excess sediments and a decrease in growth rates of juvenile King scallop when exposed to SPM concentrations >100mg/l during an 18-day exposure experiment. King scallop is therefore considered to have a medium tolerance to the impact. Any effects on growth or feeding rates are likely to be temporary (high recoverability), while likely significant effects on reproductive rates are estimated to be of short-term duration (medium recoverability). • Based on their medium adaptability, medium tolerance, and medium to high recoverability, and considering their regional importance, the sensitivity of King scallop to temporary increases in SSCs and sediment deposition is deemed to be low.
Common cockle	• Common cockles are found in surface sediments, typically living in the top 2 to 5cm of the substratum (Richardson et al., 1993). They have short siphons, which need to remain in contact with the surface of the sediment for respiration and feeding (Tyler-Walters, 2007). Therefore, common cockles are assessed as being unable to avoid the impact (negligible adaptability). The MarESA sensitivity review has assessed benthic assemblages with abundant common cockle to be broadly insensitive (high tolerance and recoverability) to increases in suspended solids, based on their common occurrence in areas where turbidity is frequently high (e.g., Tillin et al., 2016; Tillin and Tyler-Walters, 2023). The tolerance of cockles to light smothering (i.e., sediment deposition of up to 5 cm) has been assessed by MarESA as being medium, as some organisms may not be capable to return to the surface when disturbed by sediment deposition. The deposition of larger amounts of sediment (> 5cm) has been shown to cause substantial mortality in cockles, and consequently the MarESA assessment considers cockles to have a low tolerance to heavy smothering. Recovery from heavy sediment deposition is likely to occur within two to ten years (based on the MarESA assessment) as a result of a combination of adult migration from surrounding unaffected areas and repopulation by larvae during episodic recruitment events (e.g., Tillin et al., 2016; Tyler-Walters, 2007).

Receptor	Sensitivity
	• Taking into consideration the regional importance of common cockles together with their low tolerance to, and medium to low recoverability from heavy sediment deposition, the overall sensitivity of common cockles to the impact is deemed to be medium.
Common whelk	• Common whelk are found across a range of substratum types, including rock, cobbles, and gravel as well as coarse and muddy sands (e.g., Himmelman and Hamel, 1993). They are mobile but typically remain stationary when not actively searching for food, either resting on the seafloor or being to some degree buried within in the sediment (Himmelman and Hamel, 1993). They are therefore considered to have a limited capacity to avoid the impact (low adaptability), with their demersal egg cases also unable to avoid the impact (low adaptability). The tolerance of whelk to temporary increases in SSC and the deposition of sediment is assessed as being medium given their ability to bury and re-locate to nearby unaffected areas. Any potential displacement would likely be temporary (high recoverability), with individuals able to return shortly after sediment plumes have dissipated. Recovery from any likely significant effects on recruitment success due to impacts on the survival and development of demersal eggs is assessed to occur within the of short-term to medium-term (medium to low recoverability). • Based on their medium tolerance and medium to low recoverability and taking into consideration their regional importance, the sensitivity of common whelk to temporary increases in SSCs and sediment deposition is deemed to be low.
Razor clams	• The razor clam Ensis siliqua is of commercial value to the fisheries within the region (Commercial Fisheries Technical Report). Razor clams are efficient burrowers (Winter and Hosoi, 2011) and have been shown to rapidly dig to depths of more than 1m or leave their burrows when disturbed (Fraser et al., 2018). They are also capable of swimming short distances along the seabed (Fraser et al., 2018). This suggests that razor clams are able to adapt and tolerate sediment deposition (high adaptability and tolerance). The susceptibility of razor clams to increases in SSCs is likely to be low given their suspension-feeding habit. Larger increases in suspended solids may affect reproductive success or increase the energetic costs for feeding (Hill, 2006). Therefore, the tolerance of razor clams to increases in SSCs is assessed as medium. Any effects on feeding rates are likely to be temporary (high recoverability), while likely significant effects on reproductive rates are estimated to be of short-term duration (medium recoverability). • Taking into consideration the regional importance of razor clams together with their medium tolerance to, and medium to high recoverability from increases in SSCs, the overall sensitivity of the receptor to the impact is deemed to be low.
Blue mussel	• Blue mussels are sedentary and are therefore assessed as being unable to avoid the impact (negligible adaptability). The MarESA sensitivity review has assessed blue mussels to be broadly insensitive to increases in suspended solids, based on their common occurrence in areas where turbidity is frequently high and their ability to remove sediment from the mantle cavity (de Vooys, 1987; Tillin et al., 2023). Increased expenditure for feeding or impairment to growth may occur in areas of high SSC (>250mg/l), but given the temporary nature of the sediment plumes, any effects are likely to be temporary. The tolerance of blue mussels to light smothering (i.e., sediment deposition of up to 5cm) has been assessed by MarESA as being medium, as some organisms may not be capable to return to the surface when disturbed by sediment deposition. However, mortality may be avoided during single deposition events in areas where sediments are redistributed by wave or tidal action. Similarly, while the deposition of larger amounts of sediment (> 5cm) could result in substantial mortality in blue mussels due to their limited capacity to re-surface from sediment deposition deeper than 2cm, mortality may be limited or possibly avoided in areas where sediments are re-distributed by tidal currents (Tillin et al., 2023), such as in the study area. Therefore, blue mussels are considered to have a medium tolerance to the impact. Any effects on growth or feeding rates are likely to be temporary (high recoverability), while likely effects on reproductive rates are estimated to be of short-term duration (medium recoverability). • Based on medium tolerance, and medium to high recoverability, and considering their regional importance, the sensitivity of blue mussel to temporary increases in SSCs and sediment deposition is deemed to be low.

In summary, marine turtles, diadromous VERs, and viviparous and ovoviviparous elasmobranchs (including basking sharks) have been assessed as not being sensitive to the impact. The sensitivity of the remaining VERs has been assessed as medium for herring, spotted ray and common cockle and as low for all pelagic and demersal VERs, ovigerous elasmobranchs (except for spotted ray), sandeel, and all shellfish VERs with the exception of common cockle. The maximum sensitivity of fish and shellfish VERs for this impact is therefore medium.

Magnitude of impact

Ambient levels of Suspended Particulate Matter (SPM)[7] within the study area vary seasonally in response to annual wave dynamics, with highest concentrations typically found in January and lowest levels occurring during summer in June and July. Long-term data of SPM derived from satellite data (Cefas, 2016) show that concentrations are highest within the nearshore zone of the study area, peaking in Dundalk Bay around 25km north-west of the array area. Here, monthly mean sea surface SPM concentrations vary from 4.0mg/l in June to 14.0mg/l in January (± 2.0mg/l standard deviation). For the nearshore part of the ECC, the monthly mean sea surface SPM concentrations vary from 2.9mg/l in July to 8.3mg/l in December (± 1.3mg/l standard deviation). For the array area, the monthly mean sea surface SPM concentrations vary from 0.6mg/l in June/July to 4.8mg/l in January (± 0.5mg/l standard deviation). Site-specific water samples taken to the north-east and south of the array area in January 2023 indicate total suspended solid concentrations between 13 to 38mg/l for a range of water depths, noting these samples were taken following a period of strong winds (Figure 1 of Partrac, 2023). Overall, all concentrations are considered to be relatively low (Physical Processes Chapter).

The extent and magnitude of sediment plumes and associated bed level changes predicted for the different construction activities are detailed in Table 13.14, and the impact magnitude for all fish, marine turtle and shellfish VERs has been assessed in Table 13.15, based on the methodology outlined in Section 13.2.5. No specific embedded mitigation measures relevant to the impact have been defined (see Table 13.11).

The results of the site-specific modelling show that construction activities would create discrete sediment plumes that would spread over several tidal cycles prior to completely settling out. Suspended sediments would typically be transported with the tidal flow towards the north-west on the flood phase and south-east on the ebb phase, with the flood dominant flow favouring a net transport of suspended sediments to the north at most tides. Based on typical flows during a spring tide, the longest tidal excursion from the middle of the ECC extends up to 6.4km to the north-west for the flood phase and 6.3km to the south-east during the ebb phase. For the array area, the equivalent distances are estimated to be 7.2km in a north-north-west (flood) direction and 6.7km in a south-south-east (ebb) direction. Tidal excursions during neap tides are modelled to be around 50% of those occurring during springs. Sediment mobilisation (re-suspension) is strongest during spring flood flow, during which sediments up to fine sands can be mobilised into suspension. The corresponding spring peak ebb flow has the capacity to only mobilise very fine sands into suspension. In contrast, flow conditions during neap tides are insufficient to mobilise any sediment and instead would provide long periods conductive to sediment deposition (the Physical Processes Chapter).

Table 13.14 Modelled increases in SSC and sediment deposition during construction activities

Construction impact	Location	Details of increase in SSC and deposition
Seabed levelling (Project Option 2 only)	• Array area	• SSCs within sediment plumes associated with overspill can be up to 1,000mg/l close to the point of release within the tidal excursion buffer, reducing to tens of mg/l with distance, but also quickly dissipating in time after release. • After a period of around 20 hours from the initial release the plume would cover an area of between 0.2 to 0.4km2 during neap tides (peak concentrations of around 240 to 270mg/l) and 0.8 to 0.9km2 during spring tides (peak concentration of 100 to 110mg/l). • All deposition depths of settled sediments beyond the spring tidal excursion distance are estimated as less than 1mm, with all deposition depths closer to the point of release estimated to be less than 50mm (0.05m). • Spoil mounds are likely to form as a result of the instantaneous disposal of dredged sediments from the TSHD. These are predicted to cover an initial area of around 0.19km2,typically with a height between 0.3 to 1m and with a greatest height of 1.71m. The area covered by spoil depths above 0.05m is estimated to be around 0.15km2, and 0.08km2 for depths above 0.30m.
Drilling for foundation installation	• Array area	• Increased SSC above background greater than 10mg/l remain within the tidal excursion buffer. Highest concentrations in the range of 500 to 1,000mg/l are confined to the point of discharge. Outside the tidal excursion buffer suspended sediment concentrations are <10mg/l and equivalent to background levels.

[7] SPM refers to all suspended particles within the water column including organic particles. SSC refers to the suspended particles that are not organic in origin.

Construction impact	Location	Details of increase in SSC and deposition
		• On a neap tide release at 20 hours the sediment plume extends around 11.5km to the south covering an area of up to 8km2 with maximum SSC of around 26mg/l. The spring tide release at 20 hours extends over an area of around 10km2 and 11.8km to the north with a maximum SSC of around 31mg/l. • All deposition depths of settled sediment in the range of 20 to 50mm remain close to the drilling location which reduces to between 5 to 10mm up to the adjacent WTG location. Only trace levels (<1mm) exceed the tidal excursion buffer. • Subsequent drilling for adjacent WTG may lead to additional levels of deposition. For an adjacent WTG location along the same row, an initial depositional depth of up to 5 to 10mm could receive an additional 5 to 10mm.
Cable installation	• Array area	• Highest SSC in the range 300 to 500mg/l are limited along the trenching line and only occur during the period of jetting. All concentrations up to 50mg/l remain within the tidal excursion buffer with the potential for a wider spread of lower concentrations beyond the buffer over successive tidal excursions which tend to favour a northerly distribution due to the flood dominant tide. • After a period of around 20 hours from the initial release the plume covers an area of between 1.7 to 2.1km2 on neap release (peak concentration around 20 to 10mg/l, respectively) and 4.7 to 5.5km2 on spring releases (peak concentration of 11 to 8mg/l, respectively). • Highest levels of deposition between 52 to 65mm occur along the trenching line (i.e., material falling back into the trench). Levels above 1mm remain within 3.5km of the trenching line during both flood and ebb tides. Trace levels (<1mm) spread further afield with a distribution mainly to the north of the trench due to the flood dominant tide. • Where there is an adjacent cable line upstream or downstream on the tidal axis then there is a chance for some subsequent overlapping deposition for levels up to 5 to 10mm (i.e. the extent of settlement from one cable line has the chance of reaching the adjacent trench line in the direction of the tidal axis).
	• ECC	• Highest SSC in the range 600 to 800mg/l are limited along the trenching line and only occur for the period of trenching. All concentrations above 1mg/l remain within the tidal excursion buffer. • After a period of around 10 hours from the initial release the plume covers an area of between 1.2 to 1.7km2 on neap releases (peak concentration around 5 to 2mg/l, respectively) and 3.6 to 3.9km2 on spring releases (peak concentration of up to 2mg/l). • Highest levels of deposition between 17 to 32mm occur along the trenching line (i.e., material falling back into the trench). Levels above 1mm remain within 1km of the trenching line during both flood and ebb tidal axis. Trace levels (<1mm) spread further afield with a distribution mainly to the north of the trench due to the flood dominant tide.
Excavation of HDD exit pits	• ECC	• The plume covers a maximum distance of around 2.2km to the north-west (flood) and to the south-east (ebb) for concentrations >1mg/l on spring releases, and around 1.3km on neap releases. • The highest elevated concentrations remain close to the exit pits within the ECC boundary with levels up to 1,120mg/l. • The maximum spread of fine sediment deposition is around 2.5km to the north-north-west and south-south-east of the exit pit trench. The greatest depth of deposition remains close to the pits with maximum levels of between 68 to 193mm.. • Coarse sediments would fall directly back to the seabed adjacent to the exit pits and as such would not create any sediment plumes.
Bentonite release	• ECC	• The plume covers a maximum distance of around 1.1km to the north-west (flood) and 0.8km to the south-east (ebb) along the coast for concentrations >1mg/l on spring releases, and shorter distances on neap releases. • The highest elevated concentrations remain close to the HDD exit pits with levels up to 29mg/l. • The maximum spread of bentonite deposition is around 1.7km to the north-north-west and 1.4km to the south-south-east of the exit pit trench with greatest depths of deposition remaining closest to the pits with levels between 0.3 to 0.7mm (trace levels).

In summary, the results of the plume modelling indicate that any increases in SSC above background levels caused by seabed preparation and construction activities would be restricted to the near-field and adjacent far-field areas within the sedimentary ZoI. The highest SSCs (>1,000mg/l) would be confined to the points of discharge within the near-field (e.g., around WTG locations and cable trench line). Sediment deposition would consist of coarser material deposited close to the source (i.e., around the area of disturbance), with the deposition of finer material decreasing from the point of release.

Sediment plumes are expected to quickly dissipate after cessation of the construction activities due to settling and wider dispersion, with SSCs reducing within a couple of tidal cycles to background levels. Consequently, the impact will be restricted to the construction phase of the proposed development and will therefore be short-term (i.e., one to seven years as defined in the assessment methodology in Table 13.5), although works in any given discrete location within the proposed offshore development area will often be temporary (less than one year). In addition, construction activities are largely expected to be carried out on a sequential basis with minimal opportunity for successive periods of sediment disturbance to develop overlapping sediment plumes (i.e., plumes are expected to fully disperse with material settling out of suspension prior to the occurrence of a subsequent sediment disturbance event).

The impact will occur frequently during the construction phase, originating from discrete locations throughout the array area and along the ECC.

Table 13.15 Determination of impact magnitude of increased SSC and sediment deposition during construction activities

Receptor	Impact magnitude
Pelagic VERs (Atlantic mackerel, Atlantic horse mackerel, sprat)	• It has been determined that the impact may affect pelagic VERs predominantly through the effects of high levels SSCs on planktonic eggs and larvae. All pelagic VERs including their known spawning locations are widely distributed throughout the study area and wider region, and therefore the degree of overlap between these receptors and those areas subject to increases in SSCs is predicted to be small in the context of available spawning habitat. Moreover, the potential for adverse effects on eggs and larvae would be confined to areas experiencing high levels of SSC and as such would be restricted to the near-field close to the point of release. Based on this together with the short-term, intermittent and localised nature of the impact, any effects upon pelagic VERs are assessed to be either not discernible or barely discernible from baseline conditions. Consequently, the magnitude of the impact is deemed to be low (adverse).
Demersal VERs (Atlantic cod, plaice, lemon sole, common sole, common dab, American plaice, witch flounder, whiting, haddock and anglerfish)	• Cod, plaice, lemon sole, common sole, whiting, and haddock all have spawning grounds within the fish and shellfish study area (Coull et al., 1998; Ellis et al., 2010; Marine Institute, 2016). As for the pelagic VERs, it has been determined that the impact may affect demersal VERs predominantly through the effects of increased levels SSCs on planktonic eggs and larvae. Spawning grounds of these receptors are widely distributed across the study area and within the Irish Sea. Therefore, the degree of overlap between sediment plumes and the receptors, including early life stages sensitive to high SSCs, is anticipated to be small in the context of available spawning habitat and the areas likely to be affected by elevated SSCs and sediment deposition. Similarly, later life stages of the receptors are highly mobile and widely distributed within the wider region, and therefore the interaction between the receptors and the impact is assessed to be low. Considering the wide distribution of the receptors and their spawning locations within the study area and Irish Sea, and the short-term, intermittent and localised nature of the impact arising during construction, any effects on demersal VERs are assessed to be either not discernible or barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be low (adverse).
Small-spotted catshark, nursehound and skate species (thornback ray, spotted ray, blonde ray, cuckoo ray, small-eyed ray)	• It has been determined that the impact may predominantly affect these receptors through the potential smothering of egg cases deposited on the seabed. Areas affected by high SSC and sediment deposition will be highly localised. In addition, the receptors are widely distributed within the study area, and therefore the interaction between the receptors and the impact is predicted to be small in the context of available habitat. Based on this together with the intermittent and short-term nature of the impact, any effects upon the receptors are assessed to be barely discernible from baseline conditions. Consequently, the magnitude of the impact is deemed to be low (adverse).
Sandeels	• Sub-prime and suitable sandeel spawning habitats are located along most of the ECC and within the ZoI to the south of the array area (Figure 13.5). It is therefore likely that some proportion of sandeel spawning grounds would be subject to increased SSCs and smothering from sediment deposition during construction activities. The deposition of coarser sediments resulting from construction activities would be restricted to areas close to the points of release, i.e., within the trenching line and close to the HDD exit pits for activities within the ECC. Plumes of finer sediments will disperse more widely. Low intensity sandeel spawning grounds are predicted to be distributed across large parts of the Irish Sea (Ellis et al., 2010; Figure 13.5).

Receptor	Impact magnitude
	In addition, PSA data collected through INFOMAR (2023) confirm the presence of suitable sandeel habitats within the study area and wider region, with areas classed as 'Suitable' and 'Sub-Prime' for sandeel spawning being located to the south of the array area (Figure 13.5). Taking this into consideration, any effects on sandeel spawning grounds from increased SSCs and sediment deposition are assessed to be relatively small in the context of available suitable substrate in the study area and wider region. Based on this together with the short-term and intermittent nature of the impact, any effects upon sandeel populations and their spawning grounds are considered to be barely discernible from baseline conditions, and therefore the magnitude of the impact is deemed to be low (adverse).
Herring	• The closest known spawning ground for herring is located north of Dundalk Bay in the north of the study area (Mourne spawning ground) (Figure 13.5). This spawning ground does not overlap with the proposed areas for the disposal of spoil material and areas affected by the deposition of coarser material. Plumes of finer sediments may disperse into Dundalk Bay; however, the levels of SSCs in plumes reaching Dundalk Bay would be well within natural background concentrations (Table 13.14). In addition, any deposited sediment would be rapidly re-distributed by tidal currents. Therefore, no discernible changes are anticipated on spawning herring grounds from the impact during the construction phase, and consequently the magnitude of the impact is deemed to be negligible.
Nephrops	• The site-specific surveys indicated the presence of Nephrops burrows along most of the ECC and within the northern section of the array area. Nephrops within the study area are part of the western Irish Sea Nephrops population, which inhabits the fine sediments of the Western Irish Sea Mud Belt from about 54.5°N in the north to 53.5°N in the south. Therefore, the degree of overlap between sediment plumes and associated sediment deposition is considered to be small in the context of the distribution of the western Irish Sea Nephrops population. In addition, recent stock abundance estimates indicate that the western Irish Sea Nephrops population is in a good state. • Taking into consideration the wide distribution of the receptor throughout the fish and shellfish study area and wider western Irish Sea together with the short-term, intermittent and localised nature of the impact, any effects on Nephrops from increases in SSCs and sediment deposition are assessed to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be low (adverse).
Brown crab, European lobster, common whelk, common cockle, King scallop, razor clams	• Taking into account the distribution of the shellfish receptors within the study area and the short-term and localised nature of the impact, any effects on the shellfish receptors are assessed to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be low (adverse).
Common cockle	• It has been determined that the impact may affect common cockles directly through high levels of sediment deposition. Common cockles typically occur in intertidal areas and sometimes may also be found within the shallow subtidal (Tyler-Walters, 2007). A temporary increase in nearshore sediment deposition would occur during the excavation of the two subtidal HDD exit pits, with bed level changes >5cm predicted to be restricted to a narrow band within the ECC (Table 13.14). Fishing activity data indicate that the main cockle beds within the fish and shellfish study area are located in Dundalk Bay outside the area affected by this sediment deposition. In addition, none of the benthic assemblages recorded within the intertidal landfall area and adjacent shallow subtidal are characterised by common cockles (Volume 3, Chapter 12: Benthic Subtidal and Intertidal Ecology). Therefore, the number of cockles affected by heavy sediment deposition is likely to be very small, in particular when compared to the extent of large commercial beds and available intertidal and shallow subtidal soft sediment habitats within the wider region. Based on this together with the short-term nature of the impact, any effects on common cockles from the impact are expected to be not discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be negligible.
Blue mussel	• The site-specific benthic baseline surveys did not record blue mussels within the offshore development area (Volume 9, Appendix 12.1 and 12.2). In addition, fishing activity data (Marine Institute, 2016) indicate that seed mussel beds are located to the south of the offshore development area outside the sedimentary ZoI (Figure 13.11). Therefore, the number of blue mussels affected by the impact is likely to be very small, in particular when compared to the extent of large seed mussel beds within the wider region. Based on this together with the short-term and intermittent nature of the impact, any effects on blue mussels from the impact are expected to be not discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be negligible.

In summary, elevated levels of suspended sediments above background levels and associated sediment deposition during construction activities are expected to be localised within the near-field and adjacent far-field. Furthermore, these changes are expected to be temporary to short-term, intermittent, and reversible, with any changes to the baseline of sensitive receptors assessed as being not discernible for herring, blue mussel, and common cockle and at most barely discernible for the remaining receptors. The magnitude of this impact for these receptors has therefore been assessed as being negligible and low (adverse), respectively. Marine turtles, diadromous VERs and viviparous and ovoviviparous elasmobranchs (including basking sharks) were assessed as not being sensitive to the impact and were therefore screened out of the magnitude assessment.

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and maximum low (adverse) magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.2.2 Impact 2: Temporary habitat damage and disturbance of the seabed during construction activities

Direct physical damage and disturbance to the seabed would occur within the array area and along the ECC during seabed preparation prior to foundation installation, the use of jack-ups and anchored vessels, cable laying, and the installation of WTG and OSP foundations. These activities could directly lead to the disturbance or displacement of mobile species and the damage or loss of sedentary or less mobile receptors. In addition, essential seabed areas (e.g., spawning, nursery or feeding grounds) may be damaged or disturbed. It should be noted that in this instance, the terms ‘damage’ and ‘disturbance’ refer to temporary physical impacts to the seabed during the construction phase of the proposed development and any associated effects on fish, shellfish, and marine turtle receptors. The effects of permanent habitat loss due to the placement of infrastructure and associated protection measures are assessed in full in the operational phase section as Impact 7 (Section 13.5.3.3).

The sensitivity of all fish, marine turtles and shellfish receptors to physical damage and disturbance of the seabed and the magnitude of the impact have been assessed in Table 13.16 and Table 13.17 respectively, based on the methodology outlined in Section 13.2.5. No specific embedded mitigation measures relevant to the impact have been defined (see Table 13.11).

Sensitivity of receptors

Physical disturbance of the seabed during construction activities may result in injury or loss of sedentary or slow-moving receptors. This includes receptors that bury in the sediment (e.g., sandeel) and less mobile and burrowing shellfish species (e.g., *Nephrops*, common whelk, scallops), including those of regional socio-economic importance. In addition, adverse effects on fish and shellfish populations may arise through direct damage or loss of early life stages (i.e., eggs and egg cases deposited on the seabed) or indirectly through the disturbance of benthic spawning and nursery grounds.

Table 13.16 Determination of receptor sensitivities to temporary habitat damage and disturbance during construction activities

Receptor	Sensitivity
Marine turtles, basking shark, pelagic VERs (Atlantic mackerel, Atlantic horse mackerel, sprat)	• Marine turtles, basking sharks and all pelagic VERs do not depend upon benthic habitats for part or all of their life cycle and therefore are not considered susceptible to the physical damage or disturbance of the seabed that would arise during construction activities. Consequently, the sensitivity of these species to the impact is deemed to be negligible. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is imperceptible as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Demersal VERs, diadromous VERs, tope, starry smooth-hound, spiny dogfish	• As detailed in Table 13.13, these receptors are considered to have a high adaptability and tolerance to seabed disturbance events given that they are mobile and would therefore be able to move to nearby unimpacted areas. Any potential displacement would likely be temporary (high recoverability), with individuals able to return after construction activities have ceased.

Receptor	Sensitivity
	In addition, these receptors are pelagic spawners (demersal fish VERs), do not spawn within the study area (diadromous VERs), or bear live young (tope, starry smooth-hound and spiny dogfish), and therefore physical damage or disturbance of the seabed within the study area would not result in any potential disturbance or loss of available spawning locations. • Based on their high adaptability, tolerance and recoverability the sensitivity of the receptors to temporary damage and disturbance of the seabed during construction activities is deemed to be negligible. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is imperceptible as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Small-spotted catshark, nursehound and skate species (thornback ray, spotted ray, blonde ray, cuckoo ray, small-eyed ray)	• As detailed in Table 13.13, juvenile and adult small-spotted catshark, nursehound and skate species are considered to have a high adaptability and tolerance to seabed disturbance events as they are mobile and would therefore be able to relocate to nearby unimpacted areas. However, the physical disturbance of the seabed may damage or dislodge egg cases deposited on the seabed and consequently may lower the receptor's recruitment success. Therefore, overall, the receptors are assessed as having a medium tolerance to the impact. Recovery from any potential decrease in recruitment success is anticipated to occur within the short to medium-term (medium to low recoverability). • Taking into consideration the regional importance of the receptors (with the exception of spotted ray) together with their general high adaptability, medium tolerance and potential low recoverability, the sensitivity of the receptors to the impact is deemed to be low. On a precautionary basis, the sensitivity of spotted ray to the impact is classed as to medium, considering the international importance of the receptor.
Sandeel	• Sandeel exhibit strong site fidelity and spend large amounts of time buried in the sediment. In addition, sandeel are demersal spawners, with eggs remaining attached to the seabed during their development. Therefore, for the purposes of the assessment sandeel are considered a stationary receptor that has low to no adaptability to the impact. Seabed disturbances may result in some mortality of individuals, or it may directly damage or dislodge eggs, which may lead to increased egg mortality rates and reduced recruitment success. Based on this, sandeel are assessed as having a very low tolerance to direct damage and disturbance of the seabed. Any potential displacement of individuals is expected to be temporary, with individuals able to return shortly after construction activities have ceased (high recoverability). Recovery from any reduced recruitment to the population is assessed to occur within the short-term (medium recoverability). • Taking into consideration the low adaptability, very low tolerance and medium recoverability from damage to early life stages, together with the regional importance of the receptor, the sensitivity of sandeel to the impact is deemed to be medium.
Herring	• As detailed in Table 13.13, herring are demersal spawners, reliant upon the presence of suitable substrates for spawning and egg development. Their eggs are most susceptible to seabed disturbances as they would be unable to avoid the impact. Seabed disturbance may directly damage or dislodge eggs, which may lead to increased egg mortality rates and reduced recruitment success. Moreover, physical damage to the seabed may alter seabed conditions, making them potentially less favourable for egg deposition and development. Therefore, herring are assessed as having a very low tolerance to the impact. Any potential displacement of individuals is expected to be temporary, with individuals able to return shortly after construction activities have ceased (high recoverability). Recovery from any reduced recruitment to the population is assessed to occur within the short-term (medium recoverability). • Taking into consideration the regional importance of herring together with its low adaptability, very low tolerance and the medium recoverability from damage to early life stages, the sensitivity of herring to the impact is deemed to be medium.
Nephrops	• Nephrops construct and inhabit complex burrows. Berried females are largely sedentary whilst brooding eggs, generally remaining within their burrows to overwinter. For the purposes of the assessment Nephrops are therefore considered a stationary receptor, which is unlikely to move away from physical impacts to the seabed (low adaptability). Disturbance of the seabed will likely damage Nephrops burrow systems and displace its inhabitants. Some individuals may be damaged or lost. In addition, eggs carried by berried females may also be lost, potentially resulting in a decline in reproduction rates (Durkin and Tyler-Walters, 2022). Consequently, Nephrops are considered to have a low tolerance to the impact. Nephrops have shown the ability to rebuild damaged burrows within several days (Durkin and Tyler-Walters, 2022), and therefore effects of damaged or disturbed burrow networks are likely to be temporary (high recoverability). Recovery from lost individuals or a decrease in recruitment success is considered to occur within the short-term to medium-term (medium to low recoverability) following larval dispersal and successful recruitment after the impact has ceased.

Receptor	Sensitivity
	• Based on their low tolerance and low to medium recoverability and taking into consideration their regional importance, the sensitivity of Nephrops to the impact is deemed to be medium.
Brown crab	• Brown crab are considered a key commercial species within the area. Like Nephrops, berried female brown crab exhibit a largely sedentary lifestyle during the overwintering period, remaining buried in the sediment (Bennett, 1995). For the purposes of the assessment brown crab are therefore considered a stationary receptor with a limited ability to move away from physical impacts to the seabed (low adaptability). Seabed disturbances may damage or kill some specimens, and eggs carried by brooding females may be lost. The tolerance of brown crab to the impact is therefore assessed as being low with recovery considered to occur within the short-term. • Based on their low tolerance and medium recoverability and taking into consideration their regional importance, the sensitivity of brown crab to the impact is deemed to be medium.
European lobster	• European lobster are considered a key commercial species within the area. The species is not known to exhibit a sedentary overwintering habit, being typically mobile, and therefore it is considered to have a greater ability to move away from disturbances by comparison to brown crab. The tolerance of European lobster to temporary seabed disturbances is assessed as high and recovery is expected to occur within the short-term. Consequently, the sensitivity of the receptor to temporary seabed disturbance impacts is deemed low.
Common whelk	• Common whelk has been identified as a species of commercial importance to the area. Common whelk are not thought to make extensive movements, and they are therefore considered to have a limited capacity to avoid the impact (low adaptability). Seabed disturbances may damage or kill some specimens. In addition, egg cases deposited on the seabed may be lost. The tolerance of common whelk to the impact is therefore assessed as being low with recovery considered to occur within the short-term (medium recoverability). • Based on their low adaptability and tolerance and medium recoverability and taking into consideration their regional importance, the sensitivity of common whelk to the impact is deemed to be medium.
King scallop	• King scallop exhibit limited swimming, with this behaviour generally limited to predator avoidance (Marshall and Wilson, 2008). The species is therefore considered to a have limited ability to avoid physical impacts to the seabed. It is possible that some smaller individuals may be crushed and killed during construction activities. The tolerance of king scallop to the impact is therefore assessed as being medium, with recovery considered to occur within the short-term (medium recoverability). • Based on their medium tolerance and medium recoverability and taking into consideration their regional importance, the sensitivity of king scallop to temporary damage and disturbance of the seabed during construction activities is deemed to be medium.
Common cockle	• Common cockles inhabit shallow burrows and rely upon contact with the surface, which makes them susceptible to physical impacts to the seabed during construction activities. It is likely therefore that cockles have a limited ability to avoid the impact (low adaptability). The MarESA sensitivity review considers benthic assemblages with abundant common cockles to have a low resistance (i.e., low tolerance) to activities disturbing surface sediments, as individuals are likely to be exposed, damaged or lost through mortality (e.g., Tillin et al., 2016; Tillin and Tyler-Walters, 2023). Small areas cleared of cockles within dense cockle beds were found to be recolonised quickly (i.e., within weeks to months) through adult migration, while the recovery of larger disturbed patches is likely to be dependent on successful larval recruitment (Tillin et al., 2016). Therefore, the recovery of common cockles from temporary physical impacts to the seabed is considered to occur within the short-term to medium-term (medium to low recoverability). Based on their low adaptability, low tolerance and medium to low recoverability, and taking into consideration their regional importance, the sensitivity of common cockles to temporary damage and disturbance of the seabed during construction activities is deemed to be medium.
Razor clams	• The MarLIN sensitivity review has assessed razor clams as having a high intolerance (i.e., very low to low tolerance) to abrasion and physical disturbance of the seabed on the basis that they have very brittle shells that are highly susceptible to damage (Hill, 2024). Spatfall of razor clams has been reported to be sporadic and therefore the MarLIN sensitivity review concluded that recovery may occur within one year in years of good recruitment but may take up to 10 years for larger beds (Hill, 2024). Therefore, for the purpose of this assessment, the recoverability of razor clams to the impacts is deemed to be low. Based on their very low tolerance and low recoverability and taking into consideration their regional importance, the sensitivity of razor clams to the impact is deemed to be medium.

Receptor	Sensitivity
Blue mussel	• Blue mussels are sedentary, which makes them highly susceptible to physical impacts to the seabed during construction activities (no adaptability). The MarESA sensitivity review considers blue mussels to have a low resistance (i.e., low tolerance) to activities disturbing surface and shallow subsurface sediments, as individuals are likely to be affected directly through damage or indirectly through the weaking of their connecting byssus threads, which makes them vulnerable to displacement (Tillin et al., 2023). Recovery from the loss of large parts of blue mussel beds is assessed to occur within 2-10 years (medium to low recoverability) as a result of a repopulation by larvae during episodic recruitment events (Tillin et al., 2023). Based on their low tolerance and low to medium recoverability and taking into consideration their regional importance, the sensitivity of blue mussels to the impact is deemed to be medium.

In summary, marine turtles, viviparous and ovoviviparous elasmobranchs (including basking sharks), and all pelagic, demersal and diadromous VERs have been assessed as not being sensitive to the impact. The sensitivity of European lobster and all ovigerous elasmobranchs (except spotted ray) has been assessed as low and that of the remaining VERs (herring, sandeel, spotted ray and all remaining shellfish VERs) has been assessed as medium. The maximum sensitivity of fish and shellfish VERs for this impact is therefore medium.

Magnitude of impact

Up to about 6.27km^2 of seabed is predicted to be directly impacted within the array area and ECC during the construction phase of the proposed development for Project Option 1 and 5.39km^2 for Project Option 2 (Table 13.12). Within the array area, an area of approximately 4.83km^2 for Project Option 1 and 3.95km^2 for Project Option 2 is predicted to be temporarily lost or disturbed because of seabed preparations for foundations, jack-up barge and anchoring operations, boulder clearance, and the installation of infrastructure foundations and inter-array cables. This equates to approximately 5.4% of the total seabed area within the array area for Project Option 1 and 4.4% for Project Option 2. Within the areas of the ECC, an area of approximately 1.44km^2 will be temporarily disturbed during installation of export cables including burial and jointing for Project Option 1 and Project Option 2. This equates to approximately 4.0% of the total seabed area within the ECC.

With regard to the scale of the impact, disturbances to the seabed will be spatially restricted to within the immediate footprint of the infrastructure and associated installation activity. Consequently, the maximum extent of the impact will be restricted to the near-field.

Any seabed disturbances during construction activities will be restricted to the construction phase of the proposed development, which is anticipated to last up to three years. The impact will therefore be short-term (one to seven years), as defined in Table 13.5, although works in any given discrete location within the offshore development area will often be temporary (less than one year). The impact will occur frequently in discrete locations within the offshore development area during the construction phase of the development.

Table 13.17 Determination of impact magnitude of temporary habitat disturbance and loss

Receptor	Impact magnitude
Sandeel	• As described previously, site-specific PSA data suggest that sub-prime and suitable sandeel spawning habitats are located along most of the ECC. In addition, sandeel spawning grounds are predicted to be distributed across the Irish Sea (Ellis et al., 2010), and PSA data collected through INFOMAR (2023) indicate the presence of suitable sandeel habitats within the study area and wider region. Taking this into consideration, any temporary damage or disturbance to the seabed during construction activities is considered to be small (<4% of the ECC) in the context of available suitable sandeel habitat throughout the study area and wider region. Based on this together with the short-term nature of the impact, any effects upon sandeel populations and their spawning grounds are assessed to be barely discernible from baseline conditions, and therefore the magnitude of the impact is deemed to be low (adverse).
Herring	• The closest known active spawning beds for herring are located to the north of the study area outside the area to be affected by construction activities. Therefore, no direct damage or disturbance to herring spawning grounds are predicted from physical impacts to the seabed, and the magnitude of the impact is consequently assessed as being negligible.

Receptor	Impact magnitude
Nephrops	• Physical impacts to the seabed during the construction phase may damage or remove Nephrops or displace individuals to nearby undisturbed sediments, which may lead to small-scale changes in the distribution and abundance of Nephrops within the study area (i.e., within the near-field). The degree and extent of these changes are expected to be small in the context of the known distribution of Nephrops throughout the fish and shellfish study area and western Irish Sea Mud Belt (Figure 13.2). Based on this and considering the short-term and intermittent nature of the impact, any effects on Nephrops from the impact are considered unlikely to result in noticeable adverse changes to the western Irish Sea Nephrops population. Consequently, the magnitude of the impact is deemed to be low (adverse).
Brown crab, European lobster, common whelk, King scallop, razor clams	• Taking into account the distribution of the shellfish receptors within the study area and the short-term and localised nature of the impact, any effects on the shellfish receptors are assessed to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be low (adverse).
Common cockle	• As described previously (Table 13.15), the number of cockles directly affected by physical impacts to the seabed is likely to be very small, in particular when compared to the extent of large commercial beds in Dundalk Bay and available intertidal and shallow subtidal soft sediment habitats within the wider region. Based on this together with the short-term nature of the impact, no discernible changes in common cockle distribution and abundance are anticipated to result from temporary damage and disturbance to the seabed during construction activities, and consequently the magnitude of the impact is deemed to be negligible.
Blue mussel	• As described previously (Table 13.15), the number of blue mussels directly affected by physical impacts to the seabed is likely to be very small, in particular when compared to the extent of commercial seed mussel beds in the south of the study area. Based on this together with the short-term nature of the impact, no discernible changes in blue mussel distribution and abundance are anticipated to result from temporary damage and disturbance to the seabed during construction activities, and consequently the magnitude of the impact is deemed to be negligible.

In summary, the temporary damage and disturbance of the seabed during construction activities would be localised and restricted to the near-field. Furthermore, these changes are expected to be temporary to short-term, intermittent, and reversible, with any changes to the baseline of sensitive receptors assessed as being not discernible for herring, blue mussel and common cockle or barely discernible for the remaining receptors. The magnitude of this impact for these receptors has therefore been assessed as being negligible and low (adverse), respectively. Marine turtles, viviparous and ovoviviparous elasmobranchs (including basking sharks), and all demersal and diadromous VERs were assessed as not being sensitive to the impact and were therefore screened out of the magnitude assessment.

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and maximum low magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.2.3 Impact 3: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination

As assessed under Impact 1, construction activities would result in the release of sediments into the water column. While in suspension, there is potential for sediment bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water and affect fish, marine turtles and shellfish receptors.

During the construction phase, there is also a risk of accidental spillage from construction equipment or collision incidents, potentially resulting in the release of pollutants such as fuel, oil and lubricants. Accidental release of pollutants will be managed and mitigated through the implementation of an Offshore EMP (see embedded mitigation measures listed in Table 13.11). The Offshore EMP will include a Marine Pollution Contingency Procedure to manage the risk of accidental pollution during the construction phase in relation to all activities carried out seaward of the HWM.

Pollution prevention and control measures will include navigational safety measures to reduce the likelihood of collision events, procedures to safely use, store and transport harmful substances, and emergency response methods that would be implemented in the case of accidental spills or collision events. In addition, an Offshore Waste Management Procedure will be implemented to ensure all waste will be safely stored and disposed of. Implementation of these measures will reduce the likelihood of potentially harmful pollutants to be released into the marine environment, thereby reducing the likelihood of pollution impacts on potentially sensitive migratory fish species. The potential for changes in water and sediment quality due to accidental pollution and the likely significant effects on fish and shellfish receptors are therefore not considered any further in the assessment below.

The magnitude of changes in water and sediment quality resulting from the release of sediment-bound contaminants and any effects on fish and shellfish receptors have been assessed in Table 13.18, based on the methodology outlined in Section 13.2.5.

Sensitivity of receptors

For many fish and shellfish species direct data on the effects of sediment-bound contaminants released into the water column are limited. Bivalve molluscs, including blue mussels and razor clams, are known to bioaccumulate contaminants including hydrocarbons, metals and Polychlorinated Biphenyls (PCBs). Other known effects in bivalves include the development of tumours, a reduction in growth rates, fitness and life expectancies, and contaminant induced mortality, with embryonic and larval stages often found to be the most vulnerable to toxic effects (Hill et al., 2024; Tillin et al., 2023; Tyler-Walters, 2008).

Ingestion and storage of harmful compounds in body tissues have also been observed for fish and elasmobranch species (e.g., Alves et al., 2022; van der Oost et al., 2003). Other reported effects of environmental contaminants in fish include structural and functional changes in sensory organs and associated changes in foraging behaviour and feeding and growth rates (e.g., Kasumyan, 2000). Direct damage of body tissues such as gills, kidneys and liver have also been observed, which in turn may alter buoyancy behaviour, osmoregulation, and respiration, growth and survival rates (e.g., Khoshnood, 2017; Wang et al., 2013). As for bivalves, current evidence indicates that fishes are most sensitive to toxic effects during their early development stages (i.e., embryonic and larval stages) (Khoshnood, 2017), while elasmobranchs are highly susceptible to accumulate pollutants throughout their life given their often long life span and higher trophic position (Alves et al., 2022).

The likelihood and severity of toxic effects strongly depends on the concentrations of contaminants within the water column, the type of substance encountered, and the duration of exposure. For the purpose of this assessment, a pre-cautionary approach has been taken, and the tolerance of all fish and shellfish VERs to the release of contaminated sediments has been rated as low to very low, acknowledging that some species will be more tolerant than others. Recoverability has been assessed as medium to low, which takes account of the potential of adverse effects on reproductive rates and early life stages.

Based on the low to very low tolerance and medium to low recoverability, and taking into consideration their regional, national and international importance, the sensitivity of all fish and shellfish VERs to the impact is rated as medium.

Magnitude of impact

A full assessment of sediment bound contaminants within the array area and ECC and the potential impacts to water quality from the releases of contaminated sediments is presented in the Marine Water and Sediment Quality Chapter. This assessment has adopted the thresholds outlined in ‘Guidelines for The Assessment of Dredge Material for Disposal in Irish Waters’ (Marine Institute, 2006; 2019) (hereafter referred to as the Irish Action Levels) to evaluate the contamination levels recorded within seabed sediments sampled within the offshore development area.

The site-specific contaminants sampling indicate that levels of sediment-bound contaminants are low in both the array area and ECC. None of the samples taken in the array area exceeded the Irish Lower Action Levels. In the ECC, the Lower Irish Action Levels were exceeded for cadmium in two samples and for zinc in one sample. Levels of Polycyclic Aromatic Hydrocarbon (PAH) and Total Hydrocarbon (THC) were below the Irish Lower Action Levels for all sampling sites.

Likewise, levels of PCBs and organochlorine pesticides (Dibutyl Tin and Tributyl Tin) were below the Irish Sediment Quality Lower Level (Marine Water and Sediment Quality chapter).

Table 13.18 Determination of impact magnitude of reduction in water and sediment quality

Criteria	Impact magnitude
Extent	• As outlined previously, the majority of sediments re-suspended during construction activities would be dispersed and deposited in the immediate vicinity of the works within the near-field and adjacent far-field of the study area, with locations beyond the tidal excursion distance unlikely to experience any measurable change in SSCs from background levels. Sediment bound contaminants are likely to quickly dissipate due to settling and wider dispersion by the prevailing tidal currents.
Duration	• The impact would be restricted to the construction phase of the proposed development and would therefore be short-term (one to seven years), although works in any given discrete location within the proposed development area would be temporary (less than one year). Sediment plumes are expected to quickly dissipate after cessation of individual construction activities due to settling and wider dispersion with concentrations reducing within a couple of tidal cycles to background levels. In addition, construction activities are largely expected to be carried out on a sequential basis with minimal opportunity for successive periods of sediment disturbance to develop overlapping sediments plumes.
Frequency	• The impact would occur frequently in discrete areas throughout the construction phase of the development.
Consequence	• Sediment sampling within the array area and ECC showed low contaminant levels in surficial sediments, with only the lower Irish Action Levels exceeded for cadmium (two sites) and zinc (one site) in the ECC. Sediment-bound contaminants are likely to be rapidly diluted by tidal currents, and increased bio-availability that could potentially result in adverse eco-toxicological effects to fish and shellfish and their prey is therefore not expected. In addition, under normal circumstances, very small concentrations of contaminants enter the dissolved phase, with the majority adhering to sediment particles when temporarily entering suspension in the water column. Partition coefficients may be applied to estimate the concentration of the contaminants entering the dissolved phase, which will result in a reduction of several orders of magnitude than the concentrations associated with suspended sediments. As such, it is considered highly unlikely that the Maximum Allowable Concentration Environmental Quality Standards threshold, as prescribed by the Irish Action Levels, will be exceeded for any of the substances as a result of disturbing sediments during the construction phase (Marine Water and Sediment Quality Chapter). • Given the fates of the plumes, the low concentrations of sediment-bound contaminants, and the very low likelihood of increased bio-availability of contaminants in the water column, the impact is not considered to result in any discernible changes to fish and shellfish receptors from baseline conditions. The magnitude of this impact has therefore been assessed as negligible.

In summary, the potential release of very low levels of sediment-bound contaminants during construction activities is expected to be localised within the near-field and adjacent far-field. Furthermore, these changes are expected to be temporary and intermittent with effects on fish and shellfish receptors assessed as being not discernible from baseline conditions. The magnitude of this impact has therefore been assessed as negligible.

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the magnitude of the impact is predicted to be negligible. The medium sensitivity and negligible magnitude of the impact on fish and shellfish receptors would result in a not significant effect, which is not significant in EIA terms.

13.5.2.4 Impact 4: Introduction of underwater noise and vibration leading to mortality, injury, TTS and/or behavioural effects during construction

Several activities during the construction phase have the potential to introduce underwater sounds and vibration that can adversely affect fish, marine turtles and shellfish receptors. Likely significant effects on sensitive receptors range from behavioural changes to physiological responses and physical injury and mortality. The following sections provide an overview of underwater noise and hearing in in fish and shellfish receptors. This is followed by the impact assessment for a range of likely effects that may arise from underwater sounds generated during construction activities. A detailed description of the characteristics of underwater sounds is included in the Underwater Noise Modelling Report.

Potential noise sources

During construction, the following noise producing activities have the potential to affect fish and shellfish receptors:

- Impact piling or drilling during the installation of WTG and OSP foundations
- Unexploded ordnance (UXO) clearance
- General construction noise from vessels and marine works such as cable laying, dredging, drilling and rock placement; and
- Geophysical and geotechnical pre-construction surveys.

The largest impact ranges would result from pile driving of foundations (i.e., impact piling of monopiles or pin piles in the array area). These activities would generate impulse sounds, which are characterised by high acoustic energy levels with a rapid rise time followed by a rapid decay (Popper and Hawkins, 2019). Impulsive sounds would also be created during the controlled explosion of UXO, though any detonation would represent a short-term (i.e., seconds) increase in underwater noise. General construction noise arising from vessel movements, dredging and seabed preparation works would generate low levels of continuous sounds throughout the construction phase. In addition, non-impulse sounds would also be generated during geophysical and geotechnical surveys that would take place during the construction phase.

To inform the assessment of potential impacts associated with underwater noise, project-specific predictive underwater noise modelling has been undertaken. A detailed description of the noise modelling including input data, results and uncertainties is provided in the Underwater Noise Modelling Report.

Table 13.19 below provides the design scenarios applied by the modelling for the piling of foundations along with the greatest spatial and temporal extents of the impact, which have been defined as follows:

- The greatest spatial extent of the impact equates to the greatest area to be affected by subsea noise during piling operations. In the context of the proposed piling for the proposed development, the largest spatial extent of noise emissions from piling in the array area would result from the installation of one monopile foundation in a 24-hour period
- The greatest temporal extent of the impact represents the longest duration of the impact and would result from the sequential installation of two pin piles in a 24-hour period. In addition, the piling of jacket foundations (Project Option 2) would result in a larger number of active piling days compared to the piling of monopile foundations.

It is important to note that the maximum hammer energies assumed in the design scenarios are likely to be highly precautionary and that in fact for many piling events, a lesser hammer energy will be required to complete the pile installation. This is because the maximum energy needed at each foundation location will depend on the specific ground conditions, with the maximum hammer energy considered in the modelling being based on the location that would require the largest hammer energies during piling. As such, the hammer energies listed in Table 13.19 represent the upper limit of the equipment, rather than the likely energy that will be required to install any given foundation.

The underwater noise modelling also provides potential noise impact ranges from other activities (i.e., UXO clearance and non-impulse sounds generated during construction activities), with the details of the modelling scenarios presented in the Underwater Noise Modelling Report.

Table 13.19 Impact piling scenarios for the installation of foundations within the array area

Piling scenario parameter	Monopiles	Jacket foundations with pin piles
Installation approach	Installation of one monopile foundation in a 24-hour period.	Installation of two pin piles in a 24-hour period.
Pile diameter	12.5m diameter pile	6m diameter piles
Maximum hammer energy	5,500kJ	3,000kJ

Piling scenario parameter	Monopiles	Jacket foundations with pin piles
Number of piles	51 (49 WTG monopile foundations and two monopiles for OSP foundation)	144 (140 pin piles for 35 WTG foundations and four pin piles for OSP jacket foundation)
Piling duration (including soft-start and ramp up procedure)	6 hours 5 mins per pile	6 hours 40 mins for two pin piles
Approximate number of active piling days	51	72
Expected piling period	9 months	9 months

Functional hearing groups

Fish and shellfish species sense underwater noise by detecting either the acoustic pressure or the particle motion element of a sound field. Acoustic pressure is the stress (or energy) level imposed on an individual through the sound and is measured in terms of force per unit area, typically either in N/m^2 or Pascal (Pa). In contrast, particle motion describes the back-and forth movement of water, substrate or other media as a sound wave passes; it contains information on the directionality of the sound wave and can be measured as the displacement (m), velocity (m/s), or acceleration (m/s^2) of particles in the sound field (Popper et al., 2014).

All fish species can sense particle motion, while only some groups can also detect sound pressure. Particle motion is primarily detected by fish via sensory organs within the inner ear called the otolith organs. These contain numerous mechanosensory hair cells that are in close contact with a dense calcium-carbonate structure, the otolith. Mechanical energy such as particle motion leads to differential motion between the otolith and the sensory hairs cells, resulting in the deformation of the hair cells and the subsequent release of neurotransmitters, which initiates the transmission of the sound signal to the brain (Popper and Hawkins, 2019; Putland et al., 2019). A secondary means by which fish can detect particle motion is the lateral line (Popper and Hawkins, 2019). Lateral lines run along the body and are comprised of sensory epithelial cells that can detect vibration and pressure changes over short ranges. Lateral lines are known to be used to detect prey, and for predator avoidance in the near field (Higgs and Radford, 2016).

The ability of fish to utilize sound pressure in hearing depends on several factors, with the key factors being:

- Presence and size of a swim bladder or other gas-filled cavities. Pressure waves impinging upon a fish cause gas-filled chambers, such as the swim bladder, to oscillate, which allows the pressure component of the sound field to be converted into particle motion, which can then be detected by the inner ear (Higgs et al., 2003; Popper and Hawkins, 2019); and

- Mechanical coupling of the swim bladder to the ear, present in some species, such as herring, where the sound pressure energy is transmitted directly from the swim bladder to the inner ear (Popper and Hawkins, 2019).

The sensitivity of fishes to sounds is strongly dependent upon the morphology of their auditory structures, which determines the range of frequencies (or bandwidth) over which a species is able to detect sound and the lowest sound level that they can perceive (hearing threshold). For example, fish species in which hearing is enhanced through the presence of a swim bladder are more sensitive to underwater noise than species without a swim bladder owing to their wider hearing bandwidths and lower hearing thresholds. Mechanical links between the swim bladder and the sensory organs in the inner ear allow sound signals to be transmitted without attenuation, further increasing the sensitivity to noise (Popper and Hawkins, 2019).

For the impact assessment, the fish and elasmobranch VERs were grouped based on their sound detection mechanism and auditory capabilities (Table 13.20), using the hearing groups recommended by Popper et al. (2014). It is important to note that there are differences in impact thresholds for the different hearing groups, with the exception of Groups 3 and 4 (see Table 13.21). It is on this basis, that Groups 3 and 4 are assessed together, although additional sensitivity scores have been assigned to Group 4 receptors where appropriate.

Eggs and larvae are considered separately in the assessment (as recommended by Popper et al., 2014) due to their reduced mobility and small size, and the general lack of peer reviewed literature on the responses of eggs and larvae to man-made underwater noise sources.

There are limited data on the hearing abilities of marine turtles, their uses of sound and their sensitivity to sound exposure. Examinations of green and loggerhead sea turtles (Lenhardt et al., 1985; Wever, 1978) revealed marine turtles to possess a reptilian ear with underwater adaptations, with the retention of air in the middle ear suggesting the ability to detect sound pressure. The current standing in the scientific community is that fish hearing as opposed to mammalian hearing is the preferred model for marine turtles until more data becomes available (Popper et al., 2014).

Table 13.20 Hearing categories of fish receptors (Popper et al., 2014; Popper and Hawkins, 2019)

Category	Fish receptors relevant to the proposed development
• Group 1: Fishes lacking swim bladders or other gas filled body cavities. These species are sensitive only to sound particle motion within a narrow band of frequencies. Some barotrauma may occur from the exposure to sound pressure.	• Plaice, lemon sole, common sole, common dab, American plaice, witch flounder, Atlantic mackerel, horse mackerel, sandeel, river lamprey, sea lamprey, elasmobranchs (thornback ray, blonde ray, spotted ray, cuckoo ray, small-eyed ray, tope, spiny dogfish, starry smooth-hound, nursehound, small-spotted catshark and basking shark).
• Group 2: Fishes with a swim bladder or other gas filled body cavities that do not appear to play a role in hearing. Hearing in these species only involves particle motion within a narrow band of frequencies. Some barotrauma may occur from the exposure to sound pressure.	• Atlantic salmon, brown/sea trout.
• Group 3: Fishes with swim bladders that are close, but not intimately connected to the ear. These fishes can detect both particle motion and sound pressure and show a more extended frequency range than groups 1 or 2, extending up to about 500Hz. These species are susceptible to barotrauma.	• Atlantic cod, whiting, European eel*, haddock, anglerfish*.
• Group 4: Fishes that have special structures mechanically linking the swim bladder to the ear. These fishes are sensitive primarily to sound pressure, although they also detect particle motion. They have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in groups 1, 2, or 3. These species are susceptible to barotrauma.	• Herring, sprat, twaite shad.
• Marine turtles	• Leatherback turtle, loggerhead turtle, Kemp's Ridley turtle, hawksbill turtle, green turtle.
• Eggs and larvae	• All fish and shellfish species.

(*denotes uncertainty or lack of current knowledge with regard to the potential role of the swim bladder in hearing).

Likely significant effects and noise impact thresholds

The range of likely significant effects from intense sound sources, such as pile driving and explosions, includes immediate death, permanent or temporary tissue damage, temporary shifts in hearing, and behavioural changes and masking effects (Popper et al., 2014). Tissue damage can result in eventual death or may make the fish less fit until healing occurs, resulting in lower survival rates. Hearing loss can also lower fitness until hearing recovers.

The extent to which underwater sound might cause an adverse environmental impact in a particular fish species is dependent upon the level of sound pressure or particle motion, its frequency, duration and/or repetition (Hastings and Popper, 2005). In general, physical injuries as a result of underwater noise are either related to a sudden, large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor over a period of time. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration. However, when considering injury occurring due to the energy of an exposure, the time of the exposure becomes important.

To assess the significance of effects from underwater sounds on fish, shellfish and marine turtle receptors, impacts can be grouped into the following categories (Popper et al., 2014):

- Mortality and potential mortal injury
  - Exposure to sound may result in instantaneous or delayed mortality. The potential for mortality or mortal injury is likely to only occur in extreme proximity to intense sounds, such as those emitted during percussive impact piling. The risk of mortality or mortal injury occurring during piling will be reduced by use of soft-start techniques at the start of the piling sequence. This means that fish in close proximity to piling operations will move outside of the impact range before noise levels reach a level likely to cause irreversible injury.
- Recoverable injury
  - Recoverable injury is a survivable injury with full recovery occurring after exposure, although decreased fitness during the recovery period may result in increased susceptibility to predation or disease (Popper et al., 2014). The potential for recoverable injury during piling operations is likely to only occur in extreme proximity to the pile, although the risk of this occurring will be reduced by use of soft-start techniques at the start of the piling sequence. This means that fish in close proximity to piling operations will move outside of the impact range before noise levels reach a level likely to cause recoverable injury.
- Temporary threshold shift (TTS)
  - TTS is a temporary reduction in hearing sensitivity caused by exposure to intense sound or sounds of long duration (e.g., tens of minutes to hours). TTS has been demonstrated in some fishes, resulting from the loss or damage of sensory hair cells of the inner ear and/or damage to auditory nerves. However, sensory hair cells are constantly added to fishes and are replaced when damaged, and therefore the extent of TTS is of variable duration and magnitude. Normal hearing ability returns following cessation of the noise causing TTS, though this period is variable between species, lasting between a few hours to several days. When experiencing TTS, fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment (Popper and Hawkins, 2019).
- Behavioural effects
  - Behavioural effects as a result of construction related underwater noise include a wide variety of responses including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column (e.g., Hawkins et al., 2014). Depending on the intensity, timing and duration of exposure there is the potential for some of these responses to lead to significant effects at an individual level (e.g., reduced fitness, increased susceptibility to predation) or at a population level (e.g., interference with foraging, avoidance or delayed migration to key spawning grounds) (e.g., Popper and Hawkins, 2019). Some behavioural responses may only be short-term with no wider effects for the individual or population, particularly once acclimatisation to the sound has taken place (Popper and Hawkins, 2019). There is also evidence that behavioural responses can vary depending on the activity in which the receptors are engaged during sound emission (Skaret et al., 2005). For example, Wardle et al. (2001) have shown that the interaction between hearing and vision can alter the response to a noise source, with fish responses to a seismic airgun being greater when the airgun was visible. Even when disturbed by a noise source, fish rapidly returned to the swimming track they were on prior to the noise source within seconds or minutes following exposure (Wardle et al., 2001). As such, the context in which a fish is exposed to underwater noise is as important if not more so than the received sound level.

Quantitative noise thresholds for the onset of mortality, recoverable injury and TTS in fish have been recommended by Popper et al. (2014) for a range of noise sources. Table 13.21 lists the respective thresholds for sounds emitted during impact piling; the corresponding thresholds for continuous noise sources (e.g. vessel noise) and sounds from explosions are listed in Table 2.5 and Table 2.6 of the Underwater Noise Modelling Report. These thresholds represent current best practice sound exposure criteria for fish and have consequently been applied in the impact assessment.

Popper et al. (2014) present impact thresholds for pile driving as both single strike, unweighted peak Sound Pressure Levels (SPL_{peak}) and cumulative unweighted Sound Exposure Levels (SEL_{cum}). SPL_{peak} represents the maximum sound energy level of individual impulse sounds measured as differential pressure from positive to zero. By contrast, SEL_{cum} is a measure of the accumulated sound energy an animal is exposed to over an exposure period. It takes account of repeated impulse sounds such as those emitted during pile driving (Popper et al., 2014). These dual criteria (SPL_{peak} and SEL_{cum}) are commonly used to assess the risk of mortality and injury to marine receptors to multiple impulsive sounds. For single impulse sound events, such as triggered explosions during the clearance of UXO, Popper et al. (2014) recommend the use of SPL_{peak} thresholds, while impact thresholds for continuous sounds (e.g., from shipping) are presented as root-mean-square sound pressure levels (SPL_{rms}) measured over a specific time interval.

It is important to note that all impact thresholds in the Popper et al. (2014) guidelines are based on received sound pressure levels. However, as discussed previously, many species of fish and marine invertebrates detect particle motion rather than acoustic pressure (e.g., Popper and Hawkins, 2019). Research into the effects of particle motion on fish and shellfish species is scarce, with no criteria for assessment currently available. Research on particle motion is continuing, with recent publications calling for updated criteria and guidelines on how to assess the risk of effects from changes in particle motion. In the absence of this, the Popper et al. (2014) guidance is still recommended as the most suitable reference source for assessing impacts of underwater noise including particle motion on fish and marine invertebrates (Popper and Hawkins, 2019). In this respect, it should also be noted that particle motion dominates the acoustic information within the area close to the sound source, while at larger distances from the sound source the majority of the acoustic information is dominated by the propagating pressure wave (Radford et al., 2012). This indicates that particle motion effects are contained within the sound pressure impact ranges, and therefore the lack of quantitative thresholds for particle motion is not expected to alter the conclusions of the assessment.

There are also no quantitative thresholds advised to be used to assess behavioural impacts; however, Popper et al. (2014) provide qualitative behavioural criteria for fish from a range of sources. These categorise the risks of effects in relative terms as ‘high’, ‘moderate’ or ‘low’ at three distances from the sound source: near (10s of metres), intermediate (100s of metres), and far (1000s of metres), respectively. Given the current absence of quantitative thresholds to assess behavioural effects, a separate qualitative assessment has been undertaken below.

There is also a lack of data on the effects of pile driving on marine turtles; however, Popper et al. (2014) proposes the adoption of underwater noise thresholds for Group 2 fish as a precautionary approach. Due to their rigid external anatomy, it is considered likely that marine turtles are highly protected from impulsive sound effects, such as those from pile driving.

Information on the impact of underwater noise on marine invertebrates is also scarce, and no attempt has been made to set exposure criteria (Hawkins and Popper, 2014). Therefore, the impact assessment has been based on a review of peer-reviewed literature on the current understanding of the likely significant effects of underwater noise on shellfish species. Studies have shown sensitivity of marine invertebrates to substrate borne vibration (Roberts et al., 2015). It is generally their hairs that provide the sensitivity, although these animals also have other sensory systems that could be capable of detecting vibration. It has also been reported that slow, rolling interface waves that move out from a source like a pile driver can produce large particle motion amplitudes travelling considerable distances (Hawkins and Popper, 2016), with implications for demersal and sediment dwelling shellfish (e.g., *Nephrops*), particularly those located in close proximity to piling operations.

Table 13.21 Impact thresholds for pile driving (from Popper et al., 2014)

Hearing group	Mortality and potential mortal injury	Recoverable injury	TTS	Behavioural changes
Group 1	> 219dB SELcum or > 213dB SPLpeak	> 216dB SELcum or > 213dB SPLpeak	>> 186dB SELcum	Near - High Intermediate - Moderate Far - Low
Group 2	210dB SELcum or > 207dB SPLpeak	203dB SELcum or > 207dB SPLpeak	> 186dB SELcum	Near - High Intermediate - Moderate Far - Low
Groups 3 and 4	207dB SELcum or > 207dB SPLpeak	203dB SELcum or > 207dB SPLpeak	186dB SELcum	Near - High Intermediate - High Far - Moderate
Marine turtles	210dB SELcum or > 207dB SPLpeak	Near - High Intermediate - Low Far - Low	Near - High Intermediate - Low Far - Low	Near - High Intermediate - Moderate Far - Low
Eggs and Larvae	> 210dB SELcum or > 207dB SPLpeak	Near - Moderate Intermediate - Low Far - Low	Near - Moderate Intermediate - Low Far - Low	Near - Moderate Intermediate - Low Far - Low

Notes: Sound levels are usually expressed in decibel (dB) with respect to a reference value. For underwater sounds, the reference value is 1 micropascal (μPa). SPL_{peak} values are presented as dB re 1 μPa; SEL_{cum} values are represented as dB re 1μPa^2.

Predicted impact ranges

To determine the potential spatial extent of underwater noise for the different effect categories listed in Table 13.21 above, noise modelling has been undertaken for four representative locations (NW, NE, SW and SE) in the array area. To calculate received sound levels, soft-start and ramp-up procedures along with the total duration of piling and hammer strike rates were considered (full details of the modelling approach are given in the Underwater Noise Modelling Report).

For fish receptors, the modelling provides impact ranges for both fleeing receptors (with the receptors assumed to flee from the noise source at a consistent rate of $1.5ms^{-1}$) and stationary receptors to account for spawning activity of less mobile demersal spawners and for non-mobile receptors such as eggs and larvae. Of the fish receptors included in the impact assessment, only herring and sandeel are considered a stationary receptor, on the basis that they exhibit strong substrate dependence and also have spawning grounds within the study area.

The results of the noise modelling are presented in the Underwater Noise Modelling Report and referred to as appropriate in the following assessments. Table 13.22 below shows the results of the modelled maximum impact ranges for mortality and potential mortal injury, recoverable injury and TTS from the installation of monopile and multileg jacket foundations. The modelled noise contours for the respective impact onset thresholds (i.e., SEL_{cum} for 186dB, 203dB, 207dB, 210dB, 213dB, 216dB and 219dB) are shown for stationary receptors in Figure 13.13 and Figure 13.14 and for fleeing receptors in Figure 13.15 and Figure 13.16. Note that modelled impact ranges less than 100m from the piling source are not shown in the figures.

Table 13.22 Modelled maximum impact ranges for fleeing and stationary receptors from the piling of foundations within the array area

Criteria	Noise Level SPL re 1μPa SEL re 1μPa2	Monopile Foundation (piling of a single monopile in 24 hours)				Multileg Foundation (sequential piling of 2 pin piles in 24 hours)			
		NW	NE	SW	SE	NW	NE	SW	SE
Mortality and Potential Mortal Injury									
SPLpeak	213dB	130m	140m	130m	140m	110m	110m	110m	120m
SPLpeak	207dB	330m	360m	350m	360m	280m	300m	300m	310m
SELcum (static)	219dB	980m	1.1km	1.1km	1.1km	730m	800m	780m	800m
SELcum (fleeing)	219dB	<100m	<100m	< 100m	<100m	<100m	<100m	<100m	<100m
SELcum (static)	210dB	3.7km	4.1km	4.0km	4.2km	2.8km	3.1km	3.0km	3.2km
SELcum (fleeing)	210dB	<100m	<100m	<100m	<100m	<100m	<100m	<100m	<100m
SELcum (static)	207dB	5.6km	6.4km	6.2km	6.5km	4.3km	4.9km	4.7km	5.0km
SELcum (fleeing)	207dB	<100m	<100m	<100m	<100m	<100m	<100m	<100m	<100m
Recoverable Injury									
SPLpeak	213dB	130m	140m	130m	140m	110m	110m	110m	120m
SPLpeak	207dB	330m	360m	350m	360m	280m	300m	300m	310m
SELcum (static)	216dB	1.5km	1.7km	1.7km	1.7km	1.2km	1.3km	1.2km	1.3km
SELcum (fleeing)	216dB	<100m	<100m	<100m	<100m	<100m	<100m	<100m	<100m
SELcum (static)	203dB	9.5km	11km	11km	11km	7.4km	8.6km	8.2km	8.7km
SELcum (fleeing)	203dB	<100m	<100m	<100m	<100m	<100m	<100m	<100m	<100m
TTS									
SELcum (static)	186dB	59km	69km	65km	69km	51km	59km	56km	59km
SELcum (fleeing)	186dB	41km	51km	47km	50km	32km	40km	37km	40km

The following sections present the assessment of likely significant effects on noise sensitive receptors for the piling of foundations, UXO clearance and other noise generating activities during the construction phase. Consideration is given to the sensitivity of the VERs within each hearing group listed in Table 13.20, before characterising the scale and magnitude of the impact and providing the overall conclusion with regard to the predicted significance of effects. Of those considered, the noise source most important for the assessment is impact piling due to the noise levels generated and the duration it will be present. As such, likely significant effects related to impact piling have been the primary focus of the impact assessment.

Likely significant effects from impact piling

Sensitivity of receptors

Table 13.23 provides the assessment of sensitivity of the fish and shellfish VERs to impact piling for each hearing group and response category (i.e., stationary vs fleeing receptors). Consideration is given to all likely significant effects (i.e., mortality and potential mortal injury, recoverable injury, TTS and behavioural changes) to derive sensitivity scores per assessed hearing group.

Unless otherwise stated, the sensitivity of eggs and larvae has been assessed independently from the sensitivity of their respective juvenile and adult life stages.

Specific embedded mitigation measures relevant to the impact include soft-start and ramp-up procedures (see Table 13.11).

Table 13.23 Determination of sensitivity of fish and shellfish receptors to underwater noise from impact piling

Receptor	Sensitivity
Group 1: Sandeel	Group 1 VERs including sandeel lack a swim bladder and are therefore considered less sensitive to underwater noise than other species. However, as discussed previously, sandeel are highly substrate dependent given their burrowing nature and demersal spawning behaviour, and therefore they may have limited capacity to flee the area during piling operations (low adaptability). Sandeel are thought to be affected by vibration through the seabed, particularly when buried in the seabed during hibernation. Therefore, they may experience some mortality or recoverable injury in addition to TTS and behavioural responses. Consequently, sandeel have been assessed as having a low tolerance to the impact. No published data are available on TTS in fish from pile driving or other noise generating activities (Popper et al., 2014). However, it is suggested that TTS in fishes may decrease the receptor's fitness by impairing its ability to communicate, detect predators or prey and/or assess its environment (Popper et al., 2014). Existing studies suggest that fish affected by TTS recovered to normal hearing levels within a few hours to several days after noise exposure (Popper et al., 2014; Popper and Hawkins, 2019). Any potential behavioural responses are also expected to be temporary (high recoverability), with individuals anticipated to resume normal behaviours shortly after noise disturbance has ceased (Hassel et al., 2004). Recovery at the population level from any potential mortality or potential mortal injury through barotrauma is expected to occur in the short-term through recruitment in subsequent years (medium recoverability). Based on their low adaptability, low tolerance and medium (mortality and mortal injury) to high (recoverable injury, TTS, behavioural changes) recoverability and taking into consideration their regional importance, the sensitivity of sandeel to underwater noise emitted during impact piling is rated as medium.
Group 1: Plaice, lemon sole, common sole, common dab, American plaice, witch flounder, Atlantic mackerel, horse mackerel, river lamprey, sea lamprey, all elasmobranch VERs	Like sandeel, the remaining Group 1 VERs lack a swim bladder or other air-filled cavities and are therefore considered less sensitive to underwater noise than other species. In addition, these receptors are mobile and would be able to vacate the area during soft-start procedures before potential mortal injuries could occur, though there might be some temporary physiological effects in addition to behavioural responses. Therefore, the receptors have been assessed as having a medium adaptability and medium to high tolerance to the impact. As discussed previously, information on the consequences of TTS in fishes is limited; however, current evidence suggests that effects would likely to be temporary (high recoverability), with affected individuals anticipated to resume normal behaviours or recolonise areas shortly after piling has ceased (high recoverability). Taking into consideration the regional to international importance of the receptors together with their medium adaptability, medium to high tolerance, and high recoverability, the sensitivity of fleeing Group 1 VERs to underwater noise emitted during impact piling is deemed to be **low**.
Group 2: Atlantic salmon, sea trout	Group 2 species identified as of relevance to the proposed development are Atlantic salmon and sea trout. Both species are considered to primarily sense underwater noise through particle motion despite the presence of a swim bladder (Popper et al., 2014). Evidence suggests that the presence of a swim bladder increases the likelihood of injury to body tissues as sound-induced volume changes to the swim bladder can damage nearby organs (Popper et al., 2014). As such, Group 2 receptors are generally considered more susceptible to recoverable and potential mortal injuries in comparison to Group 1 receptors (Popper and Hawkins, 2019). However, given their mobile nature, Atlantic salmon and sea trout would be able to adapt their behaviour and move away from the piling location during soft-start and ramp-up procedures prior to the use of the highest hammer energies, which will reduce the number of individuals at risk of mortal or recoverable injuries. Therefore, like fleeing Group 1 receptors, Atlantic salmon and sea trout are considered to have a medium adaptability to the impact. Given their general higher susceptibility to pressure-related injuries, the tolerance of these receptors to the this aspect of the impact is deemed to be medium.. TTS and behavioural responses might occur, with any TTS likely to be temporary (Popper et al., 2014).Few studies have investigated behavioural reactions of sea trout and Atlantic salmon to piling noise, providing

Receptor	Sensitivity
	unconclusive results with some studies showing a lack of behavioural responses and others reporting changes in the abundance and distribution of Atlantic salmon due to avoidance reactions (reviewed by Gillson et al., 2022). There is, however, evidence that behavioural responses in fish as a result of underwater noise might be reduced when fish are engaged in life history critical activities such as spawning and feeding (e.g. Doksaeter et al., 2009; Pena et al., 2013; Skaret et al., 2005). While a similar damping of behavioural reactions might occur in sea trout and Atlantic salmon during migration, the implications of experiencing temporary avoidance or stress responses remain not fully understood, and it cannot be excluded that such responses delay migration in the short-term. Based on this, the receptors are assessed as having a medium tolerance to TTS and behavioural changes. Recovery from any population level effects (e.g., through barotrauma and/or a potential reduction in reproductive success through delayed migration) is assessed to occur within the short-term following recruitment in subsequent years after the impact has ceased (medium recoverability). Taking into consideration the regional importance of sea trout together with their medium adaptability, medium tolerance, and medium recoverability, the sensitivity of sea trout to underwater noise from impact piling is deemed to be low. Based on the national and international importance of Atlantic salmon, the sensitivity of this receptor is rated as **medium**.
Group 3 and 4: Cod, whiting, European eel, haddock, anglerfish, sprat, twaite shad	Group 3 and Group 4 receptors have a swim bladder, which in Group 4 species is directly involved in hearing through its connection to the inner ear. These species are considered to be the most sensitive to underwater noise, with direct detection of sound pressure, rather than just particle motion. The presence of a swim bladder makes them highly susceptible to tissue damage, and given their good hearing ability, they are also at higher risk to experience physiological and behavioural effects (Popper et al., 2014; Popper and Hawkins, 2019). However, all pelagic and demersal Group 3 and Group 4 VERs (with the exception of herring, see below) are mobile and not dependent on specific sedimentary areas for spawning. Moreover, eel spawn in the Sargasso Sea, while twaite shad spawn in freshwater. Consequently, all receptors are considered able to move away from irreversible effects during soft-start procedures, thereby reducing the likelihood of mortal or sublethal injuries. Therefore, like fleeing Group 1 and 2 receptors, fleeing Group 3 and 4 receptors are considered to have a medium adaptability to the impact. Given their higher sensitivity to underwater sounds including pressure-related injuries, the tolerance of the receptors to mortality and potential mortal injury is deemed to be medium to low. Recovery at the population level from any potential mortality or potential mortal injury through barotrauma is expected to occur in the short-term through recruitment in subsequent years (medium recoverability). Given their good hearing ability, Group 3 and Group 4 receptors are also at higher risk of experiencing physiological (i.e., TTS) and behavioural effects. As discussed previously, no published data are available on TTS in fish from pile driving or other noise generating activities (Popper et al., 2014). Furthermore, the possible consequences of TTS are unknown; however, it is suggested that TTS in fishes may decrease the receptor's fitness by impairing its ability to communicate, detect predators or prey and/or assess its environment (Popper et al., 2014). Any TTS and behavioural responses would likely be temporary (high recoverability), with affected individuals anticipated to resume normal behaviours or recolonise areas shortly after piling has ceased. Effects of TTS would also be temporary, with existing studies suggesting that fish affected by TTS recovered to normal hearing levels within a few hours to several days after noise exposure (Popper et al., 2014; Popper and Hawkins, 2019). Taking into consideration the international (European eel), national (twaite shad) and regional (remaining receptors) importance of the receptors together with their medium adaptability, medium to low tolerance, and medium recoverability, the sensitivity of the Group 3 and Group 4 VERs to underwater noise from impact piling is deemed to be **medium**.
Group 4: Herring	Herring are considered highly sensitive to the sound pressure component of underwater noise owing to the presence of a swim bladder and two pairs of air bubbles in the inner air that aid sound detection (Mann et al., 2005; Popper et al., 2022). The presence of these air-filled chambers increases their hearing sensitivities and makes them also more prone to suffer from pressure-related injuries (Popper et al., 2014). **Mortal and recoverable injury:** Herring are mobile and would be able to move away from piling noise during soft-start procedures before sound levels reach thresholds were mortal or recoverable injuries occur. However, the likelihood of herring leaving the area may be reduced when engaged in spawning activity. For the purpose of the sensitivity assessment, herring have therefore been considered to have restrictive movements with a limited capacity to leave the area during piling activities (low adaptability). Given the high susceptibility of herring to sound pressure, their tolerance to lethal or sublethal injuries has also been assessed as low. Recovery at the population level from any loss of individuals is assessed to occur within the short-term following recruitment after the impact has ceased (medium recoverability). Based on their low adaptability, low tolerance and medium recoverability and taking into consideration their regional importance, the sensitivity of herring to mortal and recoverable injuries during impact piling is deemed to be medium.

Receptor	Sensitivity
	TTS and behavioural changes: Given their good hearing ability, herring are also at higher risk of experiencing physiological (i.e., TTS) and behavioural effects. No published data are available on TTS in herring from pile driving or other noise generating activities (Popper et al., 2014). Furthermore, the possible consequences of TTS for herring and other fish species are unknown; however, it is suggested that TTS in fishes may decrease the receptor's fitness by impairing its ability to communicate, detect predators or prey and/or assess its environment (Popper et al., 2014). On a precautionary basis, it is therefore assumed that impact piling may affect the behaviour of spawning herring through TTS. With regard to behavioural changes, existing data suggest that while herring (and other clupeids) can be highly reactive to underwater noise, the type and strength of behavioural response may vary depending on the activity individuals were involved in during noise exposure. For example, studies examining the effects of seismic airguns and naval sonars showed strong response during overwintering but limited change in swimming behaviour during feeding migrations (Doksaeter et al., 2009; Pena et al., 2013). Similarly, strong vessel avoidance has been observed in overwintering herring (Vabø et al., 2002), while no avoidance behaviour was observed in spawning herring (Skaret et al., 2005). Whilst there are currently no studies on TTS and behavioural changes in spawning herring during pile driving specifically, it is likely that similar damping of behavioural reactions would occur as for other stimuli. Taking the above into consideration and considering the non-lethal nature of the effects, the tolerance of spawning herring to TTS and behavioural changes is deemed to be medium. Any behavioural responses would likely be temporary (high recoverability), with affected individuals anticipated to resume normal behaviours or recolonise areas shortly after piling has ceased. Effects of TTS would also be temporary, with existing studies suggesting that fish affected by TTS recovered to normal hearing levels within a few hours to several days after noise exposure (Popper et al., 2014; Popper and Hawkins, 2019). Recovery from any population level effects (i.e., a potential reduction in reproductive success through delayed or reduced spawning activities) is assessed to occur within the short-term following recruitment in subsequent years after the impact has ceased (medium recoverability). Based on their low adaptability, medium tolerance and medium recoverability and taking into consideration their regional importance, the sensitivity of herring to TTS and behavioural changes during piling is deemed to be **low**.
Eggs and larvae	Plaice, lemon sole, common sole, mackerel, sandeel, cod, whiting, sprat, haddock, and horse mackerel all have spawning grounds within the vicinity of the proposed development. Eggs and larvae are considered organisms of concern by Popper et al. (2014), due to their reduced mobility, small size and susceptibility to damage from sound waves and vibration. Therefore, both the adaptability and the tolerance of fish eggs and larvae to underwater noise is deemed to be low. Recovery from any potential decrease in recruitment success due to mortality or injury is assessed to occur within the short term (medium recoverability). Based on this and taking into consideration to regional to international importance of the receptors, the sensitivity of eggs and larvae to underwater noise from piling is deemed to be **medium**.
Marine turtles	Studies on the effects of underwater sounds on marine turtles are lacking, but the retention of air in the middle ear of marine turtles suggests that they are able to detect sound pressure. Because of their rigid external anatomy, it has been suggested that marine turtles are highly protected from the effects of impulsive sounds (Popper et al., 2014). Moreover, marine turtles are mobile species, and on this basis are anticipated to flee from noise disturbance and are therefore assessed as fleeing receptors during soft-start procedures before potential mortal injuries could occur. Some temporary physiological effects and behavioural responses might occur, and therefore, marine turtles have been assessed as having a medium adaptability and tolerance to the impact. Any effects would likely be temporary (high recoverability), with affected individuals anticipated to resume normal behaviours or recolonise areas shortly after piling has ceased (high recoverability). The receptors are considered to be of international importance, although the study area is not considered to be of significance for marine turtles. On the basis that marine turtles do not frequent the area surrounding the proposed development, and given their medium adaptability, medium tolerance and high recoverability to the impact, the sensitivity of the receptors to underwater noise from piling is rated as **low**.
Shellfish VERs	On the basis that invertebrates such as shellfish do not possess swim bladders or other gas filled organs, it is considered that invertebrates are primarily sensitive to particle motion rather than sound pressure (e.g., Popper and Hawkins, 2018). Likely significant effects of particle motion to marine invertebrates are relatively sparsely studied, with assumed sensitivity of many species based on a limited number of studies on a small number of species (Lewandowski et al., 2016). Given that shellfish do not possess gas filled cavities, there is less potential for tissue damage to occur due to pressure changes associated with sound waves. A study by Zhang et al. (2015) suggested that severe particle motion could irreparably damage the statocysts (a fluid filled chamber containing a mass (the statolith) surrounded by sensory hair cells) of cephalopods at short range, causing hearing impairment. This was considered likely to occur as a result of pile driving, although thought to only occur at short range from the noise source.

Receptor	Sensitivity
	By contrast, investigations on lobsters have shown no mortal effects on the species (>220dB) (Payne et al., 2007). Similarly, studies of molluscs (e.g., blue mussel Mytilus edulis and periwinkles Littorina spp.) exposed to a single airgun at a distance of 0.5m have shown no effects after exposure (Kosheleva, 1992). There are few studies which investigate the effects of particle motion, however there are a number of ecological field studies which compare mortality of a range of invertebrates, including scallop, lobster and clam, at sites where seismic survey occur compared to sites where it does not. These concluded that there is no evidence of increased mortality due to exposure to seismic surveys (Harrington et al., 2010; La Bella et al.,1996; Payne et al., 2007; Parry et al., 2002). A study of the impact of wind farm construction work on lobster and crab fisheries in the area of the Westernmost Rough wind farm off the Northeast coast of the UK showed that following a closure of the area to fishing during construction catch rates on reopening were significantly higher than pre-construction. This infers that construction noise and disturbance were not sufficient to cause the abundance and distribution of lobster and crab to decrease within the windfarm area during the construction period. A study of the impact of wind farm construction work on lobster and crab fisheries in the area of the Westernmost Rough wind farm off the Northeast coast of the UK showed that following a closure of the area to fishing during construction catch rates on reopening were significantly higher than pre-construction. This infers that construction noise and disturbance were not sufficient to cause the abundance and distribution of lobster and crab to decrease within the windfarm area during the construction period (Roach et al., 2018). Dependent on the distance to the source, sensitivity to particle motion is currently considered more likely to be important for behavioural responses rather than injury (Hawkins, 2009). For example, Roberts (2015) suggested that vibroacoustic stimuli may elicit and affect anti-predator responses, such as startle response in crabs and valve closure in mussels. Such responses would effectively be distractions from routine activities such as feeding. Behavioural changes in mussels have also been observed in response to simulated pile-driving, with increased filtration rates observed in blue mussels (Spiga et al. 2016). In addition to this, Samson et al. (2014) recorded a range of behavioural responses to underwater noise in cephalopods, including inking, colour changes and startle responses. Overall, the available evidence suggests that underwater noise may cause behavioural and physiological changes in shellfish in the nearfield, while mortality or recoverable injury are unlikely to occur. On this basis, shellfish are assessed as having a moderate capacity to accommodate underwater noise during construction activities (medium tolerance). Given their generally low mobility, all shellfish species are considered to have a limited capacity to avoid the impact (low adaptability). Any potential displacement of individuals or behavioural and physiological changes are expected to be temporary, with individuals able to return to the area or resume normal behaviours shortly after piling activities have ceased (high recoverability). Taking into consideration the regional importance of the receptors together with their low adaptability, medium tolerance and high recoverability, the sensitivity of the receptors to underwater noise from piling is deemed to be **low**.

In summary, marine turtles, shellfish, fleeing Group 1 receptors and sea trout have been assessed as having a low sensitivity to underwater noise generated during impact piling. The sensitivity of the remaining VERs has been assessed as medium. The maximum sensitivity for fish and shellfish VERs for this impact is therefore medium.

Magnitude of impact: Mortality and potential mortal injury and recoverable injury

Table 13.24 provides the determination of impact magnitude for mortality and potential mortal injury, and recoverable injury from impact piling of foundations for each of the hearing groups identified in Table 13.20. The spatial extent over which lethal or recoverable injuries may occur has been determined through site-specific modelling, based on the sound pressure thresholds recommended by Popper et al. (2014) (Table 13.21).

The piling of foundations it anticipated to take place over a period of up to 9 months, which includes transit to the construction site, any clearance operations required and any potential delays. Piling itself is expected to be split into individual piling events, with each event lasting a couple of days followed by several piling-free days between each piling event. The duration of the impact would therefore be temporary (less than one year), and it would occur intermittently during the proposed piling activities.

As stated previously, whilst the potential for effects on sensitive receptors to particle motion are widely recognised, the majority of research into underwater noise has focused on the sound pressure element of noise. Consequently, no guidance to assess impacts to fish and invertebrates from particle motion have been published. Moreover, there is a distinct lack of existing (validated) modelling methodologies for particle motion. Therefore, is not considered possible at this time to provide a quantitative assessment of the potential propagation and impact ranges of particle motion during piling operations.

It is understood that high levels of particle motion are generated in the nearfield by pile driving (Hazelwood and Macey, 2016), although literature suggests that impacts from particle motion on sensitive receptors are likely to occur local to the source, with studies having demonstrated the rapid attenuation of particle motion with distance (Mueller-Blenkle et al., 2010).

Some studies have attempted to assess the spatial scales over which fish species can detect particle motion from marine developments, with a particular focus on pile driving for offshore WTG, and operational noise from WTG. A study undertaken by Sigray et al. (2022) measured particle motion levels from piling events of an offshore windfarm in the North Sea using an autonomous bespoke sensor. Zero-to-peak SPL was estimated to be 170 to 175dB re. 1µPa about 880m from a piling operation (hammer energy 800kJ). Similarly, a study by Juretzek et al. (2021) recorded particle motion levels of 192dB re. 1µPa at 750m distance for a hammer energy of 2,890kJ. A study by Thomsen et al. (2015) during the construction of an offshore wind farm in the southern North Sea recorded elevated levels of particle motion above ambient levels within 750m of piling locations, across most of the frequency spectrum, except at very low frequencies. Although it should be acknowledged that the given range of 750m is likely a result of the regulatory requirement for monitoring, and therefore is somewhat arbitrary in terms of a potential range of effect.

Table 13.24 Determination of magnitude for mortality and potential mortal injury, and recoverable injury from impact piling

Receptor	Impact magnitude
Group 1: Sandeel	Underwater noise modelling predicts that mortality and potential mortal injury to Group 1 stationary receptors (sandeel) may occur up to 1.1km from the installation of monopile foundations and up to 800m from the sequential installation of two pin-piles for jacket foundations (>219dB SEL_{cum}). Recoverable injury in Group 1 stationary receptors during the course of piling is predicted to occur up to 1.7km from the installation of monopile foundations and 1.3km from piling of multileg foundations (>216dB SEL_{cum}). Instantaneous mortality or mortal injury, or recoverable injury during piling may occur up to 140m from monopile installation and up to 120m from the installation of jacket foundations (>213dB SPL_{peak}). As discussed previously, site-specific PSA data suggest that sediments within the array area are mostly unsuitable for sandeel (Figure 13.9), and therefore the number of sandeel to be affected is likely to be low. PSA data further suggest that sub-prime and suitable sandeel habitats are located along most of the ECC and within the ZoI to the south of the array area outside of the area where sandeel might potentially experience mortal or recoverable injuries (Figures 13.12 and 13.13). Therefore, any noise impacts are also anticipated to be small in the context of the wider environment. Given the intermittent and temporary nature of the impact, the low number of individuals likely to be impacted and the very small proportion of the population this represents, any potential mortality or potential mortal injury and recoverable injury to sandeel during impact piling is considered to be undiscernible from baseline conditions, and consequently the magnitude of the impact is deemed to be **negligible**.
Group 1: Remaining VERs	Mortality and potential mortal injury, and recoverable injury to Group 1 fleeing receptors is predicted to occur <100m from the noise source (>219dB SEL_{cum} and >216dB SEL_{cum} respectively) for the installation of both monopile and multi-leg jacket foundations. All Group 1 fleeing receptors and their respective spawning and nursery grounds are distributed widely in the study area and wider Irish Sea. Moreover, all receptors are considered able to move outside of the impact range during soft-start procedures before sound levels reach a level likely to cause mortal or sublethal injuries. Based on this and considering the small area potentially affected together with the intermittent and temporary nature of the impact, any effects upon Group 1 fleeing receptors and their spawning and nursery grounds are assessed to be barely discernible from baseline conditions. Consequently, the magnitude of the impact is deemed to be **low (adverse)**.
Group 2	Mortality and potential mortal injury, and recoverable injury to Group 2 fleeing receptors is predicted to occur <100m from the noise source (201dB SEL_{cum} and 203dB SEL_{cum} respectively) for the installation of both monopile and jacket foundations.

Receptor	Impact magnitude
	Like for Group 1 fleeing receptors, there is potential for Group 2 fleeing receptors (Atlantic salmon and sea trout) to experience mortality, potential mortal injury, or recoverable injury during impact piling close to the sound source. Both receptors are mobile and would therefore be able to vacate the area during soft-start procedures before sound levels reach a level likely to cause lethal or sublethal physical injuries. Piling activities would coincide with the peak migration periods of both Atlantic salmon and sea trout (see Section 13.3.8); however, due to their migratory nature these VERs are anticipated to be transient across the study area, and therefore any exposure of these receptors to high levels of sound pressure or particle motion is anticipated to be limited and temporary. Given the mobile and transient nature of the receptors together with the temporary and intermittent nature of the impact, and the small area over which lethal and sublethal injuries would likely occur, any likely effects on Group 2 fleeing receptors are anticipated to be barely discernible from baseline conditions. Consequently, the magnitude of the impact is deemed to be **low (adverse).**
Group 4: Herring	**Spawning adults:** Underwater noise modelling predicts that mortality and potential mortal injury to stationary herring during the spawning season (main spawning September to November) may occur up to 6.5km from single monopile installation and up to 5km from the sequential installation of two pin-piles for jacket foundations (207dB SEL_{cum}). Recoverable injury to herring during the course of piling is predicted to occur up to 11km from the installation of monopile foundations and 8.7km from piling of multileg foundations (203dB SEL_{cum}). Instantaneous mortality, mortal injury, or recoverable injury during piling may occur up to 360m from monopile installation and up to 300m from the installation of jacket foundations (>207dB SPL_{peak}). On the basis of the static receptor modelling there is no overlap between the Mourne herring spawning ground and the predicted impact ranges for mortality, mortal injury and recoverable injury (Figures 13.12 and 13.13, contours 207dB SEL_{cum} and 203dB SEL_{cum}). Consequently, spawning herring are not predicted to experience mortality, potential mortal injury, or recoverable injury during the piling of foundations, and therefore, the magnitude of the impact on spawning herring over the Mourne spawning ground is deemed to be **negligible**. **Juvenile and adults:** When considered in the context of fleeing receptors, the impact ranges of mortality and potential mortal injury and recoverable injury (207dB SEL_{cum} and 203dB SEL_{cum}, respectively) reduce to <100m for both the installation of monopile and jacket foundations. Non-spawning herring are mobile and would be able to move away from the impact with the onset of soft-start procedures. Furthermore, herring and their respective nursery grounds (Figure 13.7) are distributed widely across the study area and wider western Irish Sea. Therefore, while a small number of animals might be affected by the impact, the degree of overlap between herring and the area with potential for mortality and mortal injury is predicted to be small in the context of available habitat including nursery grounds. Based on this together with the temporary nature of the impact, any effects upon non-spawning herring are considered to be barely discernible from baseline conditions, and therefore the magnitude of the impact for non-spawning herring is deemed to be **low (adverse).** **Eggs and larvae - Mortality and potential mortal injury:** For eggs and larvae, the modelled maximum impact range for mortality and potential mortal injury is 4.2km for the piling of monopile foundations and 3.2km for the installation of jacket foundations (>210dB SEL_{cum}). As for stationary herring during spawning, instantaneous mortality or mortal injury to herring eggs and larvae during piling may occur up to 360m from monopile installation and up to 300m from the installation of jacket foundations (>207dB SPL_{peak}). On the basis of the static receptor modelling there is no overlap between the Mourne herring spawning ground where eggs would be deposited and the predicted impact ranges for mortality and potential mortal injury (Figures 13.12 and 13.13, contour 210dB SEL_{cum}). Consequently, herring eggs are not predicted to experience mortality and mortal injury during the piling of foundations, and therefore, the magnitude of the impact on herring eggs is deemed to be negligible. Similarly, larval distribution data indicate that there is no overlap between areas of high herring larval abundances and the area with potential for mortality and mortal injury (Figure 13.6). Given the lack of high larval densities within the area with potential for mortality and mortal injury and considering the temporary nature of the impact, barely discernible changes to herring larval are predicted from the impact, and therefore the magnitude of the impact for herring larvae is deemed to be **low (adverse).** **Eggs and larvae - Recoverable injury:** In accordance with the Popper et al. (2014) qualitative assessment criteria, the relative risk of recoverable injury to eggs and larvae during pile driving is moderate at the near field (10s of meters) distance from the piling location and low at both intermediate (100s of meters) and far (1,000s of meters) distances from the piling operations. The Mourne herring spawning ground where eggs would be deposited is located approximately 20km to the north of the array area. Furthermore, larval distribution data indicate low herring larvae abundances within the study area. Therefore, the risk of herring eggs and larvae to experience recoverable injury during piling operations is assessed as low. Based on this and considering the temporary nature of the impact, barely discernible changes to herring eggs and larval are predicted from the impact, and therefore the magnitude of the impact for herring eggs and larvae is deemed to be **low (adverse).**
Group 3 and 4: Remaining VERs	All remaining Group 3 and Group 4 pelagic and demersal fish VERs are considered fleeing receptors on the basis that they are mobile and do not show substrate dependency. Twaite shad and European eel are both mobile, migratory species, and these receptors are therefore also considered to be fleeing receptors. Therefore, the magnitude of the impact for static Group 3 and Group 4 receptors has not been assessed except for eggs and larvae.

Receptor	Impact magnitude
	Mortality and potential mortal injury and recoverable injury to Group 3 and Group 4 fleeing receptors is predicted to occur <100m from the noise source (207dB SEL_{cum} and 203dB SEL_{cum}, respectively) for the installation of both monopile and jacket foundations. Like Group 1 and Group 2 fleeing receptors, Group 3 and 4 fleeing receptors might experience mortality and potential mortal injury or recoverable injury during impact piling close to the sound source. However, given their mobile nature, these receptors are considered able to move outside of the impact range during soft-start procedures before sound levels reach levels likely to cause irreversible or recoverable injuries. Moreover, all Group 3 and Group 4 non-migratory fish VERs and their respective spawning and nursery grounds are distributed widely in the study area and wider Irish Sea. Based on this and considering the small area potentially affected together with the intermittent and temporary nature of the impact, any effects upon Group 3 and Group 4 non-migratory fish and their spawning and nursery grounds are assessed to be barely discernible from baseline conditions. European eel and twaite shad are also considered likely to vacate the area during soft-start procedures before irreversible effects. Moreover, due to their migratory nature these VERs are anticipated to be transient across the study area, and therefore any exposure of these receptors to underwater noise is anticipated to be minimal. Given the mobile and transient nature of the receptors, the small area potentially affected and the temporary and intermittent nature of the impact, any likely significant effects on Group 3 and Group 4 migratory fish are also assessed as being barely discernible from baseline conditions. Consequently, the magnitude of the impact for all Group 3 and Group 4 fleeing receptors is deemed to be **low (adverse).**
Eggs and larvae	For eggs and larvae, the modelled maximum impact range for mortality and potential mortal injury is 4.2km for the piling of monopile foundations and 3.2km for the installation of jacket foundations (>210dB SEL_{cum}). Instantaneous mortality or mortal injury to eggs and larvae during piling may occur up to 360m from monopile installation and up to 300m from the installation of jacket foundations (>207dB SPL_{peak}). The relative risk of recoverable injury to eggs and larvae during pile driving is moderate at a near field (10s of meters) distance from the piling location, and low at both intermediate (100s of meters) distance and far (1,000s meters) distances from the piling operations (Popper et al., 2014). Spawning grounds for all spawning fish receptors are distributed widely across the study area and western Irish Sea and therefore in the context of the wider environment, any potential mortality or irreversible injury are considered to be of local scale. Moreover, while eggs and larvae would not be able to actively move away from potential injurious effects, the risk of prolonged exposure and mortality or mortal injury may be reduced as the receptors are transported away from the sound source. Based on this and considering the intermittent and temporary nature of the impact, any mortal effects on eggs and larvae as a result of impact piling are considered to be barely discernible from baseline conditions, and consequently the magnitude of the impact for these receptors is assessed as being **low (adverse).**
Marine turtles	Mortality and potential mortal injury to marine turtles is predicted to occur <100m from the noise source for the installation of both monopile and jacket foundations (210dB SEL_{cum}). In accordance with the Popper et al. (2014) qualitative assessment criteria, the relative risk of recoverable injury on sea turtles during pile driving is high at the near field (10s of meters) distance from the noise source and low at both intermediate (100s of meters) and far (1,000s meters) distances from the piling operations. Given their mobile nature, marine turtles would be able to leave the area during soft-start procedures before sound levels reach levels that could cause lethal or sublethal injuries. Based on this and considering the small area potentially affected together with the intermittent and temporary nature of the impact and the transient nature of the receptors, any effects upon marine turtles are assessed to be barely discernible from baseline conditions. Consequently, the magnitude of the impact is deemed to be low (adverse).
Shellfish VERs	As there are currently no criteria for assessing particle motion, it is not possible to undertake a threshold-based assessment of the potential for mortality and sublethal injury to shellfish in the same way as can be done for fish and elasmobranchs. As such, a qualitative assessment of the potential for mortality and recoverable injury has been made based on an assessment of the available peer-reviewed literature. Pile driving is recognised as a source of particle motion, with increased levels of particle motion likely to occur in the near-field (Hazelwood and Macey, 2016). However, as discussed in Table 13.23, evidence suggests that this is unlikely to cause mortality, mortal injury or recoverable injury to shellfish species. Based on this and considering the temporary and intermittent nature of the impact, it is considered unlikely that there will be discernible changes to shellfish population. Consequently, the magnitude of the impact is deemed to be negligible.

In summary, the potential magnitude of the predicted changes resulting from mortality, potential mortal injury, and recoverable injury during pile driving has been assessed as being negligible for sandeel and shellfish VERs and low (adverse) for the remaining receptors.

Significance of effects: Mortality and potential mortal injury and recoverable injury

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and the maximum low magnitude of the impact on fish and shellfish receptors would result in a slight (adverse) effect, which is not significant in EIA terms.

Magnitude of impact: TTS and behavioural changes

Table 13.25 provides the determination of impact magnitude for TTS and behavioural changes from impact piling of foundations, based on the methodology outlined in Section 13.2.5. The potential magnitude of the impact is presented for each of the hearing groups identified in Table 13.20.

There are currently no thresholds for the onset of disturbance responses in fish, with the Popper et al. (2014) guidance recommending a qualitative assessment for potential disturbance effects based on a risk assessment approach (including consideration of hearing group of the species and the proximity to the sound source).

Observations of behavioural responses to impulse sounds are available for sprat and mackerel (Hawkins et al., 2014). However, the study was undertaken in a quiet sea lough, and the results are therefore not considered appropriate when defining effect thresholds for much noisier locations such as the Irish Sea. The Irish Sea is subject to high levels of anthropogenic activity and consequently noise, and the fish within this area will be acclimated to the noise and would be expected to have a correspondingly lower sensitivity to anthropogenic noise levels. On this basis and considering the wide variety of behavioural responses exhibited by fish (including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column), the qualitative assessment approach as recommended by the Popper et al. (2014) guidance is considered the most appropriate (Popper and Hawkins, 2021) and has been adopted in the assessment below.

Given the temporary nature of TTS and behavioural responses, the determination of impact magnitude has been primarily based on assessing the potential for changes in a receptors' spawning or reproductive rates and the likelihood for barriers to migration of diadromous species.

Table 13.25 Determination of magnitude for TTS and behavioural changes from impact piling

Criteria	Justification
Group 1: Sandeel	Underwater noise modelling predicts that TTS in stationary Group 1 receptors may occur up to 69km from single monopile installation and up to 59km from the sequential installation of two pin-piles for jacket foundations (>>186dB SEL_{cum}). Behavioural changes are likely to occur within these ranges, with a relative low risk of behavioural responses at distances of 1000s of metres from the sound source, a moderate risk at intermediate distances (100s of metres) and a high risk close to the sound source (10s of metres). The area likely to be affected overlaps with low intensity sandeel spawning grounds (Ellis et al., 2010, 2012), which is widely distributed in the Irish Sea. Given the broadscale distribution of potential spawning substrates, together with the intermittent and temporary nature of the impact and the temporary nature of the effect, any TSS and/or behavioural responses are assessed to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be **low (adverse)**.
Group 1: Remaining VERs	TTS in fleeing Group 1 receptors is predicted to occur up to 51km from the installation of monopile foundations and up to 40km from multileg foundation piling (>>186dB SEL_{cum}). The relative risk of behavioural changes is likely to be high at the near field (10s of meters) distance from the noise source, medium at intermediate (100s of meters) distance and low at far (1,000s meters) distances from the piling operations (Popper et al., 2014). Spawning grounds for all pelagic and demersal Group 1 fish receptors within the study area are widely distributed across the western Irish Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale. Given the broadscale distribution of potential sandeel habitats, together with the intermittent and temporary nature of the impact and the temporary nature of the effect, any TTS and/or behavioural responses are assessed to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be **low (adverse)**. The Group 1 diadromous VERs include the two lamprey species with marine life stages, river lamprey and sea lamprey. Current evidence suggests that hearing in lamprey species is limited to low frequency sounds up to about 300Hz (Mickle et al., 2018). Low frequency tones within the hearing range of lampreys have been shown to disrupt normal behaviour in juvenile and adult sea lamprey, initiating an increase in swimming behaviour and a decrease in resting behaviour (Mickle et al., 2018). While pile driving typically generates broadband sounds over a wider frequency range, there is potential for lamprey species to exhibit behavioural responses during pile driving. River lamprey are reported to typically remain in coastal and estuarine areas during their marine stage.

Criteria	Justification
	This suggests that the predicted impact ranges for the onset of TTS and behavioural responses are mainly located outside the areas of primary importance for river lamprey. Therefore, the magnitude of the impact for this species is deemed to be at most **low (adverse)**. Sea lamprey are much more widely distributed during their marine stage, and have been found within shallow coastal regions and deep offshore waters (Maitland, 2003). It is therefore assumed that there is a higher potential for sea lamprey to be present within the study area during piling activities. Sea lamprey are not thought to specifically migrate back to their natal rivers (Bergstedt and Seelye 1995; Waldman et al. 2008); instead, they are thought to return to rivers within the regional area, navigating primarily by detection of larval pheromones within shallow coastal waters to identify suitable rivers (reviewed in Hansen et al., 2016). This flexibility in migration behaviour suggests that underwater noise will not result in a barrier effect to any upstream or outgoing migration preventing the receptors from accessing a particular river to breed. Based on this and considering the intermittent and temporary nature of the impact together with the temporary nature of the effect, any likely significant effects on sea lamprey are considered to be barely discernible from baseline conditions, and consequently the magnitude of the impact for this species is deemed to be **low (adverse)**.
Group 2: Atlantic salmon, sea trout	TTS in fleeing Group 2 receptors is predicted to occur up to 51km from the installation of monopile foundations and up to 40km from multileg foundation piling (>186dB SEL_{cum}).The relative risk of behavioural changes is likely to be high at the near field (10s of meters) distance from the noise source, medium at intermediate (100s of meters) distance and low at far (1,000s meters) distances from the piling operations (Popper et al., 2014). Atlantic salmon smolts migrate out to sea to feed during late spring and summer and return as adults to their riverine spawning grounds mainly in late spring to early summer. As such, piling activities, which are expected to take place between April to September/October, would coincide with the peak migration periods of Atlantic salmon. There is therefore the potential for salmon to experience TTS or exhibit temporary avoidance reactions that might present barriers to migration. This is of particular concern for adult individuals returning to their natal rivers, with the potential of behavioural response delaying migration, which subsequently may affect the reproductive success to some individuals. The migratory process associated with Atlantic Salmon away from coastal waters to the open ocean is generally poorly understood. However, there is evidence from tracking data that salmon smolts within the east coast of Irland (where the study area is located) move quickly into deeper offshore waters upon leaving their home rivers (Barry et al., 2020). There is therefore high potential that migratory smolts from rivers on Ireland's east coast would pass through the study area including areas where noise levels may induce TTS or behavioural reactions. No information is available on the movement patterns of returning salmon; however, a similar pathway to that of outward moving smolts may be assumed. Given the mobile nature of salmon, individuals will likely be travelling and not remain exposed to the impacts for extended periods of time. In addition, the impact would be temporary (i.e. less than one year) and intermittent, with individuals expected to be able to continue their migration during piling free days. Based on this, potential changes in the behaviour and/or distribution of salmon and any potential delays in migration are not considered to alter reproductive rates to the extent that could alter the population trajectory. Therefore, the magnitude of TTS and disturbance impacts associated with impact piling on salmon is deemed to be **low (adverse)**. Tracking data indicate that sea trout remain closer to their spawning rivers and swim closer to the coast and river mouths (Barry et al., 2020). This suggests that sea trout might mostly avoid the area over which TTS or behavioural response are likely to occur (Figures 13.14 and 13.15). Therefore, the magnitude of the impact for sea trout is deemed to be at most **low (adverse)**.
Group 4: Herring	**Spawning adults:** As assessed in Table 13.23, it is considered that noise emitted during impact piling may disrupt normal spawning behaviour in herring through behavioural reactions or changes in hearing sensitivities through TTS. Underwater noise modelling predicts that TTS to stationary herring may occur up to 69km from single monopile installation and up to 59km from the sequential installation of two pin-piles for jacket foundations (186dB SEL_{cum}). On the basis of the static receptor modelling there is overlap between the predicted impact ranges for TTS in stationary herring with the Mourne herring spawning ground (Figures 13.12 and 13.13, contour 186dB SEL_{cum}). The relative risk of behavioural responses at these distances is likely to be moderate (Popper et al., 2014). Piling would coincide with part of the main herring spawning season (September to November, with peak spawning probably in late September or October (ICES, 1994)). The impact would occur intermittently during the piling activities, with active piling days followed by piling-free days. As discussed in Table 13.23, there is evidence that fish affected by TTS recovered to normal hearing levels within a few hours to a couple of days after noise exposure (Popper et al., 2014; Popper and Hawkins, 2019). Therefore, TTS and any potential associated changes in spawning activity in herring over the Mourne ground may also be intermittent, with the potential of recovery between individual piling events. In addition, as discussed in Table 13.23, there is evidence that behavioural responses in herring to vessel noise and seismic airguns are reduced when they are involved in key biological behaviours such as feeding and spawning. A similar override of any potential deterrence effects might occur in spawning herring when exposed to pile driving. Considering the potential reduction in the receptor's response to noise stimuli when engaged in spawning behaviour and factoring in the reversibility and potential intermittent nature of the effects, it is concluded that the impact may lead to a reduction in the spawning output in a small proportion of the spawning population.

Criteria	Justification
	Based on this and given that the impact would be restricted to one spawning season (i.e., the impact would be temporary lasting less than one year), any temporary decline in the spawning activity of part of the population is considered unlikely to alter the population trajectory in the long-term. Therefore, the magnitude of the impact is deemed to be **low (adverse)**. **Eggs and larvae:** The Popper et al. (2014) criteria for the onset of TTS and behavioural changes in eggs and larvae are the same as those for recoverable injury, and therefore the magnitude assessment for eggs and larvae replicates that undertaken for recoverable injury. Likely significant effects on herring eggs and larvae were assessed as being barely discernible from baseline conditions, and consequently the magnitude of the impact for these receptors has been assessed as being **low (adverse)**.
Group 3 and 4: Remaining VERS	TTS in fleeing Group 3 and 4 receptors was predicted to occur up to 51km from the installation of monopile foundations and up to 40km from multileg foundation piling (186dB SEL_{cum}). TTS and behavioural impacts are predicted to occur within the near-field and far-field. Spawning grounds for a number of Group 3 (Atlantic cod, whiting, haddock) and Group 4 (sprat) species overlap with the proposed development site or are within the wider area. Whilst the Popper et al. (2014) criteria suggest a high risk of behavioural disturbance in the intermediate field and a moderate risk in the far field, the risk assessment is likely to predicated on the individuals not being involved in activities with a strong biological driver (i.e., spawning or feeding). As such, it is likely that any behavioural impacts to fish would be reduced when spawning, with consequently limited impact on spawning potential for the relevant species. Whilst there is a paucity of evidence on migratory behaviour of European eel, it is possible that migration would be an equally strong biological driver, with similar damping of behavioural reactions. Based on this, combined with the intermittent and short-term nature of the impact and the temporary nature of the effects, any TTS and behavioural changes in Group 3 and Group 4 VERs during piling are assessed to be barely discernible from baseline conditions. Consequently, the magnitude of the impact has been assessed as **low (adverse)**.
Marine turtles	The Popper et al. (2014) criteria for TTS are the same as those for recoverable injury, and therefore the magnitude assessment for marine turtles replicates that undertaken for recoverable injury. Likely significant effects on marine turtles were assessed as being barely discernible from baseline conditions, and consequently the magnitude of the impact for these receptors has been assessed as being **low (adverse)**.
Shellfish VERs	Impacts on shellfish from particle motion are likely to occur local to the sound source, with studies having demonstrated the rapid attenuation of particle motion with distance (Mueller-Blenkle et al., 2010). Based on this and given the broad distribution of the receptors along with the temporary and intermittent nature of the impact and the reversibility of effects, at most barely discernible changes in shellfish populations from baseline conditions are anticipated, and consequently, the magnitude of the impact is deemed to be **low (adverse)**.
Eggs and larvae	The Popper et al. (2014) criteria for TTS and behavioural changes are the same as those for recoverable injury, and therefore the magnitude assessment for eggs and larvae replicates that undertaken for recoverable injury. Likely significant effects on eggs and larvae were assessed as being barely discernible from baseline conditions, and consequently the magnitude of the impact for these receptors has been assessed as being **low (adverse)**.

In summary, the potential magnitude of the predicted changes resulting from TTS or behavioural reactions during pile driving has been assessed as being low (adverse) for all receptors.

Significance of effects: TTS and behavioural changes

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and the maximum low magnitude of the impact on fish and shellfish receptors would result in slight (adverse) effects, which is not significant in EIA terms.

Likely significant effects from UXO clearance on fish, shellfish and marine turtle VERs

There is a possibility that UXO of varying sizes may exist within the offshore development area, which would need to be cleared before construction can begin. Depending on their nature, the presence of UXO within the offshore development area can be managed in a number of ways: avoidance (through micro-siting), non-destructive clearance through moving or removal of the UXO, or destructive clearance (i.e., in-situ detonation). The preference will be to avoid UXO targets where possible; if this is not an option then relocation of UXO or removal would also be attempted.

If avoidance, relocation or removal was not possible then clearance of the UXO would be required, low-order clearance (i.e., burn out of UXO without detonation) would be the preferred method and attempted before a high-order clearance was attempted. High-order clearance requires an external 'donor charge' initiator to detonate the explosive material in the UXO, producing a blast wave equivalent to full detonation of the device. High-order clearance of UXO would generate the largest sound levels during UXO clearance and has consequently been used for underwater noise modelling and the impact assessment for fish and shellfish receptors.

Any UXO clearance would be completed within the array area and ECC as part of the pre-construction site preparatory works. Until detailed pre-construction surveys have been undertaken across the array and ECC, the exact number of potential UXO that would need to be cleared is unknown. Studies to date indicate the array area to be low risk and one area within the ECC near the coast in the southwest is considered medium risk of encountering UXOs (see the Offshore Construction Strategy).

The impact assessment presented below assumes that UXO would be removed through high-order in-situ detonations. The detonation of UXO generate high amplitude sound levels that, like piling noise, are detectable over large spatial scales (10s of kms) (Lepper et al., 2024). Detonation of UXO would result in a short-term (i.e., seconds) increase in underwater noise (i.e., increase in SPL and particle motion) to levels that could cause mortality and potential mortal injury, recoverable injury, TTS or behavioural changes in fish and shellfish species, with the severity of effects depending on the proximity of the individuals to the UXO location and the size of the UXO.

Sensitivity of receptors

Small scale mortality and physical injury to fish as a result of underwater explosions have been reported by several authors, with common physical injuries including rupture of the swim bladder and haemorrhage due to rupture of blood vessels (Dahl et al., 2020; Popper et al., 2014) No published data are available on the effects of explosions on hearing (e.g., TTS) or fish behaviour; however, it is suggested that the risk of experiencing temporary TTS is higher in species where the swim bladder enhances sound pressure detection (Popper et al., 2014). Behavioural effects are likely to include startle reactions, but it is suggested that such responses are of short duration and do not necessarily cause longer-term changes in behaviour (Popper et al., 2014). However, compared to impact piling, UXO detonations are considered to have a lower likelihood of triggering population level effects due to the significantly reduced temporal footprint of the noise that would result from them (Popper et al., 2014).

Taking account of the severity of the impact particularly at close range but acknowledging that impacts would occur at individual rather than at population levels and considering that any TTS or behavioural responses would be reversible and at most temporary (Popper et al., 2014), the maximum sensitivity of the fish and shellfish receptors to underwater noise generated during high-order UXO clearance is assessed as being medium

Magnitude of impacts

An estimation of the potential impact ranges for mortality and potential mortal injury of fish from UXO clearance activities has been made, based purely on the charge weight of the UXO. This estimation does not take into account the design, composition, age, position, orientation, and sediment coverage of the UXO, which leads to a high degree of uncertainty. Due to these uncertainties, the largest impact scenario and therefore precautionary estimation has been used for the calculations, assuming the UXO is not buried, degraded or subject to any other significant attenuation.

The predicted impact ranges for the onset of mortal injuries in fish are presented in the Underwater Noise Modelling Report. The calculations considered a selection of explosives sizes. The largest equivalent charge weight for the potential UXO devices that could be present within the offshore development area has been estimated as 525kg, and an additional donor weight of 0.5kg was included in the calculations to initiate detonation.

The maximum impact range for the onset of mortality and potential mortal injury from the highest charge weight using the unweighted SPL_{peak} explosion noise criteria from Popper et al. (2014) is estimated to be 810m from the detonation. The maximum extent of the impact would therefore be restricted to the near-field, which would represent a localised impact. The impact is anticipated to occur infrequently and would be momentary (i.e., lasting seconds to minutes).

Given the high intensity nature of sounds generated during UXO detonation and their potential for adverse effects on marine species, mitigation is included by implementation of specific measures should UXO clearance be required (see Table 13.11). The clearance of UXO will follow a mitigation hierarchy with high order detonation of UXO only taken place where avoidance, relocation, removal or low order deflagration is not possible. To minimise the area affected by underwater noise and the sound levels received by marine species at any one time, UXO detonations will not occur within the same 24-hour window as piling operations, and where there may be clusters of UXO requiring detonation, these UXO would not be detonated at the same time. In addition, where auditory injury impact ranges for marine mammals from the use of high order detonations are greater than what can be mitigated using MMO/PAM watch and ADD (e.g., 120kg UXO charge weight plus donor weight), NAS in the form of bubble curtains will be used to attenuate the sound emitted during the detonation.

While the primary driver for the use of NAS is to mitigate effects on marine mammals, their use will also reduce the likelihood of mortality and potential mortal injury in sensitive receptors.

Recoverable injury, TTS and disturbance effects will occur over a larger area, with TTS and disturbance effects potentially reaching 10’s of kilometres from the UXO location (Popper et al., 2014). It is possible that UXO operations will be planned to take place year-round during the UXO clearance campaign pre-construction, and therefore they have the potential to interact with key spawning or nursery periods for different fish and shellfish species. However, each UXO clearance is a discrete event and while this may result in some temporary disturbance to fish and shellfish receptors, it is less likely to result in the displacement of receptors from specific spawning, nursery or feeding grounds, compared to longer-term activities such as piling.

Factoring in the mitigation measures above and considering the infrequent and momentary nature of the impact together with the highly localised nature of potential lethal or sublethal injuries and the temporary nature of potential TTS or behavioural changes, any effects upon the fish and shellfish VERs from high-order UXO clearance are assessed to be barely discernible from baseline conditions and would not impact the survival or condition of the receptors to the extent that could alter population trajectories. Therefore, the magnitude of the impact for all receptors is assessed as being low (adverse).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and the maximum low magnitude of the impact on fish and shellfish receptors would result in a slight effect, which is not significant in EIA terms.

Likely significant effects from other noise sources on fish, shellfish and marine turtle VERs

Besides piling and the detonation of UXO, there will be several other construction activities that will produce underwater noise, namely dredging, drilling, cable laying, rock placement, geophysical and geotechnical surveys, and vessel noise. These activities may occur either alongside piling and UXO clearance or separately. In addition, there might be the potential that turbine foundations will be installed using drilling rather than piling. All these activities will produce non-impulse sounds.

Sound levels associated with construction activities have received considerably less attention and very little monitoring data is available. Among the construction activities, suction dredging is predicted to generate the largest sound levels of 186dB re 1µPa at 1m SEL_{RMS} (Underwater Noise Modelling Report). Rock placement is generally considered to be the nosiest external protection method, since the rocks fall down a fall pipe from the rock placement vessel, which may result in underwater noise. Other external protection measures such as mattresses and grout bags are typically placed onto the seabed using an ROV or crane, and as such these are unlikely to result in any significant underwater noise.

Nedwell and Edwards (2004) found that the noise of rock placement was not detectable over the vessel noise, since there was no determinable difference between measurements taken when rock placement was ongoing, and when the vessel was holding station without placing rock. The estimated source levels of underwater noise from rock placement at the proposed development is 172dB re 1µPa at 1m, and the noise emitted from large vessels is estimated at 168dB re 1µPa at 1m (Underwater Noise Modelling Report). Vessel noise would occur from jack-up vessels during the piling of foundations and WTG installations and from other large and medium sized vessels that carry out other construction tasks and anchor handling. Additional small vessels will be required for crew transport and maintenance on site.

Additional surveys will be required prior to construction, as part of the seabed preparation phase, which are included as part of this planning application. These surveys will be required to further characterise the seabed conditions and morphology and identify any potential obstructions or hazards to the construction works. The additional pre-construction surveys include geophysical surveys that are non-intrusive and will utilize towed equipment such as side scan sonar, sub bottom profiler, multibeam echosounder and magnetometer to gather detailed information on the bathymetry, seabed sediments, geology, and anthropogenic features (e.g., existing seabed infrastructure, UXO that exist across the offshore development area (see the Offshore Construction Strategy).

The following systems may be employed during these surveys:

- Single Beam Echosounder (SBES): The Single Beam Echosounder is a system designed to provide highly precise depth measurements along with seafloor profiling data. Typical equipment includes the Kongsberg 200 9G Single Beam Echosounder, with a maximum ping rate of up to 30 pings per second. Operating frequencies are approximately 200kHz with sound pressure levels of 221.6dB re1µPa at 1m
- Multibeam Echosounder (MBES): MBES is a system for collecting detailed topographical data of the seabed. Typical equipment includes the Kongsberg EM3002D multi-beam system with mounting system including AML SV Smart Probe, Kongsberg EM 2040 MKII or similar. For these surveys the equipment will operate at a typical central frequency of 400kHz with sound pressure levels in the range of 198dB re1µPa at 1m
- Side Scan Sonar (SSS): SSS surveys are used to determine sediment characteristics and seabed features. The EdgeTech 4205 may be taken as an indicate example of an SSS device and for these surveys will have a potential operating frequency range of approximately 300/600kHz in the offshore area and 600/900kHz in the shallower nearshore area with sound pressure levels of 220-230dB re1µPa at 1m
- Sub-bottom Profiling (SBP) - Parametric SBP: Used to develop an image of the subsurface, identifying different strata encountered in the shallow sediments. The Innomar “standard” Sub-Bottom Profiler is an indicative example of a parametric system with a primary and secondary frequency range of 85-115kHz and 2-22kHz, respectively, and sound pressure levels of up to 232dB (typically operated at <200dB) re1µPa at 1m, which would be used in both nearshore and offshore areas
- SBP - Boomer: The Applied Acoustics AA301 is an indicative example of a boomer, the instrument consists of a piezo electric plate transducer mounted on a surface tow catamaran frame. Reflected sound signals are recorded using a separate hydrophone such as the Applied acoustics HYD-360/08 (50m). The Boomer SBP operates in a frequency range of 0.5kHz to 5kHz, with sound pressure levels in the range of 205-211dB re1µPa at 1m, which would be used in the nearshore shallower area
- SBP - Sparker: The applied Acoustics Dual 400 Tip is an indicative example of a sparker system used in sub-bottom profiling. Reflected sound signals are recorded using a separate hydrophone such as the Applied acoustics HYD-360/08 (50m) or a multi-channel hydrophone such as the Geometrics GeoEel LH-16™ Digital Streamer. The sparker source has a frequency range of between 0.4-5kHz and a recorded sound pressure of 203dB re1µPa at 1m
- Acoustic corer: The Acoustic Corer™ (Pangeo subsea/Kraken Robotics) creates a high-resolution 12m wide acoustic core penetrating the sub-seabed to depths greater than 40m. The Acoustic Corer provides a 3D image of stratigraphy layers and anomalies across the entire foundation footprint. The acoustic corer has a low frequency 1.5 to 6kHz and high frequency 4.5 to 12kHz chirp and Peak SL 195dB and 190dB re 1uPa at 1m, respectively

- Ultrashort Baseline (USBL) - Acoustic Positioning System: The Applied Acoustics EasyTrak Nexus Model EZT-2691 is an example of an ultrashort baseline acoustic positioning system. The system consists of a transceiver unit and a set of transponders. The transceiver unit emits acoustic signals, which are picked up by the transponders. The signals are used to determine the position and orientation of the transponders relative to the transceiver, with high accuracy and precision. The frequency emitted ranges between 18-32kHz and a recorded sound pressure of 192dB re1µPa at 1m
- Magnetometer: A magnetometer is used to identify magnetic anomalies and hazard mapping for metal obstructions, shipwrecks and unexploded ordnance on the surface and in the shallow sub-surface. The Geometrics G-882 can be taken as an indicative equipment example. Magnetometers are passive devices that do not emit any sound waves into the marine environment. Therefore, they are not considered to have the potential to injure or disturb fish and shellfish receptors

Sensitivity of receptors

There is currently no evidence that non-impulse sounds, such as those emitted during cable installation, the drilling of foundations and vessel operations, cause mortality or potential mortal injury in fish, and therefore the relative risk of lethal effects occurring is considered to be low (Popper et al., 2014).

The limited data on other effects on fish hearing indicate the potential for auditory tissue injuries and associated TTS in species with enhanced sensitivities to sound pressure (e.g., Group 3 and 4 species). TTS following non-impulse sounds, which has been observed in a few noise-sensitive species, were temporary, with full recovery taking up to fourteen days following noise exposure (reviewed in Popper et al., 2014). Observations of behavioural responses of fish to continuous noise sources are also sparse but so far have included avoidance reactions, alteration of schooling behaviour and changes in swimming speed and direction (Popper et al., 2014).

Based on the above, and given the comparatively wide distribution of the fish and shellfish receptors (including spawning and nursery grounds) in the study area in comparison to the areas potentially affected by construction noise from activities other than piling at any given time, the maximum sensitivity of the fish and shellfish VERs to the impact is deemed to be low. Given the distance of the array area and ECC from the closest known herring spawning ground (> 20km), the risk for behavioural response in spawning herring is also considered to be low, and consequently the sensitivity of spawning herring to non-impulse construction noise is rated as low.

Acoustic signals emitted during geophysical surveys (e.g., from SSS, MBES and SBP) produce higher sound levels within the mid (1-10kHz), high (10-20kHz) and ultrasound (> 20kHz) frequency range. Data on the effects of these systems on fish and shellfish receptors is limited; however, it has been suggested that fish lacking a swim bladder are unlikely to suffer from lethal or sublethal tissue injuries (Popper et al., 2014). Physical injuries might occur in receptors sensitive to sound pressure changes (i.e., those with air-filled cavities, Groups 2 to 4). Both the SSS and MBES proposed operate outside of the hearing range of all receptors and are therefore not anticipated to result in any TTS or disturbance impacts. There is however evidence that low to mid frequency acoustic signals, such as those used by some sub-bottom profiling systems, may induce TTS or result in behavioural responses in some Group 4 receptors (e.g., herring and twaite shad), given their wider hearing bandwidth (Popper et al., 2014). These changes would the temporary with affected individuals anticipated to resume normal behaviours or recolonise areas shortly after survey work has ceased. Based on the above, the maximum sensitivity of fish and shellfish receptors to non-impulse sounds is deemed to be low.

Magnitude of impact

As discussed above, there is currently no evidence that non-impulse (i.e., continuous) underwater sounds, such as those emitted during construction activities and vessel operations, cause mortality or potential mortal injury in fish. Using unweighted SEL_{RMS} thresholds for recoverable injury and TTS recommended by Popper et al. (2014), underwater noise modelling predicts that non-lethal effects from continuous construction noise in Group 3 and Group 4 fish receptors (e.g., herring) would occur less than 50m from the noise source (Underwater Noise Modelling Report). For such an effect occurring, an animal would have to stay within the immediate vicinity of the noise source for 12 hours (TTS) and 48 hours (recoverable injury).

The risk of non-lethal injuries in the remaining receptors is considered to be low at all distances from the sound source, while the risk of TTS is likely to be moderate near (10s of meters) the noise source and low at intermediate (100s of meters) and far (1,000s meters) distances (Popper et al., 2014). The relative risk of behavioural changes in marine turtles and Group 3 and Group 4 receptors is likely to be high at the near field (10s of meters) distance from the noise source, medium at intermediate (100s of meters) distances and low at far (1,000s meters) distances from the piling operations (Popper et al., 2014). For the remaining receptors, the likelihood of behavioural responses is considered to be moderate at near and intermediate distances and low at far field distances from the noise source (Popper et al., 2014).

Based on the above, any effects from noise generated by other construction activities would likely be restricted to the near-field and adjacent far-field. Furthermore, these changes are expected to be temporary to short-term, intermittent, and reversible. Given their lower hearing capabilities and the low risk of injury and TTS, any effects on marine turtles, shellfish, eggs and larvae and Group 1 and Group 2 receptors are expected to be indiscernible from baseline conditions, and consequently the magnitude of the impact for these receptors is deemed to be negligible. Given their better hearing capabilities and subsequently higher susceptibility to injuries, TTS or behavioural reactions, Group 3 and 4 receptors may exhibit barely discernible changes in baseline condition, and consequently the magnitude of the impact for these receptors is deemed to be at most low (adverse).

Any noise generated during geophysical surveys would also be restricted to the near-field and adjacent far-field. The impact would occur infrequently and would be temporary. Therefore, any effects on marine turtles, shellfish, eggs and larvae and Group 1 and Group 2 receptors are expected to be indiscernible from baseline conditions, and consequently the magnitude of the impact for these receptors is deemed to be negligible. Given their better hearing capabilities and subsequently higher sensitivity to underwater noise, Group 3 and 4 receptors may exhibit barely discernible changes in baseline condition, and consequently the magnitude of the impact for these receptors is deemed to be low (adverse).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is low, and the maximum magnitude of the impact is low (adverse). The maximum low sensitivity and the maximum low magnitude of the impact on fish and shellfish receptors would result in a slight (adverse) effect, which is not significant in EIA terms.

Likely significant effects from all noise sources

As outlined previously (Table 13.10), no simultaneous piling will be carried out for the proposed development. In addition, piling and UXO detonation would not take place within the same 24-hour window (Table 13.11). There might however be the potential that other construction activities, such as dredging or drilling, occur at the same time as piling or UXO clearance. As discussed in the previous section, the noise levels emitted during these activities may potentially cause temporary TTS in the most sensitive VERs (i.e., Group 3 and Group 4 species) as well as behavioural reactions but are not thought to cause mortal injuries. Any TTS are predicted to be restricted to the near-field (< 50m from the noise source) while behavioural reactions will be confined to within the areas over which behavioural changes might occur as a result of piling or UXO clearance. It is therefore concluded that any underwater noise effects on fish and shellfish receptors during simultaneous construction activities (e.g., dredging and piling or dredging and UXO clearance) will be no greater in magnitude than those predicted for piling and UXO clearance alone. This would result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.3 Operational Phase

This section presents the assessment of impacts arising during the operational phase of the proposed development. The effects during the operational phase of the proposed development have been assessed on fish, marine turtles, and shellfish VERs within the fish and shellfish study area as defined in Section 13.2.5. The environmental impacts arising during operational activities of the proposed development are listed in Table 13.12 along with the design options against which each operational phase impact has been assessed.

13.5.3.1 Impact 5: Temporary increase in SSC and sediment deposition arising during the maintenance activities

During the operational phase of the proposed development, the use of jack-ups and anchored vessels and cable inspection work would be expected to lead to localised seabed disturbance, which is likely to result in short-term periods of increased SSCs and sediment deposition. The maximum volume of sediment released during maintenance activities for Project Option 1 and Project Option 2 would be less compared to the maximum volumes released during the construction phase (Table 13.12), mainly owing to the redundancy of seabed preparation activities. The impact would occur intermittently through the operational phase, with individual maintenance activities (e.g., cable burial) to be temporary (i.e., lasting less than one year)). Consequently, any effects on fish and shellfish receptors would be no greater in magnitude than those encountered during construction activities (Table 13.15). The sensitivities of fish and shellfish resources to the impact remain as described for the construction phase (Table 13.13).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and the maximum low (adverse) magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.3.2 Impact 6: Temporary damage and disturbance of the seabed during maintenance activities

During the operational phase of the proposed development, the maintenance and repair of foundations and cables would result in temporary and localised disturbances to the seabed. The extent of the impact would be restricted to the immediate footprint of operational activities, which would include cable reburial and repair works and the use of jack-up vessels for the maintenance of foundations, WTG and OSP. It is anticipated that the largest area to be affected would be less than that affected during the construction phase (Table 13.12). The impact would occur infrequently during the operational phase and would be temporary. Consequently, any impacts on sensitive fish and shellfish receptors would be no greater in magnitude than that experienced during construction activities (Table 13.17). The sensitivities of fish and shellfish resources to the impact remain as described for the construction phase (Table 13.16).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and maximum low magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.3.3 Impact 7: Long-term/permanent loss of benthic habitat due to the placement of subsea infrastructure

The presence of the WTG and OSP foundations and associated scour protection, along with cable protection measures used at cable crossings and areas where cable burial is not possible, would lead to a change from a sedimentary habitat to one characterised by hard substrate. This has the potential to impact fish and shellfish receptors via the localised alteration of the structure and function of supporting habitats (e.g., spawning, nursery, and foraging habitats) and has therefore been assessed as habitat loss. Potential beneficial effects of introducing hard substratum (e.g., providing new habitats for faunal assemblages to colonise, resulting in potential benefits for fish and shellfish populations) are assessed under the Impact 9.

The sensitivity of all fish, marine turtles and shellfish receptors to the predicted changes and the magnitude of the impact have been assessed in Table 13.26 and Table 13.27 respectively, based on the methodology outlined in Section 13.2.5. No specific embedded mitigation measures relevant to the impact have been defined (see Table 13.11).

Sensitivity of receptors

As discussed above in relation to direct damage and disturbance impacts during construction activities (Section 13.5.2.2), those species which are directly reliant on the seabed for either all, or part of their life cycle, are susceptible to the effects of long-term habitat loss. This includes burrowing fish (sandeel) and shellfish species (e.g., *Nephrops*, razor clams) that live within the sediment and bottom-dwelling fish, shellfish and elasmobranch species that depend on benthic prey. In addition, adverse effects on fish and shellfish populations may arise through the loss of benthic spawning and nursery grounds.

Table 13.26 Determination of sensitivities or receptors to long-term/permanent loss of habitat

Receptor	Sensitivity
Marine turtles, basking shark, pelagic VERs (Atlantic mackerel, Atlantic horse mackerel, sprat)	Marine turtles, basking sharks and all pelagic VERs do not depend upon the seabed for part or all of their life cycle and therefore are not considered susceptible to the long-term loss of subtidal sediments that would arise during the operational phase of the proposed development. Consequently, the sensitivity of these species to the impact is deemed to be **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Demersal VERs, diadromous VERs, tope, starry smooth-hound, spiny dogfish	As detailed in Table 13.16, these receptors are considered to have a high adaptability and tolerance to seabed disturbance events (including seabed loss) given that they are mobile and would therefore be able avoid the impact. Recoverability is also assessed as high. In addition, these receptors are pelagic spawners (demersal fish VERs), do not spawn within the study area (diadromous VERs) or bear live young (tope, starry smooth-hound and spiny dogfish), and therefore the physical loss of benthic habitats within the study area would not result in any loss of available spawning locations. Based on this and considering the regional importance of the receptors, the sensitivity of all demersal and diadromous VERs and tope, starry smooth-hound and spiny dogfish to long-term habitat loss is deemed to be **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table13.6), and the impact is therefore not considered further for these receptors.
Small-spotted catshark, nursehound and skate species (thornback ray, spotted ray, blonde ray, cuckoo ray, small-eyed ray)	Small-spotted catshark, nursehound and skates are oviparous that attach egg cases onto the seabed. In addition, these receptors depend to some degree on the seabed for feeding. All receptors are highly mobile and would be able to relocate to nearby suitable feeding and egg-deposition grounds. Therefore, they are assessed as having a high adaptability and tolerance to the impact. Based on this and considering the regional importance of the receptors, the sensitivity of small-spotted catshark, nursehound and skate species to long-term habitat loss is deemed to be **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Sandeel	As discussed previously, sandeel are susceptible to the long-term loss of sedimentary habitats as they exhibit strong site fidelity and have specific substrate requirements throughout their juvenile and adult life history. Therefore, they have been assessed as having a low tolerance to the impact. Site-specific sediment data indicate sub-prime and suitable sandeel habitats along most sections of the ECC. In addition, sandeel spawning grounds are predicted to be distributed across the Irish Sea (Ellis et al., 2010, 2012; Figure 13.5), and PSA data collected through INFOMAR (2023) confirm the presence of suitable sandeel habitats within the study area and wider region. In light of this, it is considered that sandeel may be able to relocate to nearby unimpacted areas. Taking this into consideration together with their regional importance, the sensitivity of sandeel to long-term habitat loss is deemed to be medium.
Herring	Herring rely upon specific substrates on which to deposit their eggs, which makes them susceptible to long-term changes in substratum type within spawning grounds. As discussed in Section 13.3.6, the closest known active spawning beds for herring are located in the north of the study area outside the areas to be affected by the placement of infrastructure. Therefore, no loss to herring spawning grounds is predicted from the proposed development, and therefore for the purpose of this assessment the sensitivity of herring to the impact has been assessed as **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for this receptor.
Nephrops	Berried female Nephrops are considered largely sedentary, remaining in their burrows during the overwintering period. Furthermore, Nephrops are confided to particular substrate types and exhibit some site fidelity. Therefore, they are considered to have a low adaptability and very low tolerance to the permanent loss of sedimentary habitat. Although the loss of habitat will persist over the long-term, Nephrops may be able to recover by resettling in nearby unaffected areas. Recovery from any localised decline in population numbers or reproductive success is anticipated to occur within the short-term to

Receptor	Sensitivity
	medium-term through larval dispersal and recruitment into surrounding unaffected areas (medium to low recoverability). Taking into consideration the regional importance of Nephrops together with their low adaptability, very low tolerance and low to medium recoverability, the sensitivity of Nephrops to long-term habitat loss is deemed to be **medium**.
Brown crab, European lobster, common whelk, common cockle, King scallop, razor clams	These species are of commercial importance to the region. They are substrate dependent and are therefore susceptible to the long-term loss of sedimentary habitats. Whelk typically remain stationary when not actively searching for food, either resting on the seafloor or being to some degree buried within in the sediment. Cockles are found in surface sediments, and King scallop typically prefer clean firm sand, fine or sandy gravel substrates. Brown crab occur on a range of substrate types, including boulders, mixed coarse grounds, and offshore sands, and berried females overwinter in pits dug in the sediment or under rocks. Adult European lobster typically inhabit rocky substrata, living in holes and excavated tunnels, while juvenile lobsters are known to spend large amounts of time within their burrows. Based on their dependence on sedimentary habitats, either for all or part of their life cycle, these receptors are considered to have a very low tolerance to the permanent loss of habitat during the operational phase. Although the loss of habitat will persist over the long-term, the receptors would be able to recover by resettling in nearby unaffected areas. Recovery from any localised decline in population numbers or reproductive success is anticipated to occur within the short-term to medium-term through larval dispersal and recruitment into surrounding unaffected areas (medium to low recoverability. Taking into consideration the regional importance of the receptors together with their low adaptability, very low tolerance and low to medium recoverability, the sensitivity of the remaining shellfish VERs to the long-term loss of benthic habitats is deemed to be **medium.**
Blue mussel	Blue mussels occur on a wide variety of substrata including sedimentary and rock substrata and artificial structures (Tillin et al., 2023). Offshore wind farm structures including turbine foundations and scour protection are known to provided suitable substrates for blue mussel settlement and growth (e.g., Degraer et al., 2020; Maar et al., 2009). A change in substratum type due to the placement of infrastructure may therefore not change the ability of blue mussels to colonise the offshore development area, and therefore the sensitivity of blue mussels to the impact is deemed to be **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for this receptor.

In summary, marine turtles, basking sharks, herring, blue mussel and all pelagic, demersal, diadromous and elasmobranch VERs have been assessed as not being sensitive to the impact. The sensitivity of the remaining VERs (sandeel and all remaining shellfish VERs) has been assessed as medium. The maximum sensitivity of fish and shellfish VERs for this impact is therefore medium.

Magnitude of impact

The predicted long-term loss of sedimentary benthic habitats during the operational phase of the proposed development would occur within the area subject to temporary damage and disturbance during the construction phase (Impact 2, Section 13.5.2.2). Within the array area, an area of approximately 0.26km^2 is predicted to be lost after the installation of cable protection measures and WTG and OSP foundations and associated scour protection under Project Option 2 and 0.24km^2 for Project Option 1. This equates to approximately 0.3% of the total seabed area within the array area for Project Option 1 and Project Option 2. Within the ECC, an area of approximately 0.04km^2 of sedimentary habitat would be lost due to the installation of export cable protection material for both Project Option 1 and Project Option 2, which equates to approximately 0.1% of the total seabed area within the ECC. The total habitat loss within the array area and ECC would equate to approximately 0.3km^2 of seabed within the study area under Project Option 2 and 0.28km^2 for Project Option 1 (Table 13.12).

The loss of sedimentary habitat would be restricted to the footprint of the installed infrastructure and associated protection material. Consequently, the maximum extent of the impact would be restricted to the immediate vicinity of infrastructure. The predicted footprint of habitat loss during the operational phase would fall within the area of direct damage and disturbance during the construction phase.

As a minimum, the impact would occur throughout the operational period (35 years) and therefore would be long-term (15-60 years), as defined in the assessment methodology (Section 13.2.5, Table 13.5). Seabed infrastructure left in place following the decommissioning of the proposed development would result in a permanent change in substratum type.

Table 13.27 Determination of impact magnitude of long-term and permanent loss of habitat

Receptor	Impact magnitude
Sandeel	As described previously, site-specific PSA data suggest that sub-prime and suitable sandeel spawning habitats are located along most of the ECC. In addition, sandeel spawning grounds are predicted to be distributed across the Irish Sea (Ellis et al., 2010, 2012), and PSA data collected through INFOMAR (2023) indicate the presence of suitable sandeel habitats within the study area and wider region. Taking this into consideration, any long-term or permanent loss of soft substratum is considered to be small in the context of available suitable sandeel habitat throughout the study area and wider region. Therefore, any effects upon sandeel populations and their spawning grounds are considered to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be **low (adverse).**
Nephrops	As described previously, site-specific survey data suggest the presence of Nephrops along the ECC and within the northern section of the array area. Nephrops within the study area are part of the western Irish Sea Nephrops population, which inhabits the fine sediments of the Western Irish Sea Mud Belt from about 54.5°N in the north to 53.5°N in the south. Considering the localised nature of the impact, the areas affected by long-term or permanent habitat loss are considered to be small in the context of the study area and the distribution of the western Irish Sea Nephrops population. Taking into consideration the wide distribution of the receptor together with the localised nature of the impact, any effects on Nephrops from the impact are considered to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be **low (adverse).**
Brown crab, European lobster, common whelk, common cockle, King scallop razor clams,	It is predicted that the impact may affect the receptors through the long-term or permanent loss of sedimentary habitats, including potential overwintering grounds. The subtidal benthic substrates that would be affected are common and widespread within the study area and throughout the wider region. Therefore, any long-term or permanent loss of soft sedimentary habitats is considered small in the context of their overall extent. Based on the highly localised nature of the impact, no to barely discernible changes to the receptors are anticipated, and consequently the magnitude of the impact for these receptors is assessed as being at most **low (adverse).**

In summary, the loss of benthic habitats during the operational phase of the proposed development would be localised and restricted to the immediate vicinity of subsea infrastructure, with effects on sensitive fish and shellfish receptors assessed as being not discernible or barely discernible from baseline conditions. The maximum magnitude of this impact has therefore been assessed as low (adverse). Marine turtles, herring, blue mussel and all elasmobranch, demersal, pelagic and diadromous VERs were assessed as not being sensitive to the impact and were therefore screened out of the magnitude assessment.

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and maximum low magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.3.4 Impact 8: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination

As described for Impact 5, the use of jack-ups and anchored vessels and cable repair work during the operational phase would lead to localised seabed disturbance, which is likely to result in short-term periods of increased SSCs and sediment deposition. This has the potential for sediment-bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on fish, marine turtles and shellfish receptors. Furthermore, there is a risk of accidental spillages from equipment or collision incidents during maintenance activities, potentially resulting in the release of pollutants such as fuel, oil and lubricants. As discussed previously in Section 15.5.2.3, the accidental releases of pollutants will be managed and mitigated through the implementation of an Offshore EMP, which will include Marine Pollution Contingency and Offshore Waste Management procedures (Table 13.11).

Waste will be safely stored and disposed of, and pollution prevention and control measures will include navigational safety measures to reduce the likelihood of collision events, procedures to safely use, store and transport harmful substances, and emergency response methods that would be implemented in the case of accidental spills or collision events. Implementation of these measures will reduce the likelihood of potentially harmful pollutants to be released into the marine environment, thereby reducing the likelihood of pollution impacts on potentially sensitive migratory fish species. Therefore, accidental contamination is not considered further in the assessment.

As detailed in Table 13.12, elevated levels of suspended sediments and associated releases of sediment-bound contaminants would be less to those experienced during the construction phase. Sediments are likely to be rapidly dispersed by the prevailing tidal currents, and increased bio-availability resulting in adverse eco-toxicological effects to fish and shellfish receptors and their prey are therefore not expected. In addition, any maintenance activities to support the ongoing operation would be temporary. Consequently, any impacts on fish and shellfish receptors would be no greater in magnitude than those encountered during construction activities (Table 13.18). Therefore, the magnitude of the impact has been assessed as negligible. The sensitivities of fish and shellfish resources to the impact remain as described for the construction phase (Impact 3).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the magnitude of the impact is negligible. The medium sensitivity and negligible magnitude of the impact on fish and shellfish receptors would result in a not significant effect, which is not significant in EIA terms.

13.5.3.5 Impact 9: Increase in hard substrate and structural complexity due to the placement of subsea infrastructure

Any introduction of infrastructure such as WTG and OSP foundations, cable protection and scour protection would result in the introduction of hard substrate to the current sedimentary habitats within the array area and ECC. The heterogeneity of the seabed substrate would be increased and a subsequent change in the composition of the benthic communities would result. This in turn would represent a change to the structure and function of supporting habitats (e.g., spawning, nursery and foraging habitats) for fish, marine turtles and shellfish receptors.

The loss of habitat for those species that are directly reliant on the sediment for either all, or part of their life cycle (e.g., demersal spawners) has been assessed above (Impact 7). With regard to increasing habitat complexity however, this will lead to an alteration of the structure and dynamics of ecological communities in areas where infrastructure exists, with increased complexity often leading to greater species diversity and abundance (Smith et al., 2014). This increase in diversity and productivity as a result of the colonisation of seabed structures may affect fish, marine turtles and shellfish receptors, resulting in either attraction or increased productivity.

The magnitude of the impact (increased areas of hard substrate and structural complexity) and the sensitivity of all fish, marine turtles and shellfish receptors has been assessed in Table 13.28 and Table 13.29 respectively, based on the methodology outlined in Section 13.2.5. An Offshore EMP with a detailed biosecurity plan will be implemented to ensure that the risk of potential introduction and spread of INNS will be minimised (see Table 13.11).

Sensitivity of receptors

Hard substrate habitats are rare within the fish and shellfish ecology study area, and as such their introduction would represent a shift in the baseline condition. The presence of artificial structures and hard substrate materials would increase the structural complexity of the seabed environment and provide settlement opportunities for epibenthic species (e.g., Causon and Gill, 2018). Potential beneficial effects for benthic assemblages are associated with the likely increase in local biodiversity and biomass, as has been, for example, observed at the Egmond aan Zee Offshore Windfarm in Dutch territorial waters (Lindeboom et al., 2011).

Fish and shellfish receptors may react to these changes in different ways, both beneficial and adverse. Some species may benefit directly from the presence of hard structures and associated epifaunal communities, as these may provide shelter from predation or surfaces for egg deposition (Hermans et al., 2020). For example, the attraction of both brown crab and Atlantic cod to wind- and wave power foundations is well documented (e.g., Krone et al., 2017; Langhamer and Wilhelmsson, 2009; Reubens et al., 2013), and juvenile cod, in particular, are known to benefit from structurally complex habitats to seek shelter from predators (Froese and Pauly, 2023). Studies at the Horns Rev Offshore Wind Farm (OWF) in Denmark provided evidence that OWF structures can provide successful nursery habitats for edible crabs (BioConsult 2006). Receptors may also profit indirectly from the presence of artificial structures by taking advantage of the increase in biomass and diversity of prey species. For example, fish communities living around oil and gas platforms off the coast of California have been shown to have higher rates of production compared to fish communities in other coastal and offshore environments within the region (Claisse et al., 2014).

The implications of these structures for the wider fish and shellfish assemblages remain unknown. Fish and shellfish species potentially attracted to artificial hard substrates may induce indirect and adverse effects through increased predation on, or competition with, neighbouring soft sediment species. However, such effects are difficult to predict.

Table 13.28 Determination of sensitivities or increased hard substrate and structural complexity as the result of the introduction of infrastructure

Receptor	Sensitivity
Marine turtles, basking shark, pelagic VERs (Atlantic mackerel, Atlantic horse mackerel, sprat)	Marine turtles, basking sharks and all pelagic VERs do not depend upon the seabed for part or all of their life cycle and therefore are not considered susceptible to the introduction of hard substrate to the seabed during the operational phase of the proposed development. Consequently, the sensitivity of these species to the impact is deemed to be **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Demersal VERs, diadromous VERs, elasmobranch VERs	The receptors are expected to avoid or adapt to changing substratum conditions given their mobile nature (high adaptability). Depending upon the species, individuals may forage/and or find refuge in the structures, thereby benefitting from them or relocate to nearby suitable habitat (high tolerance). In addition, ovigerous elasmobranch species may utilise artificial hard surfaces as egg deposition sites. The extent of available spawning locations for the remaining receptors is not expected to be affected by changes in substratum type as these receptors are pelagic spawners (demersal fish VERs), do not spawn within the study area (diadromous VERs) or bear live young (tope, starry smooth-hound and spiny dogfish). Based on this, the sensitivity of all demersal, diadromous and elasmobranch VERs to the impact is deemed to be **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Sandeel	As assessed in Table 13.26, sandeel are susceptible to the long-term loss of sedimentary habitats as they have specific substrate requirements throughout their juvenile and adult life history. Their tolerance to changes in substratum type is therefore assessed as very low. Recovery is expected to occur in the long-term, only following the removal of seabed infrastructure after the decommissioning of the proposed development. However, suitable sandeel habitats are present within the study area and wider region (Figure 13.9), and displaced sandeel would therefore be able to relocate to nearby unimpacted areas. Taking this into consideration together with their regional importance, the sensitivity of sandeel to the introduction of hard substratum and increased structural complexity is deemed to be **medium**.
Herring	As assessed in Table 13.26, for the purpose of this assessment, herring have been assessed as not being sensitive to the long-term or permanent loss of benthic habitats given that no active spawning grounds are located within the array area and ECC. Consequently, the sensitivity of herring to the introduction of hard substrate has been assessed as **negligible**. Irrespective of the magnitude of the impact, the significance of the impact for these VERs is **imperceptible** as defined in the significance matrix (Table 13.6), and the impact is therefore not considered further for these receptors.
Shellfish VERs	There is the potential for beneficial effects for some shellfish species, such as brown crab, European lobster and blue mussel, due to the expansion of favourable habitats and refuge areas created from foundations and scour protection installed in areas of soft sediments (e.g., BioConsult, 2016; Krone et al., 2017; Taormina et al., 2020a). The sensitivity of these receptors to an increase in hard substratum and structural complexity during the operational phase is therefore assessed as **negligible**.

Receptor	Sensitivity
	As detailed in Table 13.26, the remaining shellfish VERs are confined to particular soft substratum types and are therefore susceptible to long-term changes in seabed conditions. Their sensitivity to the long-term loss of soft-substratum (and the simultaneous increase in the extent of hard substratum) is deemed to be **medium** (Table 13.26). The colonisation of new habitats by shellfish receptors could lead to the introduction of non-indigenous and invasive species (see the Benthic Ecology chapter for detailed discussion). This may have indirect adverse effects on shellfish populations as a result of competition. The implementation of a PEMMP, which will include a biosecurity plan, would ensure that the risk of potential introduction and spread of INNS will be minimised.

In summary, marine turtles, herring, brown crab, European lobster, blue mussel, and all pelagic, demersal, diadromous and elasmobranch VERs have been assessed as not being sensitive to the impact. The sensitivity of the remaining VERs (sandeel and all remaining shellfish VERs) has been assessed as medium. The maximum sensitivity of fish and shellfish VERs for this impact is therefore medium.

Magnitude of impact

Any introduction of hard substrates due to the placement of subsea infrastructure and associated protection measures would lead to a permanent change in seabed conditions throughout the 35-year operational phase of the windfarm development. The impact may be reversible if the infrastructure is removed; however not all introduced hard substrate is likely to be removed, with scour protection assumed to be remaining in-situ.

The extent of the impact would be restricted to the area covered by infrastructure and protection material. The seabed footprint of introduced hard substratum within the array area and ECC would equate to approximately 0.32km^2 for Project Option 1 and 0.26km^2 for Project Option 2, which equates to approximately 0.26% of the array area and ECC for Project Option 1 and 0.21% for Project Option 2 (Table 13.12). An additional 0.13km^2 would be introduced as lateral surfaces through the placement of WTG and OSP foundations for Project Option 2 and 0.1km^2 for Project Option 1.

The impact will be for the duration of the 35-year operational period and therefore will be long-term (15-60 years).

Table 13.29 Determination of magnitude of increased hard substrate and structural complexity as the result of the introduction of infrastructure

Receptor	Impact magnitude
Sandeel	As discussed previously, suitable sandeel habitats are present within the study area and wider region, and any long-term loss of soft substratum (and associated increase in hard substratum) is considered to be small in the context of available suitable sandeel habitat throughout the study area and wider region. Therefore, any effects upon sandeel populations and their spawning grounds as a result of an increase in hard substrate are considered at most to be barely discernible from baseline conditions, and consequently the magnitude of the impact is deemed to be **low (adverse).**
Herring	As discussed previously, no known herring spawning grounds are located within the array area and ECC. Therefore, no loss of herring spawning grounds are predicted from the introduction of hard substrate, and the magnitude of the impact has consequently been assessed as being **negligible**.
Nephrops, King scallop, common cockle, common whelk, razor clams	As discussed in Table 13.27, given the localised spatial extent of the impact and the wide distribution of supporting benthic habitats, any increase in hard substrate (and the associated loss of soft sediments) is considered to result in no or barely discernible changes from baseline conditions. The magnitude of the impact is therefore deemed to be at most **low (adverse).**

In summary, the increase in hard substrate and structural complexity during the operational phase of the proposed development would be highly localised and restricted to the immediate vicinity of subsea infrastructure, with effects on sensitive fish and shellfish receptors being not discernible or barely discernible from baseline conditions. The maximum magnitude of this impact has therefore been assessed as low (adverse). Marine turtles and all elasmobranch, demersal, pelagic and diadromous VERs were assessed as not being sensitive to the impact and were therefore screened out of the magnitude assessment.

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and maximum low magnitude of the impact on fish and shellfish receptors at most results in a slight (adverse) effect, which is not significant in EIA terms.

13.5.3.6 Impact 10: Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables

The transmission of power through the inter-array and export cables during the operational phase of the proposed development would produce EMFs in the surrounding sediment and water column. These fields have the potential to affect fish and shellfish receptors that use electric or magnetic senses for foraging, navigation or communication.

Artificial EMFs are generated by electric currents that pass through power cables. Two types of EMFs are produced directly by subsea cables: electric fields (E-fields), which are generated by static electric charges of the cable, and magnetic fields (B-fields), which are produced by moving electric currents. A third type of EMF, induced electric fields (Ie-fields), is generated indirectly from B-fields, either by the movement of alternating B-fields (in the case of alternating current (AC) transmission) through seawater or by the movement of seawater and/or an organism through a static B-field (in the case of direct current (DC) transmission).

EMFs also occur naturally in the marine environment from a variety of sources. The dominant source of background (natural) EMF is that from the geomagnetic field of the Earth. The other important type of natural EMF is small bioelectric fields generated by electrical currents moving through living organisms (e.g., Tricas and Gill, 2011). The EMFs generated by geomagnetic and bioelectric fields are the signals that magneto- and electrosensitive marine species rely on for navigation and prey detection, respectively.

EMFs would result from the operation of 111km of inter-array cables for Project Option 1 and 91km inter-array cables for Project Option 2, and two 18km long HVAC export cables for either project option, with proposed operating voltages of either 66kV or 132kV for the inter-array cables and 220kV for the two export cables. All cables would contain industry standard shielding, which prevents E-fields from passing into the marine environment. Therefore, likely significant effects of E-fields have not been considered any further in the assessment. Cable shielding and/or burial does not however prevent or reduce the emission of B-fields, which consequently can emanate into the water column, where they are likely to create Ie-fields.

B-fields are measured as Teslas (T) or micro-Teslas (μT). The background magnetic field strength in Irish waters is approximately 49μT (National Oceanic and Atmospheric Administration (NOAA), 2020). The strength of B-fields is directly related to the power of the current passing through the cable, which is commonly measured in amperes (A).

Field measurements have shown that B-fields attenuate rapidly horizontally and vertically away from electricity cables, with the magnetic field generated by the cables typically having reached zero within 10m of the cable (reviewed by Tricas and Gill, 2011). Burial of cables or surface-laid cable protection will not reduce the strength of B-fields; however, it moves the cables further from the receptors, and as such the receptors will be subject to reduced B-field strengths.

The strength of Ie-fields is directly related to the strength of the B-fields generating them, being strongest closest to the cable and attenuating horizontally and vertically away from the cable. Ie-fields are measured as volts per metre (V/m), with values seen at cables in the marine environmental being in the μV/m range.

The strength of B-fields (and resulting Ie-fields) emitted from subsea cables into the surrounding environment also depends on a range of factors, including the technical specifications of the cable, the type and intensity of the electric current flowing through the cable, the cable installation method (e.g., buried or unburied) and the characteristics of the surrounding environment (e.g., seabed type, water depth) (Taormina et al., 2020b). For example, inter array cables, being lower powered, typically generate smaller EMFs than export cables or inter-platform cables.

The sensitivity of all fish, marine turtles and shellfish receptors to artificial EMFs that would be generated by subsea cables has been assessed in Table 13.30, based on the methodology outlined in Section 13.2.5. Export and inter-array cables will have sufficient shielding to contain any E-fields generated. In addition, export and inter-array cables will be buried where possible, typically to a target cable burial depth of 1m-3m, which would reduce the EMF strengths that receptors are subjected to (see Table 13.11).

Sensitivity of receptors

Many marine species are known to use magnetic or electric senses. These magneto- and electro-receptive species utilise natural EMFs for a range of ecological processes including short- and long-range spawning and feeding migrations and the detection of prey, predators and sexual mates (Béguer-Pon et al., 2015, cited in Gill et al., 2023; Rivera-Vicente et al., 2011). Perhaps the most well recognised use of electric fields is by elasmobranchs, which use electroreceptors to detect prey, which may be buried in sediment or under rocks. Migratory fishes such as salmonids and eels can detect EMFs via magnetoreception, while some shellfish species also have well-developed magneto-sensory systems. The EMFs generated during the operational phase of the proposed development may affect magneto- and electrosensitive species by disrupting bioelectric or geomagnetic cues, thereby masking prey or altering migratory behaviour.

Potential impacts of anthropogenic EMFs on marine organisms are relatively sparsely investigated, with studies having so far focussed on a small number of species. Additionally, due to challenges of monitoring a wide variety of marine organisms in single studies in situ, many studies have been laboratory based, which has limited ability to determine behavioural reactions that may or may not occur in real world scenarios.

Table 13.30 Determination of receptor sensitivities to EMFs from cables

Receptor	Sensitivity
Marine turtles	Marine turtles are known to use the Earth's magnetic field amongst other senses to migrate between nesting beaches and feeding grounds (Lohmann et al., 2008). Whilst turtles are potentially sensitive to magnetic fields from EMFs, effects to navigation would be expected to be in the absence of other cues (e.g. sunlight) and likely a greater concern for hatchlings where cables are inshore in shallow waters (Tricas and Gill, 2011). Other studies have demonstrated that whilst the attachment of magnets to turtles' results in less direct migration, most individuals successfully migrated to their breeding island (Luschi et al., 2007). Furthermore, marine turtles are primarily pelagic species and will only interact with the fields generated by subsea cables when diving in most cases. The rapid attenuation of the EMF from the proposed development will ensure that any interaction is limited and is not considered likely to impact on turtles. Therefore, the sensitivity of marine turtles to EMFs is deemed to be **negligible**.
Elasmobranch VERs	Elasmobranchs (sharks, skates and rays), especially demersal species, are known to be the most electro-sensitive of all fish. All species within this group have specialised organs, called ampullae of Lorenzini, which contain a large array of individual receptors that can detect E-fields. The electro-receptors are primarily used to detect bioelectric fields emitted by potential prey (Kalmijn, 1971, cited in Hutchison et al., 2021). Studies (e.g., Hutchison et al., 2020a; Kalmijn, 1966; Kajiura and Holland, 2002; Kajiura and Fitzgerald, 2009) have shown that elasmobranchs show behavioural reactions to electrical fields of between 5-30µV/m. Studies have shown that Ie-fields can cause either attraction or repulsion of elasmobranch species, depending on the field strength applied (Gill and Taylor, 2001; Kimber et al., 2011). The threshold for the change between attraction and avoidance of Ie-fields in elasmobranchs is between about 400-1,000µV/m (reviewed in CMACS, 2012). These levels would only likely be found at or within 1-2m of the seabed for a cable buried at 1m. For deeper burial, the Ie-field at the seabed would be correspondingly lower. Observations of behavioural reactions of elasmobranchs to Ie-fields caused by offshore electricity cables is limited, with some studies showing small changes in behaviour when the cable is powered compared to when not, suggesting that elasmobranchs can detect EMFs generated by underwater cables (Gill et al., 2009). However, the behavioural changes appeared to be dependent on the individual and species observed, and as such consequences at the population level are uncertain. A more recent study by Hutchison et al. (2020b) quantified behavioural responses of the electro-sensitive little skate (*Leucoraja erinacea*) to EMF emissions of a subsea high voltage direct current (HVDC) transmission cable. The study observed an increase in exploratory/foraging behaviour in the skates in response to EMFs. A study commissioned by the British Marine Management Organisation (MMO) (2014) found no evidence to suggest that EMF posed a significant risk to elasmobranchs at the site or population level. In a review by Tricas and Gill (2011), it was noted that the sensitivity of elasmobranchs to E-fields was highest at frequencies of 1-10Hz, with a broader response frequency range of 0.01-25Hz where fields intensities of 10x or greater were required to elicit a reaction. This suggests that weak fields such as those generated by offshore wind AC cables are likely to be mostly undetectable.

Receptor	Sensitivity
	Overall, current knowledge suggests that elasmobranch species may exhibit some behavioural changes to the localised EMFs generated during the operational phase of the proposed development. No significant changes to populations or distributions of species have so far been recorded (Hvidt et al., 2004; MMO, 2014). Taking this into consideration, all elasmobranchs VERs are deemed to be of **low** sensitivity to impacts from EMF.
Diadromous VERs	Most research on the sensitivity of teleost fish to EMFs has been undertaken in migratory species such as Salmonidae, Anguillidae and Scombridae (reviewed in Tricas and Gill, 2011). Some of these species, such as Atlantic salmon and the European eel, have magneto-receptors, which are thought to primarily be used for navigation using the Earth's magnetic field (Gill and Bartlett; Hutchison et al., 2020a,b). There have therefore been suggestions (Gill et al., 2005) that the presence of magnetic fields (B-fields) generated by submarine cables may interrupt navigation and consequently migration in these species. Field studies investigating the response of magneto-sensitive species to artificial EMF emissions are limited. Using acoustic transmitters, Wyman et al. (2018) studied the movement patterns of Chinook salmon smolts before and after the installation of a high-voltage current cable within San Francisco Bay. Their data showed mixed effects with salmon smolts swimming parallel to the cable observed to swim faster, and some possible attraction to the active cable leading to misdirection and increased transit times. However, the survival and outward migration success was not affected (Wyman et al., 2018). Minor route deviations and short-term delays in migration have also been observed in the European eel in response to AC and DC B-fields; however, the effects were of short duration and not considered to impact the overall migration (reviewed in Öhman et al., 2007). Of importance to the proposed development, no effects were seen in European eel from AC fields of 9.6µT (Orpwood et al., 2015), suggesting that there may be differences in effects between DC and AC cabling. Overall, the current evidence suggests that magneto-receptive diadromous fishes like Atlantic salmon and European eel may exhibit short-term, localised behavioural changes to magnetic fields emitted by subsea power cables, which, however, are unlikely to affect their migratory patterns and behaviour in the long-term. Impacts from induced electric fields (Ie-fields) would not be expected. Taking this into consideration, Atlantic salmon and European eel are deemed to be of low sensitivity to impacts from EMFs. Some migratory species may be sensitive to electric fields. Lampreys possess specialised ampullary receptors that are responsive to weak, low frequency E-fields (Bodznick and Northcutt, 1981; Bodznick and Preston, 1983), but information regarding what use they make of the electric sense is limited. Observations by Chung-Davidson et al. (2008) suggest that weak E-fields may play a role in the reproduction of sea lamprey, with electric stimuli thought to be important in detecting potential mates, retaining lampreys in their nests or in regulating sexual behaviour.. Others have suggested that adult sea lamprey may use their electric senses to locate prey over short distances or to navigate by using the electric fields induced in the water column by the Earth's magnetic fields (Bodznick and Preston, 1983). Laboratory tests conducted on adult sea lamprey (i.e. individuals at their marine stage) showed strong reductions in swimming behaviour at electric fields strengths of 30µV/cm and above (Chung-Davidson et al., 2004). Overall, current evidence suggests that the threshold for behavioural response in sea lamprey lies within the range of electric field induced by subsea power cables (CMACS, 2003; Normandeau Associates et al., 2011). Taking the above into consideration, river and sea lamprey are deemed to be of **low** sensitivity to impacts from EMFs from subsea power cables. Information on the impact of EMFs on the other diadromous species (sea trout and twaite shad) is limited. A broad scale study of fish aggregations and directional movement around subsea cables at the Nysted offshore wind farm in Denmark showed no evidence of any change in directionality or distribution of species as a result of the cable installation (Hvidt et al., 2004). Taking this into consideration, these species are deemed to be at most of **low** sensitivity to impacts from EMF.
Pelagic, demersal and substrate-spawning VERs	Information on the impact of EMFs on other fish species is limited. A broad scale study of fish aggregations and directional movement around subsea cables at the Nysted offshore wind farm in Denmark showed no evidence of any change in directionality or distribution of species as a result of the cable installation (Hvidt et al., 2004). Taking this into consideration, all other fish VERs are deemed to be at most of **low** sensitivity to impacts from EMF.
Shellfish VERs	Many marine invertebrates are thought to be magneto-sensitive, with this often being used for navigational purposes, such as during migration. However, evidence for potential impacts from anthropogenic B-fields is limited and has been contradictory even within the same species. Studies on the green shore crab have been directly contradictory, with one study demonstrating reduced aggression in response to AC, B -fields matching those from an offshore wind farm (Everitt, 2008), while another study showed no effects from static B-fields (Bochert and Zettler, 2004). Behavioural responses were also observed in the Dungeness crab Metacarcinus magiste, with more frequent changes in behaviour observed within the first two days of EMF exposure (Woodruff et al., 2012). Brown shrimp were recorded as being attracted to B-fields of the magnitude expected from offshore wind cabling (ICES, 2003). A recent study (Hutchison et al., 2020b) indicated potential subtle changes to exploratory behaviour in American lobster Homarus americanus in response to DC B-fields when in tanks placed near a subsea cable.

Receptor	Sensitivity
	However, the authors noted that there was no indication that the behavioural change was related to the differing EMF strengths within the enclosure. Conversely, no behavioural responses were observed in an aquarium study of juvenile European lobsters to an artificial magnetic field gradient with a maximum intensity of 200µT (Taormina et al., 2020a). Recent studies have also identified both behavioural (Scott et al., 2018) and physiological (Scott et al., 2021) reactions in brown crab from EMF. Scott et al. (2018) suggests that the natural roaming behaviour, where individuals will actively seek food and/or mates has been overridden by an attraction to the source of the EMF. However, the exposure to EMF does not affect the activity levels of the crabs but affects their ability to select a site to rest. Scott et al. (2021) investigated the effects of EMF (strengths 250µT, 500µT and 1000µT) from submarine power cables on edible crab and showed limited physiological and behavioural effects on the crabs exposed to EMF of 250µT. EMF of 500µT or above showed physiological stress in crabs, and changes to behavioural trends, specifically an attraction to EMF. It is to be noted however, that these studies investigated EMF strengths significantly higher than those that receptors will typically be exposed to as a result of offshore wind cables in the marine environment. Specifically, the lowest experimental EMF used in Scott et al. (2021) was a factor of 10 higher than that expected for the proposed development, with no impacts identified at this EMF strength. Effects were only noted in these studies using EMF strengths which were a factor of 20-1,000 higher than those expected from cables. A very small number of studies have suggested that some invertebrates may also be able to detect E-fields (Patullo and Macmillan, 2007; Steullet, et al., 2007). However, E-fields are thought to trigger chemo- and mechano-sensory neurons rather than specialised E-field receptors (unlike the ampullae of Lorenzini present in elasmobranchs) (Tricas and Gill, 2011). The studies were undertaken using voltages which were orders of magnitude greater than those predicted from the proposed development (Patullo and Macmillan, 2007; Steullet, et al., 2007). Taking the above into consideration, it is concluded that B-fields generated during the operational phase may lead to behavioural changes in some shellfish species. Such changes would be restricted to the immediate vicinity of the cable, and therefore, the sensitivity of the shellfish VERs to EMFs is deemed to be **low**.

In summary, the maximum sensitivity of fish and shellfish receptors to the introduction of EMFs is deemed to be low.

Magnitude of impact

EMFs generated by the power cables are likely to be detectable above background levels only in close proximity to the cables (i.e., within about 10 metres), as the EMFs created will rapidly attenuate away from the centre line of the cables (e.g. Normandeau Associates et al., 2011). The maximum extent of the impact will therefore be localised and restricted to the immediate vicinity of the cables.

The impact will occur constantly throughout the 35-year operational phase of the development when the cables are carrying a current, and therefore it will be long-term (15-60 years).

The impact will be highly localised and restricted to discrete areas within the array area and ECC. It is predicted that the impact may affect fish and shellfish receptors directly, potentially leading to behavioural changes within the near-field. Diadromous VERs will be transient across the study area, while the remaining receptors are widely distributed within the study area and Irish Sea; therefore, any localised behavioural changes are considered small compared to the overall extent of available habitat across the study area and wider region. Based on this, any effects of EMFs on fish and shellfish receptors are assessed as being at most barely discernible from baseline conditions. Consequently, the maximum magnitude of the impact is deemed to be low (adverse).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is low, and the maximum magnitude of the impact is low (adverse). The maximum low sensitivity and maximum low magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.4 Decommissioning Phase

This section presents the assessment of impacts arising during the decommissioning phase of the proposed development. The effects during decommissioning of the proposed development have been assessed on fish, marine turtles, and shellfish VERs within the fish and shellfish study area as defined in Section 13.2.5. The environmental impacts arising during decommissioning of the proposed development are listed in Table 13.12 along with the design options against which each decommissioning phase impact has been assessed.

13.5.4.1 Impact 11: Temporary increase in SSC and sediment deposition arising during the decommissioning phase

During the decommissioning phase, the removal (or partial removal) of any surface and subsurface infrastructure and associated protection measures would be expected to lead to localised seabed disturbance, which is likely to result in short-term periods of increased SSCs and sediment deposition. Elevated levels of suspended sediments and associated bed level changes would be comparable or less to those experienced during the construction phase. The impact would occur intermittently through the decommissioning phase and would be temporary or of short-term duration. Consequently, the magnitude of impact for the different fish and shellfish receptors would be no greater than that during construction activities (Table 13.15). The sensitivities of the fish and shellfish VERs to the impact would remain as described for the construction phase (Table 13.13).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and the maximum low (adverse) magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.4.2 Impact 12: Temporary habitat damage or disturbance of the seabed during decommissioning activities

Decommissioning of subsea infrastructure would cause temporary damage or disturbance to the seabed in the array area and ECC. The extent of the impact would be restricted to the immediate footprint of decommissioning activities within the near-field. It is anticipated that the area to be affected would be comparable or less to that affected during the construction phase (Table 13.12). The impact would occur infrequently in discrete locations and would be of short-term duration (one to seven years), although works in any given discrete location within the offshore development area will often be temporary (less than one year). Consequently, any impacts on fish and shellfish receptors would be no greater in magnitude than those encountered during construction activities (Table 13.17). The sensitivities of fish and shellfish VERs to the impact remain as described for the construction phase (Table 13.16).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the maximum magnitude of the impact is low (adverse). The maximum medium sensitivity and maximum low magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.5.4.3 Impact 13: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination

As described for Impact 11, the removal (or partial removal) of any surface and subsurface infrastructure and associated protection measures during the decommissioning phase would lead to localised seabed disturbance, which is likely to result in short-term periods of increased SSCs and sediment deposition. This has the potential for sediment-bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on fish, marine turtles and shellfish receptors. Furthermore, there is a risk of accidental spillages from equipment or collision incidents during decommissioning activities, potentially resulting in the release of pollutants such as fuel, oil and lubricants. Accidental releases of pollutants will be managed and mitigated through the implementation of an Offshore EMP (Table 13.11), and this aspect is therefore not considered further in the assessment.

As detailed in Table 13.12, elevated levels of suspended sediments and associated releases of sediment-bound contaminants would be comparable or less to those experienced during the construction phase. Consequently, any impacts on fish and shellfish receptors would be no greater in magnitude than those encountered during construction activities (Table 13.18). The sensitivities of fish and shellfish VERs to the impact would remain as described for the construction phase (Impact 3).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is medium, and the magnitude of the impact is negligible. The medium sensitivity and negligible magnitude of the impact on fish and shellfish receptors would result in a not significant effect, which is not significant in EIA terms.

13.5.4.4 Impact 14: Introduction of underwater noise and vibration leading to mortality, recoverable injury, TTS and/or behavioural effects during decommissioning

The removal (or partial removal) of any surface and subsurface infrastructure and associated protection measures during the decommissioning phase would generate underwater noise, which may affect sensitive receptors. However, impact piling or clearance of UXO would not be necessary, thereby reducing the likelihood of lethal effects.

Any potential TTS or behavioural reactions as a result of non-impulse sounds (e.g. during vessel operations or the removal of foundations) are expected to be reversible. Moreover, the impact is expected to be of short-term duration (one to seven years, as defined in the EPA guidance, 2022), although works in any given discrete location within the offshore development area may be temporary (less than one year).

Based on the above, any effects on fish and shellfish receptors from underwater noise during decommissioning would be no greater or less in magnitude than those resulting from non-impulse sounds generated during construction activities (Impact 4: Likely significant effects from other noise sources). The sensitivities of fish and shellfish VERs to the impact remain as described for the construction phase (Impact 4: Likely significant effects from other noise sources).

Significance of effects

Overall, it is predicted that in relation to Project Option 1 and Project Option 2 the maximum sensitivity of the fish and shellfish receptors to the impact is low, and the maximum magnitude of the impact is low (adverse). The maximum low sensitivity and maximum low magnitude of the impact on fish and shellfish receptors would at most result in a slight (adverse) effect, which is not significant in EIA terms.

13.6 Mitigation and Monitoring Measures

Mitigation measures that were identified and adopted as part of the evolution of the proposed development design (embedded into the project design) and that are relevant for fish and shellfish receptors are listed in Table 13.11. No additional mitigation or monitoring measures are considered necessary for the construction, operation and decommissioning phases specific to the potential impacts on fish and shellfish ecology.

13.7 Residual Effects

This section presents the residual effects of the proposed development once the mitigation outlined in Section 13.6 has been applied. No additional measures are considered necessary to mitigate against potential significant effects on fish and shellfish VERs, and therefore there is no difference between the pre-mitigation effects outlined in Section 13.5 and the residual effects. Table 13.31 provides a summary of the impact assessment outcomes.

Table 13.31 Residual effects relating to fish and shellfish ecology

Potential Impact	Likely significant effect– Project Option 1	Likely significant effect– Project Option 2	Residual effect – Project Option 1	Residual effect – Project Option 2
Construction				
Impact 1: Temporary increase in SSC and sediment deposition arising during the construction phase	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 2: Temporary damage and disturbance of the seabed during construction activities	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 3: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination	Not significant	Not significant	Not significant	Not significant
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 4: Introduction of underwater noise and vibration leading to mortality, injury, TTS and/or behavioural effects during construction	Mortality and recoverable injury - Slight TTS and behavioural changes - Slight UXO clearance - Slight Other noise sources - Slight	Mortality and recoverable injury - Slight TTS and behavioural changes - Slight UXO clearance - Slight Other noise sources - Slight	Mortality and recoverable injury - Slight TTS and behavioural changes – Slight UXO clearance VERs - Slight Other noise sources - Slight	Mortality and recoverable injury - Slight TTS and behavioural changes - Slight UXO clearance - Slight Other noise sources - Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Operations and Maintenance				
Impact 5: Temporary increase in SSC and sediment deposition arising during maintenance activities	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 6: Temporary damage and disturbance of the seabed during maintenance activities	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 7: Long-term/permanent loss of benthic habitat due to the placement of subsea infrastructure	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
	Not significant	Not significant	Not significant	Not significant

Potential Impact	Likely significant effect– Project Option 1	Likely significant effect– Project Option 2	Residual effect – Project Option 1	Residual effect – Project Option 2
Impact 8: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 9: Increase in hard substrate and structural complexity due to the placement of subsea infrastructure	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 10: Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Decommissioning				
Impact 11: Temporary increase in SSC and sediment deposition arising during the decommissioning phase	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 12: Temporary damage and disturbance of the seabed during decommissioning activities	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 13: Reduction in water and sediment quality through the release of contaminated sediments and/or accidental contamination	Not significant	Not significant	Not significant	Not significant
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	
Impact 14: Introduction of underwater noise and vibration leading to mortality, recoverable injury, TTS and/or behavioural effects	Slight	Slight	Slight	Slight
			No further mitigation (in addition to that already identified in Table 13.11) is considered necessary. No ecologically significant adverse residual effects on fish and shellfish ecology receptors have therefore been predicted.	

13.8 Transboundary Effects

Transboundary effects are defined as those effects upon the receiving environment of other states, whether occurring from the proposed development alone, or cumulatively with other projects in the wider area.

This assessment considers the potential for transboundary effects arising from the residual effects of the proposed development (i.e., after any additional mitigation measures have been applied).

Among the impacts assessed in Section 13.5, the following impacts would be restricted to the offshore development area and have therefore been screened out of the assessment of transboundary effects: Temporary habitat damage and disturbance of the seabed during construction, maintenance and decommissioning activities (Impacts 2, 6 and 12), Long-term and permanent loss of benthic habitats due to the placement of subsea infrastructure (Impact 7), Increase in hard substrate and structural complexity due to the placement of subsea infrastructure (Impact 9), and Potential barriers to movement through the presence of turbines and EMF from inter-array and export cables (Impact 10).

Sediment plumes generated during construction (Impact 1), maintenance (Impact 5) and decommissioning (Impact 11) activities have the potential to disperse into UK waters during periods of spring tides; however, any sediment plumes reaching UK waters are predicted to be imperceptible against natural background levels (Physical Processes Chapter). Therefore, sediment plumes moving into UK waters are not anticipated to affect fish and shellfish receptors outside Irish waters. Any effects resulting from the potential release of sediment-bound contaminants during construction (Impact 3), maintenance (Impact 8) and decommissioning (Impact 13) activities have been assessed to be of negligible magnitude, and as such these impacts are not anticipated to result in significant transboundary effects.

Potential mortality or recoverable injury to fish and shellfish receptors due to underwater noise from impact piling and UXO clearance are predicted to be restricted to areas within Irish waters (Impact 4, Table 13.12, Figures 13.13 to 13.16). However, TTS or behavioural reactions as a result of piling during the construction phase would occur over larger ranges (tens of kilometres) with the potential for effects to occur in UK waters (Figures 13.13 to 13.16).

With the exception of spawning herring, the magnitude of any disturbance impacts (TTS and behavioural changes) has been assessed as being low (adverse) for all fish and shellfish VERs, with the significance of any effects (including transboundary effects) concluded to be slight (adverse), which is not significant in terms of the EIA regulations. On a precautionary basis, the magnitude of any TTS and behavioural responses in spawning herring has been assessed as medium (adverse), with the sensitivity of herring to non-lethal noise effects from piling deemed to be low. Therefore, the significance of transboundary TTS and behavioural disturbance in spawning herring is concluded to be slight (adverse), which is not significant in EIA terms.

13.9 Cumulative Effects

Likely significant cumulative effects of the proposed development in-combination with existing and/ or approved projects for fish and shellfish ecology have been identified, considered and assessed. The methodology for this cumulative assessment is a three-stage approach which is presented in the Cumulative and Inter-Related Effects Chapter.

The Cumulative and Inter-Related Effects Chapter contains the outcome of Stage 1 Establishing the list of ‘Other Existing and/or Approved Projects’; and Stage 2 ‘Screening of ‘Other Existing and/or Approved Projects’. This section presents Stage 3, an assessment of whether the proposed development in-combination with other projects grouped in tiers, would be likely to have significant cumulative effects.

The assessment specifically considers whether any of the approved developments in the local or wider area have the potential to alter the significance of effects associated with the proposed development. Developments which are already built and operating, and which are not identified in this chapter, are included in the baseline environment or have been screened out as there is no potential to alter the significance of effects.

The assessment of cumulative effects has considered likely significant effects that may arise during construction, operation and decommissioning of the proposed development. Cumulative effects were assessed to a level of detail commensurate with the information that has either been directly shared with the proposed development or was publicly available at the time of assessment.

Given the location and nature of the proposed development, a tiered approach to establishing the list of other existing and/or approved projects has been undertaken in Stage 1 of the cumulative effects assessment. The tiering of projects is based on project relevance to the proposed development, and it is not a hierarchical approach nor based on weighting. Further information on the tiers is provided in in Section 13.9.2 and in the Cumulative and Inter-Related Effects Chapter.

13.9.1 Fish and shellfish cumulative screening exercise

The existing and/or approved projects selected as relevant to the cumulative effects assessment of impacts to fish and shellfish ecology are based on an initial screening exercise undertaken on a long list (see Cumulative and Inter-Related Effects Chapter) based on spatial distance to the proposed development. Consideration of effect-receptor pathways, data confidence and temporal and spatial scales has then allowed the selection of the relevant projects for the fish and shellfish ecology cumulative short-list.

The initial long list was established by applying a screening range of 100km buffering the array area to encapsulate potential cumulative impacts from underwater noise. Based on project-specific noise modelling for the proposed development, the greatest impact range for the onset of TTS (186dB SEL_{cum}) for stationary fish during piling of foundations is 69km (Table 13.22). To inform the cumulative assessment, it is assumed that maximum impact ranges for underwater noise effects resulting from other consented and proposed OWFs within the Irish Sea would be similar to those predicted for the proposed development. For example, for the Awel y Mor (AyM) OWF located in Welsh waters, the predicted maximum impact range for the onset of TTS was 36km for stationary receptors and 17km for fleeing receptors (RWE, 2023). Therefore, a screening range of 100km is considered to be suitably precautionary and to encapsulate the area within which potential significant cumulative effects on fish and shellfish receptors from underwater noise might occur.

A screening range of 100km has also been applied to encompass potential cumulative impacts relating to seabed disturbance events including increases in SSC and sediment deposition. It is acknowledged that sediment plumes created during the construction, operation, and decommissioning phases of the proposed development are predicted to be detectable above background levels at distances up to 12km (Physical Processes chapter), and consequently cumulative effects as a result of overlapping plumes and sediment deposition events with other projects would be confined to a much smaller area than the selected screening range of 100km. However, there is potential for non-overlapping sediment plumes or sediment deposition to simultaneously disturb spawning or nursery grounds, which may lead to cumulative effects on the reproductive or recruitment success of sensitive receptors. For this reason, a wider screening range of 100km has been applied, which encapsulates the extent of mapped fish spawning grounds within the western Irish Sea. As described in the Fish and Shellfish Technical Baseline and summarised in Section 13.3.6, several VERs (e.g., plaice and cod) favour shallower inshore areas for spawning, with many spawning grounds showing a predominantly north-south orientation along the coast.

For the full list of projects considered, including those screened out, please see the Cumulative and Inter-Related Effects Chapter and Appendix 38.1.

13.9.2 Projects considered within the cumulative effects assessment

The planned, existing and/or approved projects selected through the screening exercise as potentially relevant to the assessment of impacts to fish and shellfish ecology are presented in Table 13.32.

The tiers for the assessment are:

- Tier 1 is limited to the Operation and Maintenance Facility (OMF) for the proposed development. The OMF option being considered involves the adaption and leasing part of an existing port facility at Greenore. Further detail is provided in the Offshore Description Chapter
- Tier 2 is the east coast Phase One Offshore Wind Farms.
- Tier 3 is all other projects that have been screened in for this topic.

The tiering structure is intended to provide an understanding of the potential for likely significant effects of the proposed development with the construction of its OMF (tier one); followed by a cumulative assessment of the likely significant effect of that scenario combined with the east coast Phase One Offshore Wind Farms (tier two); and lastly the combination of tier one and tier two with all other existing and/or approved projects that have been screened in (tier three).

Table 13.32 Projects and plans screened into the cumulative effects assessment

Development Type	Project	Status	Distance to array area	Distance to ECC	Data Confidence	Justification for screening into the assessment
Tier 1						
Proposed development OMF at Greenore	Greenore OMF	Pre-consent	33.9km	38.8km	Low - No published documentation available at time of writing.	Owing to the early stage of the project within the planning process, exact information related to the proposed works is not available. However, it is anticipated that some piling may be required for the pontoon, for which there may be an impact on fish and shellfish receptors. The proposed construction of the OMF is limited to the onshore expansion of facilities and is therefore not considered to have the potential to contribute to changes in SSC, sediment deposition or cumulative temporary or long-term damages or disturbances of the seabed. Therefore, only underwater noise in the only impact screened into the cumulative assessment.
Tier 2						
Phase One OWFs	Oriel Wind Park	Pre-consent	16.9km	21.6km	Medium - Scoping report available at time of writing. A foreshore license has been granted for site investigations (2022-2027). Reference FS007383	Owing to the early stage of the project within the planning process, exact information related to the proposed works is not available. However, up to 25 WTGs have been identified as the offshore design parameters for this Project. Construction is anticipated to take place 2026-2028.
	Dublin Array	Pre-consent	32.9km	37.6km	Medium - Scoping report available at time of writing. A foreshore license has been granted for site investigations (2022-2027). Reference FS007188. Site investigations have been undertaken and EIA in prep.	Owing to the early stage of the project within the planning process, exact information related to the proposed works is not available. However, up to 49 WTGs, two export cables and one OSP have been identified as the offshore design parameters for this Project. Offshore construction has been scheduled to take place between 2028-2032.
	Codling Wind Park	Pre-consent	50.9km	56.9km	Medium - Scoping Report available at the time of writing. A foreshore licence has been granted for site investigations. Reference FS007045	Owing to the early stage of the project within the planning process, exact information related to the proposed works is not available. However, up to 140 WTGs, 6 export cables and up to 5 OSPs have been identified as the offshore design parameters for this Project. Construction is anticipated to take place during 2027-2028.
	Arklow Bank Phase 2	Pre-consent	76.4km	80.0km	Medium - Scoping report available at time of writing. A foreshore license has been granted for site investigations (2022-2027). Reference FS007339.	Owing to the early stage of the project within the planning process, exact information related to the proposed works is not available. Between 36 and 60 WTGs, two export cables and one or two OSPs have been identified as the offshore design parameters for this Project. Construction is anticipated to take place 2026-2030.

Development Type	Project	Status	Distance to array area	Distance to ECC	Data Confidence	Justification for screening into the assessment
					Site investigations have been undertaken and EIA in prep.	
Tier 3						
Dredging, disposal at sea, and coastal assets and infrastructure	Drogheda Port Company	Consented	11.7km	10.2km	High - Consented Permit S0015-03 Licence FS005747 Licence FS007028	Maintenance dredging between the period 2021 and 2029 within the commercial estuary of the river Boyne and associated release of dredged material from vessels at predefined dumping sites approximately 4km northeast (site A1) and 4km north (site A2) from the Drogheda port entrance.
Dredging, disposal at sea, and coastal assets and infrastructure	Dublin Port Company MP2 Project	Consented	18.6km	31.9km	High - Under construction Licence FS006893 Permit S0024-02 Permit S0024-03	Construction activities in Dublin Harbour scheduled to take place 2022-2032; works include dredging within Dublin Harbour and the release of dredged material from vessels west of Burford Bank in outer Dublin Bay. Various activities in Dublin Port including construction of passenger building and new jetty.
Disposal	Warrenpoint B	Consented	23.7km	28.9km	High - Consented Licence ML2023040	Sea disposal of dredging material from Warrenpoint Harbour for 2024-2027 to be disposed of at Warrenpoint B sea disposal site.
Subsea cables	Mares Connect	Pre-consent	33.2km	41.5km	Low – Pre-consent	Subsea power cable; construction anticipated 2024-2027.
Subsea cables	Havhingsten Telecoms Cable	Active	0.7km	9.7km	High - Operational	Active power and telecommunication cables; screened into the assessment to evaluate the potential for cumulative effects from the operation of additional subsea cables within the fish and shellfish in-combination assessment area.
Subsea cables	Rockabill Telecoms Cable	Active	4.9km	13.0km	High - Operational	
Subsea cables	East West Interconnector	Active	5.0km	11.4km	High - Operational	
Subsea cables	HIBERNIA ‘C’	Active	7.7km	17.0km	High - Operational	
Subsea cables	SIRIUS SOUTH	Active	9.4km	18.7km	High - Operational	
Subsea cables	CeltixConnect	Active	11.3km	20.1km	High - Operational	
Subsea cables	ZAYO Emerald Bridge One	Active	12.1km	20.2km	High - Operational	
Subsea cables	ESAT 2	Active	14.4km	24.2km	High - Operational	
Subsea cables	HIBERNIA ATLANTIC	Active	28.9km	26.7km	High - Operational	

Development Type	Project	Status	Distance to array area	Distance to ECC	Data Confidence	Justification for screening into the assessment
Subsea cables	Western HVDC Link	Active	54.2km	62.6km	High - Operational	
Subsea cables	HIBERNIA 'A'	Active	56.0km	64.5km	High - Operational	
Subsea cables	MANX-N.IRELAND	Active	64.2km	71.7km	High - Operational	
Subsea cables	LANIS 2	Active	84.3km	92.3km	High - Operational	
Subsea cables	Arklow Phase 1 Power Cable	Active	87.6km	89.8km	High - Operational	
Subsea cables	LANIS 1	Active	92.8km	101.3km	High - Operational	
Subsea cables	SCOTLAND - N.IRELAND 1	Active	99.8km	106.6km	High - Operational	
Survey	Proposed Mares Connect Electricity Interconnector Site Investigation	Consented	17.9km	2.0km	Medium Licence FS007635	Geophysical survey for five months in summer/autumn of 2024; included in the cumulative assessment to account for potential survey delays.
Survey	Codling Wind Park Site Investigation	Consented	68.7km	76.3km	Medium Licence FS007546	Ongoing geophysical and geotechnical site surveys to inform EIA/AA and construction; survey schedule unknown but assumed to cover period up to end of construction in 2028.
Survey	Arklow Bank Wind Park Phase 2	Consented Pre-consent	76.6km	81.0km	Medium Licence FS007339 Low Licence FS007555	Ongoing geophysical and geotechnical site surveys; survey schedule unknown, assumed to cover period up to end of construction in 2030.
Coastal assets and infrastructure	Dublin Port maintenance dredging	Consented	23.4km	36.0km	High Licence FS007132	Ongoing maintenance dredging at various locations in Dublin Port from 2022-2029.
Coastal assets and infrastructure	Ringsend Wastewater Treatment Works Extension	Consented	23.5km	36.2km	Medium Licence D0034-01	Works include the construction of a marine outfall pipeline from Baldoyle Estuary to a discharge point 1km north-east of Ireland's Eye.
Coastal assets and infrastructure	Greenore Port Development	Consented	32.5km	34.2km	Medium Licence FS006748	Construction of Berth 2 at Greenore Port, which includes dredging works.

Development Type	Project	Status	Distance to array area	Distance to ECC	Data Confidence	Justification for screening into the assessment
Coastal assets and infrastructure	Arklow Bank Phase 2 Operations and Maintenance Base	Consented	79.9km	92.4km	High Planning application 211316	Construction of the Arklow 2 onshore OMF, which may include dredging of nearshore areas to provide for navigational depth for vessels.

Construction of the proposed development is anticipated to occur between 2026 to 2029, with offshore construction currently being scheduled between 2027 and 2029, including preparation works. After construction, the proposed development would be operational for 35 years.

13.9.3 Project impacts included in the assessment

The identification of potential impacts has been undertaken by considering the relevant characteristics from both project options (refer to Section 13.4.1) and the potential for a pathway for them to have direct and indirect effects on known receptors (as identified in Section 13.3) when combined with other projects. Each identified impact relevant to fish and shellfish ecology is presented in Table 13.12.

For each impact, the project option with the greatest potential for a likely significant effect has been determined based on the comparison and justification provided in Table 13.32. The impacts and the project option considered in the cumulative assessment are presented in Table 13.33.

The identification of potential impacts has been undertaken by considering the outcome of the residual effects assessment (Section 13.7) and the potential for a pathway for those impacts to have direct and/or indirect effects on known receptors (as identified in Section 13.3) when combined with the impacts from other projects. Each identified impact relevant to the cumulative assessment of fish and shellfish ecology is presented in Table 13.33. As the residual effects for Project Option 1 and Project Option 2 are the same (as identified in Section 13.7), the cumulative effects assessment presented in this section applies to both options.

13.9.3.1 Tier 1

The OMF will be required to service the offshore wind farm throughout the operational phase of the proposed development. Since the OMF will be subject to separate planning/permitting consents, it is considered within the cumulative impact assessment for fish and shellfish. The OMF will be located onshore as a part of an existing port facility at Greenore. The port will need to be adapted to provide, amongst others, berthing facilities to support the crew transfer vessels. In addition, it is expected that a new pontoon would need to be constructed, and therefore it is anticipated that piling will take place during the construction of the OMF.

13.9.3.2 Tier 2

All Phase One OWFs in Ireland have been awarded a Maritime Area Consent (MAC); however, none of the projects will have formally submitted applications for planning consent and were not awarded consent within the timescales for delivery of the EIAR for the proposed development. Notwithstanding this, due to the likely similar development timelines of the Phase One projects and the resultant risk associated with cumulative effects, Phase One OWF projects were assessed under Tier 2. In line with the tier hierarchy (for more details see the Cumulative and Inter-Related Effects Chapter), the assessment for Tier 2 also includes Tier 1 projects.

Owing to the early stage of the Phase One OWF projects within the planning process, site-specific information relating to the spatial and temporal extent of impacts from these projects is limited.

Plans for the Oriel OWF indicate that the proposed development will comprise 25 WTGs. Construction is anticipated to take place between 2026 and 2028, with piling of foundations anticipated to take place in 2027. This suggests that construction work would be mostly completed before offshore construction of the proposed development commences.

Plans for Dublin Array OWF indicate that the proposed development will comprise 49 WTGs, one OSP and two export cables. Dates for offshore construction have been identified as 2028-2032, which indicate that the majority of offshore construction for the proposed development would be completed before construction of Dublin Array commences.

Plans for Codling OWF indicate that the proposed development may comprise 140 WTGs, 6 export cables and 5 OSPs. Indicative dates for construction have been identified as 2027 to 2028, which suggests that work would overlap with the construction of the proposed development.

Plans for Arklow Bank Phase 2 OWF indicate that the proposed development may comprise 60 WTGs, two export cables and two OSPs. Dates for construction have been identified as 2026 to 2030, which indicates overlap with the construction of the proposed development.

13.9.3.3 Tier 3

Tier 3 projects that may contribute to cumulative effects through simultaneous or sequential activities prior to or during the construction phase of the proposed development include dredging and associated sediment disposal at the Drogheda and Dublin ports, construction of the Mares Connect power cable, and activities associated with the Greenore Port extension, the construction of the Arklow Bank Operations and Maintenance Base, and the extension of the Ringsend Wastewater Treatment Plant (Table 13.32). Existing and proposed power and telecommunications cables within the cumulative assessment area are considered for their potential to give rise to effects in-combination with EMFs emitted from cables installed at the proposed development. In addition, geophysical surveys that may take place during the construction phase of the proposed development are assessed for their potential to contribute to cumulative effects from underwater noise.

Table 13.33 Potential cumulative impacts and tiers for assessment

Potential cumulative impact	Phase	Tiers and Projects	Justification for inclusion in cumulative effects assessment
Cumulative Impact 1: Cumulative increase in SSC and sediment deposition	Construction, Operation, Decommissioning	**Tier 2** Phase One Offshore Wind Farms (OWF) **Tier 3** Drogheda Port Company Warrenpoint B Dublin Port Company MP2 Project and Dublin Port maintenance dredging Mares Connect power cable Ringsend Wastewater Treatment Plant extension Greenore Port Development Arklow Bank Phase 2 Operations and Maintenance Base	Dredging and sediment disposal, seabed preparation works, foundation and cable installation works from other projects can cause temporary increases in SSC and sediment deposition. If these activities overlap temporally with either construction, decommissioning or operational activities at the proposed development, there is potential for cumulative SSC and sediment deposition to occur, which may affect sensitive fish and shellfish receptors.
Cumulative Impact 2: Cumulative temporary damage and disturbance of the seabed	Construction, Operation, Decommissioning	**Tier 2** Phase One Offshore Wind Farms (OWF) **Tier 3** Drogheda Port Company Warrenpoint B Dublin Port Company MP2 Project and Dublin Port maintenance dredging Mares Connect power cable Ringsend Wastewater Treatment Plant extension Greenore Port Development Arklow Bank Phase 2 Operations and Maintenance Base	Dredging and disposal, and seabed preparation works and foundation and cable installation activities for other projects would result in temporary disturbance and damage of the seabed. If these activities overlap temporally with either construction, decommissioning or operational activities at the proposed development, there is potential for cumulative effects on fish and shellfish receptors that fully or partly depend on the seabed throughout their life cycle.
Cumulative Impact 3: Cumulative underwater noise and vibration	Construction	**Tier 1** Greenore OMF **Tier 2** Phase One OWF Projects **Tier 3** Greenore Port Development Geophysical and geotechnical surveys Non-impulse sounds all other projects	Concurrent construction activities or the long-term exposure to sounds due to sequential operations over prolonged periods of time could adversely affect sensitive fish and shellfish receptors. Cumulative effects may also arise from non-impulse sounds associated with geophysical and geotechnical surveys and vessel and/or construction activities from other projects within the region.

Potential cumulative impact	Phase	Tiers and Projects	Justification for inclusion in cumulative effects assessment
Cumulative Impact 4: Cumulative long-term loss of benthic habitats due to the placement of subsea infrastructure	Operation	**Tier 2** Phase One OWFs **Tier 3** Mares Connect power cable	The presence of OWF and other marine infrastructure in the marine environment, including foundations, scour protection and cable protection has the potential to cause long-term changes in the distribution of benthic fish and shellfish habitats through the presence of hard structures on the seabed.
Cumulative Impact 5: Cumulative barriers to movement through the presence of EMF from cables	Operation	**Tier 2** Phase One OWFs **Tier 3** Mares Connect power cable Active power and telecommunication cables	The installation of power cables would result in additional anthropogenic EMFs, which could affect electro- and magneto-sensitive receptors.

13.9.4 Cumulative Impact 1: Cumulative increase in SSC and sediment deposition

Dredging and sediment disposal, seabed preparation works, and foundation and cable installation activities associated with other projects can cause temporary increases in SSC and associated sediment deposition, which if temporarily overlapping with works at NIS may give rise to additive effects on sensitive receptors. This impact is associated primarily with activities that take place during the construction and decommissioning phases. The potential for significant cumulative effects on fish and shellfish receptors, as a result of cumulative increases in SSC and sediment deposition, is assessed in the following sections.

13.9.4.1 Tier 1

The proposed construction of the OMF is limited to the onshore expansion of facilities and is therefore not considered to have the potential to contribute to cumulative increases in SSC and sediment deposition (Table 13.32).

13.9.4.2 Tier 1 and Tier 2

The potential maximum magnitude of effects arising from the impact at the proposed development has been assessed as low (adverse) based on the short-term duration of construction, maintenance and decommissioning activities, and the intermittent, localised and temporary nature of changes in SSC and sediment deposition. Sediment plumes and deposition generated by the other Phase One OWF projects considered here, are anticipated to behave in a similar pattern as the sediments being disturbed by the proposed development due to expected similarities in activities combined with a similar environmental setting and sediment characteristics. Based on the distance between the Phase One projects, sediment plumes generated during activities at the Oriel OWF may be sufficient to interact with plumes from the proposed development. However, the potential increases in SSC, when considered cumulatively, are still anticipated to be temporary and intermittent, with SSC across overlapping plumes likely to be close to natural background levels. Any potential simultaneous disturbance effects on sensitive fish and shellfish receptors within the cumulative assessment area due to concurrent activities are expected to be localised, temporary and intermittent as sediment plumes are expected to quickly dissipate following cessation of activities. Similarly, any areas likely to be exposed to heavy sediment deposition would be localised and as such are expected to be small in the context of available suitable habitats of sensitive receptors in the study area and wider region. Therefore, any potential cumulative effects on fish and shellfish receptors resulting from the simultaneous increase in SSC and sediment deposition from the proposed development in-combination with Tier 2 projects are anticipated to be at most barely discernible from baseline conditions. Consequently, the maximum magnitude of the cumulative impact with respect to Tier 2 projects is assessed as being low (adverse).

As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

13.9.4.3 Tier 1, Tiers 2 and Tier 3 (all tiers)

A small number of dredging and dredge disposal sites are located within the cumulative assessment area, which have the potential to contribute to cumulative effects with the proposed offshore construction works through sediment plume or deposition effects. Those projects include ongoing maintenance dredging activities at Drogheda Port and Warrenpoint Harbour and the associated disposal of dredged material offshore at designated disposal sites (Drogheda Port Company project and Warrenpoint B disposal site) and port extension and maintenance dredging activities within Dublin Port and Bay and any associated dredge disposal west of Burford Bank in outer Dublin Bay (Dublin Port Company MP2 Project and Dublin Port maintenance dredging). Other activities that may contribute to the cumulative increase in SSC and sediment deposition include the installation of the proposed Mares Connect power cable, construction of the Greenore Port development, installation of a sewage outfall pipe as part of the Ringsend Wastewater Treatment plant extension, and the dredging of nearshore areas as part of the proposed construction of the Arklow Bank Phase 2 Operations and Maintenance Base (Table 13.32).

It is not known what volumes of sediment will be disturbed and/or released at the construction and disposal sites at any one time. However, given the distance between the projects and the offshore development area (the nearest Tier 3 project is the Drogheda Port project, with the nearest licensed sea disposal site located >10km from the array area), the potential for sediment plumes to interact is considered to be low.

If several dredging or construction activities are undertaken at the same time, there is potential for simultaneous disturbance effects within the cumulative assessment area; however, any changes in SSCs associated with the Tier 3 projects are expected to be temporary and intermittent, with sediment plumes expected to quickly dissipate following cessation of activities. Any areas likely to be exposed to heavy sediment deposition (i.e., at dredge disposal sites and areas in close proximity to construction activities) are expected to be small in the context of available suitable habitats of sensitive receptors in the study area and wider region. Therefore, any potential cumulative effects on fish and shellfish receptors resulting from the simultaneous increase in SSC and sediment deposition at the proposed development in-combination with Tier 3 projects are anticipated to be at most barely discernible from baseline conditions. Consequently, the maximum magnitude of the cumulative impact with respect to Tier 3 projects is assessed as being low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

In summary, sediment plumes and deposition generated by Tier 2 and Tier 3 projects are anticipated to behave in a similar pattern as the sediments being disturbed by the proposed development due to expected similarities in activities combined with a similar environmental setting and sediment characteristics. Any plumes associated with these projects will be intermittent and disperse rapidly within a couple of tidal cycles. Any heavy sediment deposition will be localised and small in the context of available suitable habitats of fish and shellfish receptors that depend on the seabed. Therefore, it is concluded that the maximum magnitude of potential cumulative effects on fish and shellfish receptors from the proposed development in-combination with Tier 2 and Tier 3 projects will be comparable to the project alone, i.e. low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms. Therefore, no additional mitigation to that already identified in Table 13.11 is considered necessary, and no significant adverse residual cumulative effects on fish and shellfish receptors have been predicted in respect to this impact.

13.9.5 Cumulative Impact 2: Cumulative temporary damage and disturbance of the seabed

Dredging and disposal, seabed preparation works, and foundation and cable installation activities associated with other projects can temporarily damage and disturb the seabed, which may give rise to additive effects on sensitive fish and shellfish receptors. This impact is associated primarily with activities that take place during the construction and decommissioning phases. The potential for significant cumulative effects on fish and shellfish receptors as a result of cumulative temporary disturbances of the seabed is assessed in the following sections.

13.9.5.1 Tier 1

The proposed construction of the OMF is limited to the onshore expansion of facilities and is therefore not considered to have the potential to contribute to cumulative damages or disturbances of the seabed (Table 13.32).

13.9.5.2 Tier 1 and Tier 2

Temporary disturbance and damage of the seabed associated with the Tier 2 Phase One OWF projects are anticipated to be similar in scale as the changes resulting from the proposed development due to expected similarities in project designs and offshore activities. Specifically, any changes to the seabed and effects on sensitive fish and shellfish receptors resulting from these projects are expected to be restricted to discrete areas within the array areas and ECCs of these projects, and as such these would be of local spatial extent Cumulative impacts would be of short-term duration, intermittent and reversible. Broadscale habitat maps (INFOMAR, 2023) suggest that the subtidal benthic substrates that would be affected are common and widespread within the wider region. Furthermore, the fish and shellfish receptors, including their spawning and nursery grounds are widely distributed within the cumulative assessment area. Therefore, any effects on fish and shellfish receptors when considered cumulatively, are still anticipated to be at most barely discernible from baseline conditions. Consequently, the maximum magnitude of the cumulative impact with respect to Tier 2 projects is assessed as being low (adverse).

As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

13.9.5.3 Tier 1, Tier 2 and Tier 3 (all tiers)

Of the Tier 3 projects screened into the cumulative assessment, ongoing maintenance dredging associated with the Drogheda Port project, Warrenpoint Harbour and the Dublin Port Company MP2 project may contribute to the cumulative damage and disturbance of the seabed through simultaneous dredging or sediment deposition. In addition, cumulative effects may arise during simultaneous offshore construction activities associated with the installation of the proposed Mares Connect power cable, the proposed port developments at Greenore and marine works associated with the extension of the Ringsend Wastewater Treatment Plant.

Physical impacts to the seabed associated with the Tier 3 projects are expected to be of local extent, temporary and reversible, with the cumulative duration of activities expected to be at most short-term. Broadscale habitat maps (INFOMAR, 2023) suggest that the subtidal benthic substrates that would be affected are common and widespread within the wider region. Furthermore, the fish and shellfish receptors are widely distributed within the study area and wider western Irish Sea and also use comparatively large areas for spawning (see Section 13.3). Therefore, any cumulative effects on fish and shellfish receptors resulting from potential simultaneous disturbances to the seabed from the proposed development in-combination with Tier 3 projects are anticipated to be at most barely discernible from baseline conditions. Consequently, the maximum magnitude of the cumulative impact with respect to Tier 3 projects is assessed as being low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

In summary, temporary damage or disturbance to the seabed resulting from the Tier 2 and Tier 3 projects will be localised, intermittent and reversible. Any cumulative changes to the distribution and abundance of sensitive fish and shellfish receptors resulting from Tier 2 and Tier 3 are assessed to be barely discernible from baseline conditions given the localised nature of the impact and the wide distribution of available supporting seabed habitats including spawning and nursery grounds. Therefore, it is concluded that the maximum magnitude of potential cumulative effects on fish and shellfish receptors from the proposed development in-combination with Tier 2 and Tier 3 projects will be comparable to the project alone, i.e. low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms. Therefore, no additional mitigation to that already identified in Table 13.11 is considered necessary, and no significant adverse residual cumulative effects on fish and shellfish receptors have been predicted in respect to this impact.

13.9.6 Cumulative Impact 3: Cumulative underwater noise and vibration

As presented in Table 13.33, all listed projects with the exception of existing power and telecommunications cables have been taken forward for this impact. As for the project alone, potential cumulative effects on sensitive fish and shellfish receptors include mortality and potential mortal injury, recoverable injury, TTS and behavioural changes as a result of construction activities (inclusive of piling activities, UXO clearance, seismic surveys, and non-impulse sounds from vessel operations and construction activities).

13.9.6.1 Tier 1

Cumulative underwater noise from piling

Construction of the OMF may involve piling as part of pontoon installation. Site-specific information relating to the duration and specifications (e.g., hammer energies) of these operations are currently not available. However, it is anticipated that piling at the OMF will take place between 2025 and 2026 before the piling of foundations within the array area. Moreover, given the distance of the OMF and the proposed development, the maximum impact ranges for the onset of mortality and recoverable injuries for these two projects are unlikely to overlap. Therefore, the potential for cumulative lethal or recoverable injury effects is limited. Moreover, piling for the OMF is anticipated to occur at most infrequently and would be temporary.

Any potential TTS or behavioural responses would be temporary and reversible, and it is therefore expected that sensitive receptors would resume to normal behaviour and distribution before the piling of foundations at the proposed development commences. Based on this, no discernible cumulative effects are expected to occur with respect to piling at the OMF, and therefore, as per the project alone assessment, the maximum significance of the impact is considered to be slight (adverse), which is not significant in EIA terms.

13.9.6.2 Tier 1 and Tier 2

Cumulative underwater noise from piling

The greatest risk of cumulative impacts of underwater noise on fish and shellfish species has been identified as being that produced by impact piling during the construction phase of other offshore wind farm sites within 100km of the proposed development. Effects on sensitive receptors may result from concurrent piling at different wind farm sites or the long-term exposure to sounds due to sequential piling operations over prolonged periods of time.

Owing to the early stage of the Irish Phase One OWF Projects within the planning process, no site-specific information relating the scale of piling (e.g., number of piles to be piled and hammer energy used) is available. It is therefore assumed that project parameters for the installation of foundations would be similar to those applied for the proposed development, i.e., installation of large diameter monopiles using impact piling and high hammer energies. Piling operations would represent intermittent occurrences at these offshore wind farm sites, with each individual piling event likely to be similar in duration to those at the proposed development. The indicative construction programmes of the east coast Phase One OWF projects (Table 13.32) suggest that the total duration of piling for these projects would be short-term (i.e., lasting one to seven years, as defined by the EPA guidance, 2022).

Mortality and potential mortal injury and recoverably injury

Mortality and potential mortal injury and recoverable injury of fleeing fish and marine turtles is predicted to occur <100m from the piling location, while based on a stationary receptor model effects on sandeel, spawning herring, and egg and larvae may occur up to 1.1km, 6.5km and 4.2km from the noise source, respectively (Table 13.24). Given similar scales of development and technologies of the other Irish east coast Phase One projects, it is anticipated that the impacts arising from these projects alone would be of similar magnitude to that predicted for the proposed development. Therefore, it is considered that the maximum impact ranges for the onset of mortality and recoverable injuries for each individual project are unlikely to overlap. Furthermore, the potential for mortal or recoverable injuries to mobile receptors is likely to be reduced due to the implementation of soft-start and ramp-up procedures, which will allow mobile species to move away from the piling location prior to the use of highest hammer energies, thereby reducing the number of individuals at risk of mortal or recoverable injuries. Furthermore, the mobile receptors are widely distributed within the region and would hence be able to move to nearby unimpacted areas. Therefore, while the concurrent or sequential piling of different Phase One OWFs has the potential to result in additive mortality or recoverable injury, the adaptability of the receptors together with the implementation of good practice measures (i.e., soft-start procedures) is anticipated to minimise the risk of these effects occurring. Therefore, as for the project alone, the maximum magnitude of potential cumulative mortality and recoverable injury from piling on mobile VERs (i.e., pelagic and demersal fish, elasmobranchs, marine turtles, and diadromous fish VERs) is assessed as low (adverse).

The potential for the proposed development to contribute to cumulative mortality or recoverable injuries to sandeel is assessed as negligible, given that the sediments within the array area are mostly unsuitable for sandeel and as such the number of sandeel to be affected by piling noise is likely to be low (Table 13.24). Therefore, as for the project alone, the magnitude of potential cumulative mortality and recoverable injury to sandeel is assessed as negligible. Similarly, given that there is no overlap between the predicted impact ranges for the onset of mortality, mortal injury and recoverable injury and the Mourne herring spawning ground (Figures 13.12 and 13.13), the potential for the proposed development to contribute to any cumulative mortality or recoverable injuries to spawning herring is assessed as negligible. In the case of shellfish species, current evidence suggests that piling noise is unlikely to cause mortality, potential mortal injury or recoverable injuries (Table 13.23), and as such, the magnitude of potential cumulative lethal or sublethal injuries for shellfish species is, as for the project alone assessment, deemed to be negligible.

As per the project alone assessment, the maximum sensitivity of the receptors to mortality, potential mortal injury and recoverable injury is deemed to be medium. This together with the maximum low magnitude of cumulative impacts would at most, result in slight (adverse) cumulative effects, which is not significant in EIA terms.

TTS and behavioural changes

Based on the noise modelling for the proposed development, TTS (186dB SEL_{cum}) in fish may occur up to 69km from the piling location for stationary receptors and 51km for fleeing receptors. Behavioural changes are likely to occur within these ranges, with the relative risk of behavioural responses at far distances (1000s of metres) considered to be low (Popper et al., 2014).

Assuming similar noise propagation ranges for the other Phase One OWFs compared to the proposed development, noise emitted during piling at the Oriel Wind Farm (located about 17km to the north of the proposed development array area) and the Dublin Array (located about 33km to the south of the proposed development array area) may be sufficient to result in cumulative TTS or behavioural reactions in sensitive receptors, which may result in the temporary re-distribution of individuals between the affected areas. However, construction of Dublin Array is expected to commence in 2029 after piling at the proposed development has been completed, and it is therefore concluded that the risk of cumulative noise effects from Dublin Array are low. Construction of the Oriel wind farm is anticipated to take place between 2025 and 2028, suggesting that construction work would be mostly completed before piling of foundations for the proposed development commences in 2028. The risk of cumulative TTS and behavioural effects from overlapping noise contours during concurrent piling operations at Arklow Bank Phase 2 and Codling Wind Farm is considered to be low, given the distances (>50km) between these projects and the array area of the proposed development. However, there still remains the potential for cumulative disturbances of sensitive receptors due to sequential and/or simultaneous piling activities, with the potential for some temporary redistribution of receptors between the areas affected by underwater noise. The most hearing sensitive fish species (e.g. herring, cod) would be most at risk, with other, non-hearing specialist fish species are considered to be less at risk.

Spawning herring

With regard to herring, it has been concluded that impact piling when carried out during the Mourne herring spawning season (main spawning period: September to November) may lead to a reduction in the reproductive success in a small proportion of the western Irish Sea herring spawning population as a result of behavioural reactions or changes in hearing sensitivities through TTS (Tables 13.23 and 13.25). Given the proximity of the Oriel windfarm to both the offshore development area and the Mourne herring spawning ground , there is potential for cumulative effects on the herring spawning population from impact piling. Construction of the Oriel wind farm is anticipated to take place between 2025 and 2026, suggesting that construction work would be mostly completed before piling of foundations for the proposed development commences in 2028. However, the potential timing, duration and type of foundation installation work at Oriel are unknown; it has therefore been assumed that there is potential for either concurrent disturbances from simultaneous piling or additional disturbances to spawning herring in the years prior to the construction of the proposed development.

It is anticipated that the duration of the impact at Oriel would be temporary (i.e., less than one year) to short-term (i.e., one to seven years) (as defined by the assessment methodology, Section 13.2.5.2), and any TTS or behavioural effects on herring would be intermittent, and reversible. The overall duration of cumulative impacts would also be short-term (potentially spanning over two spawning seasons). Based on this, any temporary decline in the spawning activity of part of the spawning population as a result of sequential or concurrent piling activities is considered unlikely to affect the viability of the western Irish Sea herring population in the long-term. Therefore, the magnitude of potential cumulative impacts is deemed to be at most medium (adverse).

As per the project alone assessment, the sensitivity of herring to TTS and behavioural changes is deemed to be low. This together with the medium magnitude of the impact would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

Atlantic salmon

With regard to Atlantic salmon, it has been concluded that impact piling may disrupt normal migration behaviour in the short-term, potentially leading to a reduction in the spawning success in a small proportion of the population (Tables 13.23 and 13.25). Given the location of the Phase One OWF projects offshore to rivers known to support salmon, there is potential for cumulative effects as a result of both concurrent piling at different locations and sequential piling of different projects over several years. It is anticipated that the duration of the impact for the different Phase One OWF projects would be at most short-term, and any effects on migrating salmon would be intermittent and temporary. The overall duration of any potential cumulative impacts would also be short-term.

Given the short-term and intermittent nature of the impact, the mobile and transient nature of the receptor and the reversibility of effects, potential temporary changes in the behaviour and/or distribution of salmon are not considered to alter the fitness and reproductive rates to the extent that could alter the trajectory of salmon populations along Ireland's east coast in the long-term. The magnitude of potential cumulative changes in salmon are therefore rated as low (adverse).

As per the project alone assessment, the sensitivity of Atlantic salmon to TTS and behavioural changes is deemed to be medium. This together with the low magnitude of the impact would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

Remaining receptors

As for herring and salmon, any TTS or behavioural responses in the remaining receptors would be temporary and reversible, with affected individuals anticipated to resume normal behaviours or recolonise areas shortly after piling has ceased. The proportions of spawning and nursery grounds of the receptors predicted to be affected by underwater noise from piling operations are expected to be small in the context of available spawning and nursery habitats in the cumulative assessment area and wider region. Whilst the Popper et al. (2014) criteria suggest a high risk of behavioural disturbance in the intermediate field (100s of metres) and a moderate risk in the far field (1000s of metres), the risk assessment is likely to predicated on the individuals not being involved in activities with a strong biological driver (i.e., spawning, feeding or migrating). As such, it is likely that any behavioural reactions to fish would be reduced when spawning, with consequently limited impact on spawning potential for the relevant species.

Based on the above combined with the intermittent and short-term nature of the impact and the temporary nature of the effects, any cumulative TTS and behavioural changes in fish and shellfish receptors during piling are assessed to be barely discernible from baseline conditions. Consequently, the magnitude of the cumulative impact with respect to Tier 2 projects is concluded to be low (adverse). Furthermore, given that no discernible cumulative effects are expected to occur from the proposed development and piling at the OMF (Tier 1 project, see previous section), it is concluded that when considered across Tier 1 and Tier 2 projects, effects as a result of piling would be no greater in magnitude than those predicted for the proposed development in-combination with the Phase One OWF projects (i.e., low (adverse)).

As per the project alone assessment, the maximum sensitivity of the receptors to TTS and behavioural changes is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

Summary: Cumulative underwater noise from piling

Potential cumulative effects of underwater noise from piling at the proposed development in-combination with other east coast Phase One OWF projects are concluded to result in at most barely discernible changes to baseline conditions, and as such the overall magnitude of the cumulative impact is deemed to be low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to underwater noise from piling is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms. Therefore, no additional mitigation to that already identified in Table 13.11 is considered necessary, and no significant adverse residual cumulative effects on fish and shellfish receptors have been predicted in respect to this impact.

Cumulative underwater noise from UXO clearance

As assessed in Section 13.5.2.4 (Impact 4), UXO clearance has the potential to result in mortality, mortal injury, recoverable injury, TTS and disturbance to fish and shellfish species, depending on the proximity of the individuals to the UXO location and the size of the UXO. Any potential mortality and recoverable injury resulting from high-order UXO clearance are anticipated to be restricted to the vicinity of the detonation (100s of metres), and as such this is expected to be a small-scale impact, and the maximum impact ranges for the onset of mortality and recoverable injuries for each individual project are unlikely to overlap. Moreover, UXO clearance operations at the Phase One OWF sites will likely follow a UXO mitigation hierarchy similar to that adopted for the proposed development, with high order UXO detonation only used when other clearance options (e.g., avoidance, removal and low order deflagration) are not possible.

TTS and disturbance effects would occur over a larger area, potentially reaching 10's of kilometres from the UXO location. However, as discussed previously, these effects would be reversible, and sensitive receptors are anticipated to resume normal behaviour and distribution shortly after the clearance event. Each UXO clearance is a discrete event with impulse sounds anticipated to be momentary (i.e., seconds to minutes). Therefore, the likelihood of concurrent clearance events between projects is considered to be low, thereby reducing the likelihood of cumulative effects. Moreover, while these events may result in some temporary disturbance and re-distribution to fish, they are unlikely to result in widespread and long-term displacement of fish from specific spawning or nursery grounds, compared to longer-term activities such as piling.

Based on the above, it is concluded that any cumulative effects upon fish and shellfish receptors from UXO clearance would at most result in barely discernible changes from baseline conditions. Consequently, the magnitude of the cumulative impact with respect to Tier 2 projects is concluded to be low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

Cumulative underwater noise from other noise sources

As assessed in Section 13.5.2.4 (Impact 4), non-impulse sounds such as those emitted during cable installation, the drilling of foundations, geophysical surveys or vessel traffic would not represent a risk to mortality and mortal injury to fish and shellfish species. However, there is potential for auditory tissue injuries and TTS, particularly in species with enhanced sensitivities to sound pressure, but current evidence suggests that these effects are temporary and reversible (Popper et al., 2014). Similarly, any potential behavioural reactions would be temporary. Therefore, these activities are considered to have a much lower likelihood to result in significant adverse effects in fish and shellfish receptors compared to piling, both alone and cumulatively with other projects.

It is anticipated that, following standard practises, vessel moving to and from offshore windfarm sites will, for the majority, use existing vessel routes for pre-existing vessel traffic (Table 13.11), which fish and shellfish will be accustomed to. They may also have become habituated to the noise generated by regular vessel movements, and therefore it is considered that potential cumulative effects may predominantly result at the construction sites.

Assuming similar construction activities of the Phase One projects, any potential recoverable injuries or TSS in Group 3 and Group 4 species as a result of non-impulse sounds are anticipated to be highly localised (i.e., within 10s of metres, see Section 13.5.2.4), and therefore the potential for cumulative effects is limited. Similarly, the risk of adverse cumulative behavioural reactions from overlapping noise contours or as a result of sequential disturbances across the cumulative assessment area is considered to be low, given the reversibility of the effects and the intermittent and temporary to short-term nature of the activities. Therefore, as for the project alone assessment, the magnitude of the impact for Group 3 and Group 4 VERs is deemed at most low (adverse). Given their lower hearing capabilities and the lower risk of recoverable injuries and TTS, the magnitude of the impact for the remaining receptors is deemed to be negligible.

As per the project assessment alone, the maximum sensitivity of all fish and shellfish VERs to non-impulse sounds is deemed to be low. This together with the maximum low magnitude of the impact would at most result in slight (adverse) cumulative effects, which is not significant in EIA terms.

13.9.6.3 Tiers 1, Tier 2 and Tier 3 (all tiers)

The Tier 3 projects screened into the cumulative assessment for underwater noise (Table 13.33) will generate non-impulse sounds similar to those generated during the construction of the proposed development (e.g., dredging and vessel noise, noise generated during geophysical surveys). As for the construction activities associated with the Phase One OWF projects including the proposed development, the noise levels emitted during these activities may potentially cause temporary TTS in the most sensitive VERs (i.e., Group 3 and Group 4 species) as well as behavioural reactions but are not thought to cause mortal injuries. Any TTS are predicted to be restricted to the near-field (10s of meters), while behavioural reactions may occur over larger areas (1000s of meters). It is anticipated that, following standard practises, vessel moving to and from offshore construction and sediment disposal sites will, for the majority, use existing vessel routes for pre-existing vessel traffic (Table 13.11), which fish and shellfish will be accustomed to. They may also have become habituated to the noise generated by regular vessel movements, and therefore it is considered that potential cumulative effects from Tier 3 projects may predominantly result from activities at construction and survey sites (e.g., along the Mares Connect cable corridor and within the areas covered by geophysical and geotechnical surveys). Activities associated with the Tier 3 projects are anticipated to be temporary (i.e., lasting less than one year), with most activities such as geophysical surveys and maintenance dredging operations expected to be of shorter duration (days to weeks). Any potential TTS and disturbance effects will be temporary, with affected individuals expected to resume to normal behaviours shortly after the activities have ceased (i.e., within days to one to two weeks) (Popper et al., 2014).

Based on the above, it is concluded that any simultaneous or sequential disturbance effects resulting from Tier 3 projects in-combination with any underwater noise generated during the construction phase of the proposed development (i.e., piling of foundations, UXO clearance, other construction activities and pre-construction surveys) would be no greater in magnitude than those predicted for the project alone (i.e., low (adverse), Impact 4). Furthermore, given the intermittent and temporary nature of Tier 3 activities combined with the reversibility of any potential TTS and behavioural effects, it is concluded that when considered across all tiers, effects on sensitive receptors would be no greater in magnitude than those predicted for the proposed development in-combination with Tier 1 and Tier 2 project (i.e., low (adverse), see previous section).

In summary, the above assessments concluded that when considered across all tiers (i.e., Tier 1, Tier 2 and Tier 3 projects), underwater noise would result in at most barely discernible changes to baseline conditions of the most sensitive receptors, and as such the overall magnitude of the cumulative impact from underwater noise is deemed to be low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms. Therefore, no additional mitigation to that already identified in Table 13.11 is considered necessary, and no significant adverse residual cumulative effects on fish and shellfish receptors have been predicted in respect to this impact.

13.9.7 Cumulative Impact 4: Cumulative long-term or permanent loss of benthic habitats due to the placement of subsea infrastructure

The presence of infrastructure in the marine environment, including turbine foundations, scour protection and cable protection will cause long-term changes in the extent and distribution of benthic habitats, which may affect the distribution and abundance of sensitive fish and shellfish receptors that depend on the seabed. Also, any infrastructure left in situ following decommissioning will represent a permanent loss of habitat. The potential for significant cumulative effects on fish and shellfish receptors, as a result of simultaneous long-term or permanent loss of benthic habitats, is assessed in the following sections.

13.9.7.1 Tier 1

The proposed construction of the OMF is limited to the onshore expansion of facilities and is therefore not considered to have the potential to contribute to cumulative losses of the seabed (Table 13.32).

13.9.7.2 Tier 1 and Tier 2

Owing to the early stage of the Irish Phase One OWF Projects within the planning process, no site-specific data relating to long-term or permanent loss of benthic habitats is available. However, it is anticipated that the changes resulting from these projects would be of a similar magnitude to those assessed for the proposed development based on similar technology and analogous project designs. Specifically, any long-term or permanent loss of seabed habitats associated with the Tier 2 Phase One OWF projects is expected to be highly localised and restricted to discrete areas within the array areas and ECCs of these projects. Broadscale habitat maps (INFOMAR, 2023) suggest that the subtidal benthic substrates that would be lost are common and widespread within the wider region. Furthermore, the fish and shellfish receptors that rely on these substrates are widely distributed within the cumulative assessment area Therefore, any effects on fish and shellfish receptors due to the cumulative loss of benthic habitats from the proposed development in-combination with the Tier 2 Phase One OWF projects are anticipated to be at most barely discernible from baseline conditions. Consequently, the maximum magnitude of the cumulative impact with respect to Tier 2 projects is assessed as being low (adverse).

As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

13.9.7.3 Tier1, Tier 2 and Tier 3 (all tiers)

Of the Tier 3 projects screened into the cumulative assessment, the proposed Mares Connect power cable may contribute to the cumulative long-term loss of benthic fish and shellfish habitats through the placement of cable protection measures. No information relating to the use of cable protection by the project is currently available. However, any loss of seabed habitats predicted from the project would be highly localised, and as such no discernible loss of resource for fish and shellfish receptors in the context of the Irish Sea populations are anticipated from the Mares Connect project alone.

Cumulatively with the proposed development and the Tier 2 projects, at most barely discernible changes to fish and shellfish receptors are expected. Consequently, the maximum magnitude of cumulative losses of the seabed with respect to Tier 2 and Tier 3 projects is assessed as being low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be medium. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms. Therefore, no additional mitigation to that already identified in Table 13.11 is considered necessary, and no significant adverse residual cumulative effects on fish and shellfish receptors have been predicted in respect to this impact.

13.9.8 Cumulative Impact 5: Cumulative barriers to movement through the presence of EMF from cables

13.9.8.1 Tier 1

The proposed construction of the OMF is limited to the onshore expansion of facilities and is therefore not considered to have the potential to contribute to EMF from cables (Table 13.32).

13.9.8.2 Tier 1 and Tier 2

The potential maximum magnitude of the impact during the operation of the proposed development has been assessed as low (adverse), based on the rapid attenuation of EMFs within the environment and the localised nature of behavioural changes in sensitive receptors. Based on similar technology and project designs, the extent of EMF emissions from the considered Phase One OWF projects is also expected to be highly localised and restricted to discrete areas within the immediate proximity of the cable lines. The receptors are widely distributed within the Irish Sea and have comparatively large feeding, spawning and nursery areas. Therefore, cumulative increases in the spatial extent of areas affected by artificial EMFs emitted from cables of the proposed Phase One OWF projects are likely to be small in relation to the wider environment. As per the project alone assessment, any cumulative behavioural responses of sensitive fish and shellfish receptors are therefore assessed as being at most barely discernible from baseline conditions. Consequently, the maximum magnitude of cumulative emissions of EMF with respect to Tier 2 projects is assessed as being low (adverse).

As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be low (adverse). At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

13.9.8.3 Tier 1, Tier 2 and Tier 3 (all tiers)

Of the Tier 3 projects screened into the cumulative assessment, the proposed Mares Connect power cable would together with existing active power and telecommunications cables contribute to ongoing EMF emission within the cumulative assessment area. Based on the same rationale as presented above for EMF generated by Tier 2 projects, any cumulative behavioural responses of sensitive fish and shellfish receptors are expected to be restricted to the immediate proximity of the cable lines and would at most be barely discernible from baseline conditions. Consequently, the maximum magnitude of cumulative emissions of EMF with respect to Tier 3 projects is assessed as being low (adverse). As per the project alone assessment, the maximum sensitivity of the receptors to the impact is deemed to be low. At most, this would result in a slight (adverse) cumulative effect, which is not significant in EIA terms.

In summary, EMFs emitted from the proposed development and all tiers screened into the assessment are predicted to result in highly localised behavioural responses in electro- and magneto-sensitive receptors. Given the wide distribution of the receptors within the cumulative assessment area and the distances between the assessed projects (1000s of metres), any potential cumulative changes in the distribution of individuals are assessed to result in at most barely discernible changes to baseline conditions, and as such the overall magnitude of the cumulative impact when assessed across all tiers is deemed to be low (adverse). This together with the maximum low sensitivity of the receptors would result in a slight (adverse) cumulative effect, which is not significant in EIA terms. Therefore, no additional mitigation to that already identified in Table 13.11 is considered necessary, and no significant adverse residual cumulative effects on fish and shellfish receptors have been predicted in respect to this impact.

13.10 References

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