Appendix E

Fish and Shellfish Ecology Supporting Information

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

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ORIEL WIND FARM PROJECT

Natura Impact Statement

Appendix E: Fish and Shellfish Ecology – Supporting Information

MDR1520B
NIS – Appendix E
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1 FISH AND SHELLFISH ECOLOGY

1.1 Introduction

This report describes the potential impacts of the Oriel Wind Farm Project (hereafter referred to as "the Project") on fish and shellfish ecology. It considers the potential impact of the offshore infrastructure (i.e. the offshore wind farm and offshore cables) of the Project below the High-Water Mark (HWM) during the construction, operational and maintenance, and decommissioning phases.

1.2 Purpose

The primary purpose of this report is to provide supporting information on the potential impacts of the Project on fish and shellfish ecology, which is used to inform the assessment of adverse effects in the NIS. In particular, this report:

- Identifies European sites which have relevant fish and shellfish qualifying features and presents the existing environmental baseline established from desk studies and consultation (section 1.4 and section 3); and
- Identifies potential impacts, their magnitude and their sensitivity on relevant fish and shellfish qualifying features, based on the information gathered (see section 6). An assessment of potential in-combination effects is provided in section 7.

1.3 Zone of Influence

The Zone of Influence (ZoI) varies with each impact source and receptor interaction. The ZoI is contained within the study area, described below.

To understand the potential ZoI in which the Project could impact on fish and shellfish ecology, it was necessary to define two study areas due to the temporal and spatial variability of fish and shellfish namely:

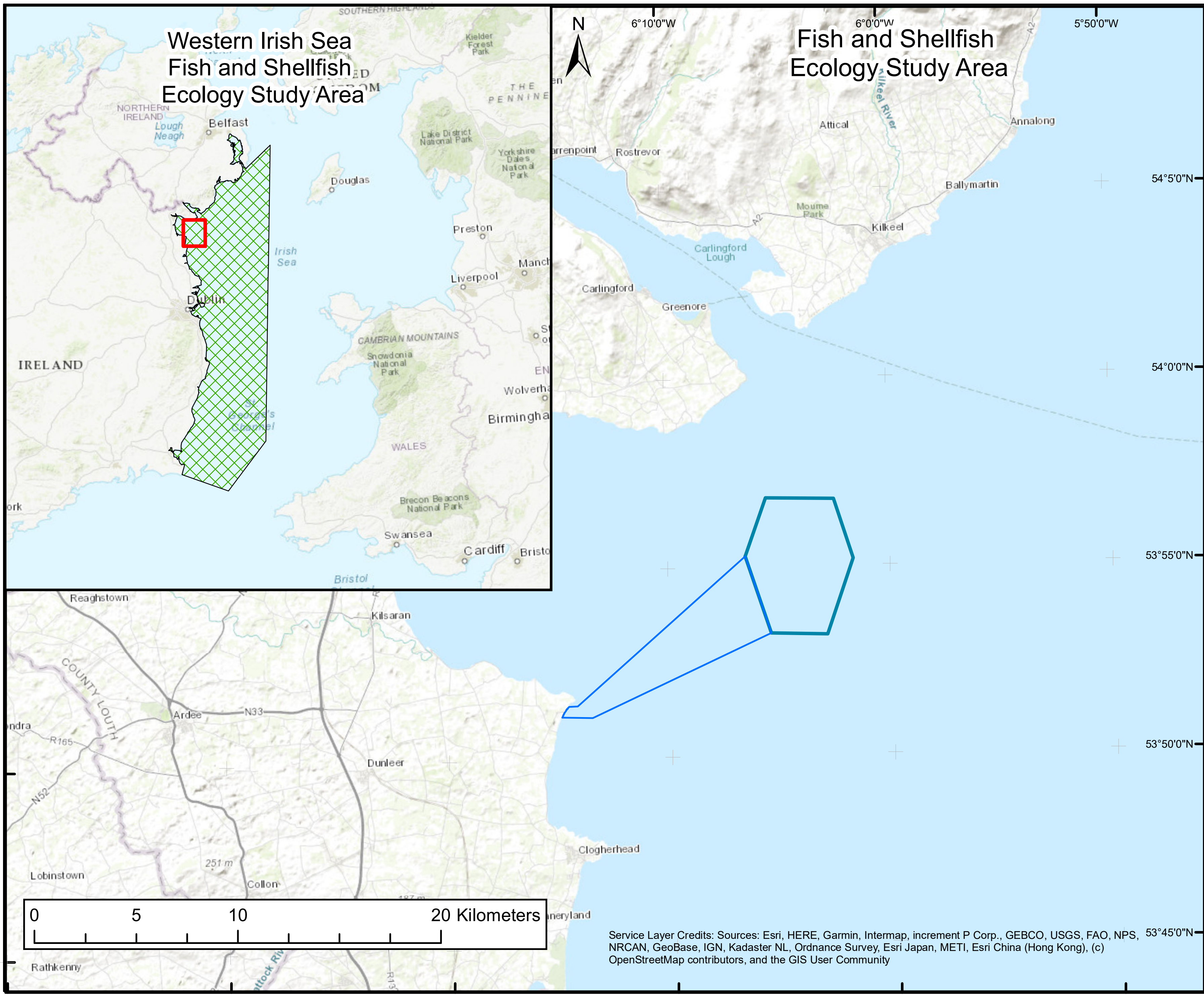
- The Fish and Shellfish Ecology Study Area; and
- The Western Irish Sea Fish and Shellfish Ecology Study Area.

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

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

The Western Irish Sea Fish and Shellfish Ecology Study Area is also used to inform the in-combination assessment (see section 7). Any Northern Ireland and Republic of Ireland projects falling inside the study area that have the potential to have in-combination effects on fish and shellfish ecology with the Project have been assessed. The study areas were defined based on professional judgement and author experience of offshore wind farm impact assessments.

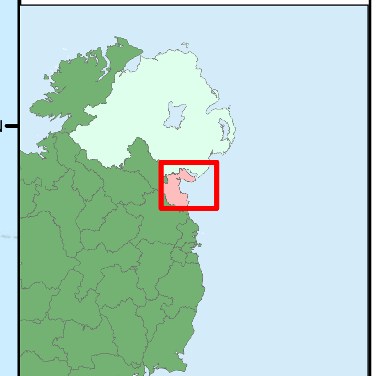
[1] Delineated by the continental shelf, and artificially extended to the centre point between Ballyquintin Point (Northern Ireland) and the Mull of Galloway peninsula (Scotland).



Legend

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

Data Sources: Client



Client

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Project

Oriel Wind Farm Project

Title

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

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1.4 Consultation

Table 1-1 below summarises the issues raised relevant to Fish and Shellfish Ecology which have been identified during consultation activities undertaken to date, together with how these issues have been considered in the production of this report.

Table 1-1: Summary of key issues raised on fish and shellfish ecology.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this appendix
September 2019	Inland Fisheries Ireland (IFI) – E-mail response	Identified that Dundalk Bay is promoted as an angling venue for a range of species and the bay receives waters from a number of rivers in the Neagh International River Basin District. These include species which are valuable from a fisheries perspective and contain a number of migrating species which include Annex II species under the European Habitats Directive such as salmon and sea lamprey. Highlighted importance of mitigation measures to ensure protection and conservation of the aquatic habitats.	Fish and shellfish receptors have been identified through a desktop study and are discussed in section 3. Measures included in the Project are discussed in section 4.2.
March 2021	IFI – Meeting	Consultation regarding: Baseline data – specifically presence of sea bass in Dundalk Bay; Approach to scoping impacts (specifically temperature increases from cables); Underwater noise assessment and potential effects on fish, particularly diadromous fish, including barrier effects to migratory species from underwater noise.	Baseline information provided and included in section 3. Justification for scoping impacts out of assessment (including temperature changes from cables) is presented in section 4.3. Effects of underwater noise are discussed in section 6.2.
March 2021	Marine Institute – Email	Provided additional data sets to be used to characterise the baseline including marine institute data and monitoring reports from offshore wind parks in Belgium. The Marine Institute recommended the consideration of ecosystem service provision of habitats assessed. Suggested it would be useful to provide a list of the sites and conservation designated to be considered.	Additional data sets have been included to characterise the baseline in section 3. European sites and their relevant fish and shellfish Qualifying Interest (QIs) are listed in Table 3-1 and assessed in the NIS provided under separate cover. The potential impacts of the Project on QI fish and shellfish species are discussed in section 6 and assessed in the NIS.
April 2021	National Parks and Wildlife Service (NPWS) – Meeting	Discussion regarding the baseline data sources, assessment methodology, important ecological receptors and impacts scoped in/out. Discussion on the consideration of the impact of a change in fish and shellfish prey species on ornithological receptors. Discussion on whether the assessment considered changes in fishing practices within the offshore wind farm area.	Consideration of the impact of a change in fish and shellfish prey species on ornithological receptors is considered in appendix H: Offshore Ornithology – Supporting Information. Based on RPS experience, offshore wind farms in the North Sea have been able to co-exist with the fishing industry, particularly shellfish potting. There is not expected to be a change in the benthic

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this appendix
		Discussion on whether the introduction of hard substrate will promote colonisation of the area by larger predatory fish due to the reef effect and therefore reduce the smaller fish availability.	communities as a result of changes to fishing activities. The impact of colonisation of hard substrate has been scoped out and justification provided in Table 4-3.
January/February 2023	Members of the public during public consultation	Query regarding potential impacts of the Project on fish stocks.	The potential impacts of the Project on QI fish and shellfish species are assessed in section 6.
September 2023	Department of Agriculture, Environment and Rural Affairs (including Natural Environment Division's response)	Consultation regarding the following: • MPAs; • Marine Invasive species; • Marine National Protected Species; • Marine Policy Statements.	A Marine Invasive Non-Native Species Management Plan is included in appendix K: Management Plans to manage and prevent the introduction/spread of invasive species. The potential impacts of the Project on Qualifying Interest (QI) fish and shellfish species are discussed in section 6 and assessed in the NIS. Relevant policy has been discussed in the NIS.
October 2023	Loughs Agency	Consultation regarding the following: • Validity of data; • Consideration of surveys to support the knowledge gap; • Suggested modelling of receptor effects and their interactions; • Consideration of quantitative assessments.	The validity of data has been described in the NIS. No surveys are proposed to support the conclusion made in this report or the NIS. Based on RPS experience and the size of the Project, modelling is not required (beyond underwater noise and physical processes modelling) as impacts have been assessed as to be not significant in AA terms. The potential impacts of the Project on QI fish and shellfish species are assessed in section 6.
October 2023	Isle of Man Government	Consideration of MPAs; and Potential effects on *Nephrops* (note that this comment is in relation to the fishing ground).	The potential impacts of the Project on Qualifying Interest (QI) fish and shellfish species are discussed in section 6 and assessed in the NIS.
June & November 2023	An Bord Pleanála; pre-application consultation	• Concerns raised with regards to herring spawning and the effects of sedimentation during construction; and • Consider 'wake effects' (loss of wind energy being transmitted to the water column due to the presence of turbines may impact herring spawning) as a potential impact.	Consideration of the impacts on marine mammal and offshore ornithological receptors resulting from an impact on herring spawning is considered in appendix F: Marine Mammals and Megafauna – Supporting Information; and appendix H: Offshore Ornithology – Supporting Information. Regarding 'wake effects', the potential changes to the wave and tidal regime from the operational wind turbines area considered in appendix B: Marine Processes Technical Report. This demonstrated that any changes to marine processes would be very limited and would not impact seabed habitats, including sediments on which herring are reliant for spawning.

2 METHODOLOGY TO INFORM THE BASELINE

2.1 Desktop study

The Project is located off the east coast of the Republic of Ireland, for which extensive data and knowledge regarding fish and shellfish ecology is already available. This data/information has been acquired through:

- Publicly available journals;
- Academic studies;
- Commissioned reports by local interest groups;
- Published reports including other ecological assessments;
- Fisheries data and reports from IFI, Bord Iascaigh Mhara (BIM) and the Marine Institute;
- Historical characterisation studies undertaken for the Project; and
- Nature conservation designations occurring within the Western Irish Sea Fish and Shellfish Ecology Study Area.

Information on fish and shellfish ecology within the Fish and Shellfish Ecology Study Area and the Western Irish Sea Fish and Shellfish Ecology Study Area was collected through a detailed desktop review of existing studies and datasets. The key sources (i.e. data and reports) used to inform the baseline characterisation of the Fish and Shellfish Ecology Study Area are summarised in Table 2-1 below. Where reports and data date back to the 1990s, up-to-date data and information have been used to ensure these sources are still valid.

Table 2-1: Summary of key sources.

Title	Year	Author
Offshore Wind Farm, Environmental Impact Statement, Main EIS, Volume 2 of 3	2007	Oriel Windfarm Limited (OWL)
A report on fishing in the waters between Carlingford and Clogher Head based on published data, Appendix VIII within OWL, Offshore Wind Farm, Environmental Impact Statement, Appendices, Volume 3 of 3	2003	Roden and Ludgate
An Offshore Wind Farm on the Kish and Bray Banks. Environmental Statement. January 2012 – Revision 1. Section 8: Marine Ecology	2012	Dublin Array Offshore Wind Farm Limited (DAOWFL)
Offshore Wind Farm at Codling Bank: Non-Technical Summary. Volume 2 of 3	2002	Codling Wind Park
River Boyne and River Blackwater SAC. Site Synopsis (Site Code: 002299)	2014	Department of Arts, Heritage and the Gaeltacht (DAHG)
Slaney River Valley SAC. Site Synopsis (Site Code: 000781)	2015	DAHG
Strategic Environmental Assessment (SEA) of the Offshore Renewable Energy Development Plan (OREDP) in the Republic of Ireland.	2010	AECOM and Metoc
Ireland Red List No.11: Cartilaginous Fish	2016	Clarke *et al.,*
Ireland Red List No.5: Amphibians, Reptiles and Freshwater Fish	2011	King *et al.,*
Spawning and nursery grounds of selected fish species in UK Waters	2012	Ellis *et al.,*
Fisheries Sensitivity Maps in British Waters	1998	Coull *et al.,*
An Inventory of Irish Herring Spawning Grounds	2013	O'Sullivan *et al.,*

Title	Year	Author
Celtic Sea Trout Project – Technical Report	2016	CSTP
Western Irish Sea Nephrops Grounds (FU15) 2019 UWTV Survey Report and Catch options for 2020	2019	Lundy *et al.,*
Fifty years of marine tag recoveries from Atlantic salmon. ICES Cooperative Research Report No. 343	2018	Ó Maoiléidigh *et al.,*
Atlas of Commercial Fisheries for Shellfish around Ireland	2017	Tully (Marine Institute)
Shellfish Stocks and Fisheries Review 2019: An assessment of selected stocks	2020	Marine Institute and BIM
Shellfish Stocks and Fisheries Review 2018: An assessment of selected stocks	2019	Marine Institute and BIM
Sampling Fish in Rivers 2018 - Fane, Factsheet No. 3. National Research Survey Programme	2019a	Matson *et al.,*
Sampling Fish in Rivers 2018 - Flurry, Factsheet No. 4. National Research Survey Programme	2019b	Matson *et al.,*
Assessment, Monitoring and Management of the Dundalk Bay and Waterford Estuary Cockle (*Cerastoderma edule*) Fisheries in 2007	2008	Hervas *et al.,*
All fisheries landings from ICES rectangle 38E3 from 2016-2019	2016-2019	DAERA personal comms.
Cumulative Impact Assessment: Aquaculture activities within and adjacent to Natura 2000 designated sites in Carlingford Lough	2015a	Agri-Food and Bioscience Institute (AFBI)
Marine Institute provided benthic survey raw data from Dundalk Bay and the western Irish Sea	2021	Marine Institute
Pot Fishing In Northern Ireland	2015b	AFBI
Biodiversity maps	Various	https://maps.biodiversityireland.ie/# https://atlas.marine.ie/#?c=53.9000:-15.9000:6
ICES Division VIIa technical reports series	Various	Cefas (https://www.cefas.co.uk/cefas-data-hub/)

2.2 Identification of relevant European sites and features (species and habitats)

All designated European sites within the Western Irish Sea Fish and Shellfish Ecology Study Area and qualifying interests (QIs) that could be affected by the construction, operational and maintenance, and decommissioning phases of the Project were identified using the three-step process described below:

- Step 1: All European sites within the Western Irish Sea Fish and Shellfish Ecology Study Area were identified using the sources outlined in section 2 and the NPWS website.
- Step 2: Information was compiled on the relevant fish and shellfish QIs for each of these sites. The known occurrence of species within the Fish and Shellfish Ecology Study Area was based on the relevant desktop information presented in section 2.
- Step 3: Using the above information and expert judgement, sites were included for further consideration if:
  - A designated site with Fish and Shellfish Ecology QIs directly overlaps with the Western Irish Sea Fish and Shellfish Ecology Study Area;
  - Sites and associated features were located within the potential Zone of Influence (ZoI) (i.e. the Western Irish Sea Fish and Shellfish Ecology Study Area*)* for impacts associated with the Project (e.g. habitat loss/disturbance, underwater noise during construction);

- Features of a designated site were either recorded as present during historic surveys within the area, or identified during the desktop study as having the potential to occur within the Western Irish Sea Fish and Shellfish Ecology Study Area.

3 BASELINE ENVIRONMENT

3.1 Relevant European sites

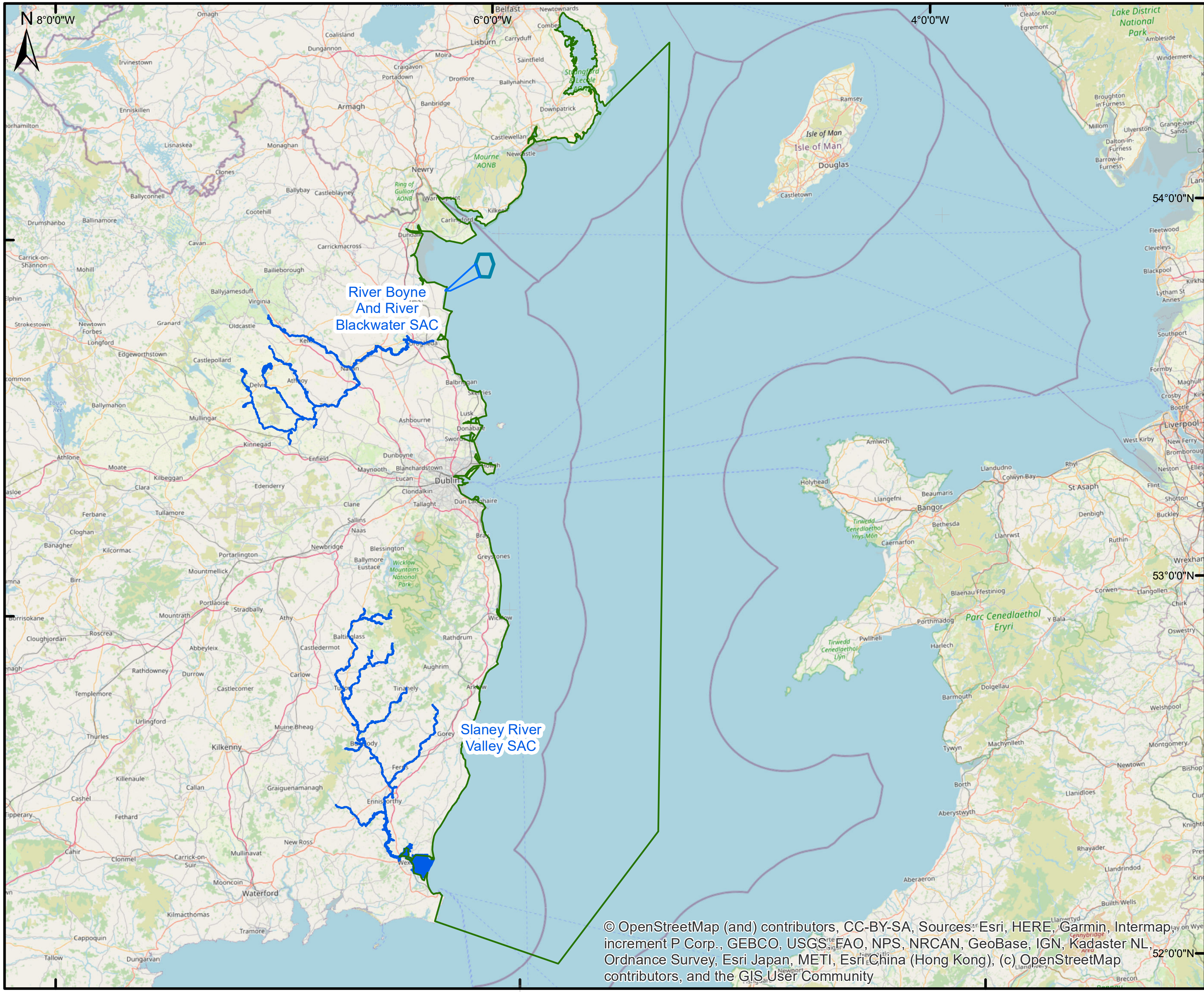
Relevant European sites which have fish and shellfish qualifying features and which have been considered in this fish and shellfish ecology report for the Project are described in Table 3-1 and illustrated in Figure 3-1 below.

Table 3-1: Relevant European sites and qualifying features for fish and shellfish[a].

European site (code)	Closest distance and direction to Fish and Shellfish Ecology Study Area (km)	Relevant Qualifying Feature(s)
River Boyne And River Blackwater SAC (IE002299)	23.5 southwest	• River Lamprey *Lampetra fluviatilis* • Atlantic Salmon *Salmo salar*
Slaney River Valley SAC (IE000781)	102.1 south	• Freshwater Pearl Mussel *Margaritifera margaritifera*[b] • Sea Lamprey *Petromyzon marinus* • River Lamprey *Lampetra fluviatilis* • Twaite Shad *Alosa fallax fallax* • Atlantic Salmon *Salmo salar*

a Note: other non-fish features (e.g. mammals such as otter and seal) of these SACs are not presented (see appendix F: Marine Mammals – Supporting Information and appendix I: Onshore Biodiversity – Supporting Information). Similarly, those purely freshwater fish features (e.g. brook lamprey) are also not presented as there is no impact pathway.

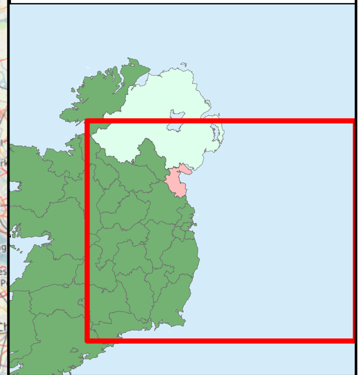
b Note: Although no direct impact pathway exists between the freshwater pearl mussel and the Project, this species lives on the gills of salmon and brown trout in the first year of life and hence could feasibly be impacted by the Project if these species are impacted (e.g. if fish migration to the relevant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



Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- Western Irish Sea Fish and Shellfish Ecology Study Area
- Special Areas of Conservation (SAC)
- Inshore Waters Boundary

Data Sources:



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Project

Oriel Wind Farm Project

Title

Figure 3-1 Relevant European sites within the western Irish Sea Fish and Shellfish Study Area with fish and/or shellfish Qualifying Interests

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Scale: 1:1,500,000@ A4	**Projection:** ITM (IRENET95)
Date: 08/03/2024	Geographic Co-ordinates: ETRS89

3.2 Relevant qualifying features

3.2.1 Atlantic salmon

The juvenile life stage typically lasts between one to four years before migrating to the sea. Following migration to the sea, salmon are known as post-smolts until the spring of the following year and after one winter as grilse. Salmon that spend one to three years at sea before returning in spring are known as spring salmon (Davies *et al.*, 2004). Adult Atlantic salmon spend the majority of their lives at sea, growing rapidly and only returning to freshwater environments to spawn (SNH, 2017). Due to a highly acute sense of smell, the Atlantic salmon is able to locate the river in which it originated and on maturity migrates back to spawn (Dipper, 2001; Lockwood, 2005). The length of time an Atlantic salmon spends in the sea varies from one to five years (Klemetsen *et al.*, 2003).

Data and information on the movements of salmon during their sea migration is limited. Smolts are believed to school and move to deep-sea feeding areas. Prior to seaward migration, the fish undergo a preparatory smolting process involving morphological, biochemical, physiological and behavioural changes that preadapt them for life within the marine environment (Hoar, 1988; Høgasen, 1998; Thorpe *et al*., 1998; Finstad and Jonsson, 2001). The migration from freshwater through the estuary and into the marine environment is predominantly nocturnal during the early part of the smolt run. During the latter part of the season, a significant proportion of the smolts switch to migration during both day and night (Thorstad *et al.,* 2012). The average total body length of wild smolts is usually 10–20 cm, and they may weigh from 10 to 80 g (Thirsted *et al*., 2011).

Atlantic salmon are widely distributed throughout Ireland and are recognised as an Annex II (EU Habitats Directive) species, an OSPAR species and declared as Vulnerable on the Ireland Red List (King *et al.*, 2011). They are currently both nationally and internationally important species and as such the River Boyne and River Blackwater, and the Slaney River Valley have been designated as SACs.

The River Boyne and River Blackwater SAC is located approximately 23 km from the offshore wind farm area (see Figure 3-1). Atlantic salmon are known to run the River Boyne almost every month of the year, with large multi-sea-winter salmon generally arriving in February, with smaller spring salmon in April/May and grilse arriving in July. A later run occurring in late August has also been observed. The River Boyne and River Blackwater SAC is able to support the full range of salmon life-history types (DAHG, 2014). The Slaney River Valley SAC, located approximately 102 km to the south of the Project, is primarily known for its spring salmon which spawn within the upper Slaney and tributary headwaters (DAHG, 2015).

Commercial fisheries information provided in OWL (2007) suggests that the majority of watercourses flowing into Dundalk Bay contain salmon. Adult salmon migrate through this area on their way to feeding grounds at sea and when returning to inland rivers. The rivers containing salmon which flow into Dundalk Bay include the River Dee, River Fane, River Glyde, the Ballymascanlan River, Flurry River and the Castletown River. Further to this, the Marine Institute operates a programme to map the migration routes of the Atlantic salmon. There is evidence of a northerly migration route for Irish salmon stocks in the early months of their long migration (Ó Maoiléidigh *et al.,* 2018). From this it can be assumed that salmon migrating from the River Boyne and River Blackwater SAC and Slaney River Valley SAC, as well as other rivers whereby salmon may be present, are likely to pass through the Fish and Shellfish Ecology Study Area, as they migrate from northern Atlantic waters.

Inland Fisheries Ireland (IFI) have placed counters on the rivers Slaney and Boyne, recording throughout 2017. The River Slaney showed the transiting of 329 salmon in the spring and 592 salmon in the late summer. The River Boyne showed the passage of 333 salmon in the spring and 2,042 salmon in the late summer, providing further evidence of salmon using these rivers (IFI, 2018). Salmon are also regularly sampled from the Fane and Flurry river catchments (Matson *et al.,* 2019a and 2019b). IFI also have a tagging project for salmon and sea trout called the COMPASS project (Collaborative Oceanography and Monitoring for Protected Areas and Species). The project aims to investigate marine habitat use by salmon and sea trout as they migrate. They have set up a network of mini-acoustic receivers moored to the seabed along the coast between Dundalk and Larne. This network provides passive telemetry coverage in key areas along the northeast coast for smolts captured by electrofishing, trapping or angling, which are tagged with tiny acoustic transmitters as they migrate downstream. Initial results suggest that salmon smolts travel north towards the North Channel once they left their natal rivers and can travel up to 250 km in a period of 32 days (Barry *et al*., 2020).

3.2.2 Sea lamprey

The sea lamprey is distributed throughout Irish waters. Spawning occurs between May and June, with the eggs deposited in redds excavated in gravel. Upon hatching, juvenile lamprey (ammocoete) will often bury themselves in gravel, silt or sand, to prevent predation. The process of metamorphosis from ammocoete to adult can take four weeks to four months. In Ireland this process appears to be initiated between July and September. After five years in freshwater the lamprey progressively make their way to the open sea to mature (Maitland, 2003; Igoe *et al.,* 2004).

Sea lamprey has been designated as an EU Habitats Directive Annex II species and is listed as Near Threatened on the Ireland Red List (King *et al.*, 2011).

Records of sea lamprey occurring along the east coast of Ireland are limited. The Biodiversity Maps indicates no lamprey sightings, but they are present within the Slaney River Valley SAC (NPWS, 2015) and lamprey have also been sampled from the Fane and Flurry river catchment (Matson *et al.,* 2019b), although the species was not specified.

3.2.3 River lamprey

The river lamprey can be found throughout Ireland and the western reaches of Europe and shares a similar ecology to the sea lamprey but is morphologically smaller (Maitland, 2003).

The river lamprey has been identified as a QI for the Slaney River Valley SAC and River Boyne and River Blackwater SAC.

3.2.4 Twaite shad

Twaite shad are in decline in many parts of Europe due to overfishing, pollution and migratory route obstructions. They reach sizes of up to 40 cm in length. Twaite shad return from the sea to spawn in spring, usually between April and June. The habitat requirements are not fully understood. They are known to spawn at night in shallow areas near deeper pools. The eggs are released into the water column, sinking into the interstices between coarse gravel/cobble substrates, with the majority of adults dying after spawning. After hatching the fry develop and slowly drift downstream. Recruitment seems to be highest in warm years, and high flows between May and August may result in fry being washed prematurely out to sea (Howson and Picton, 1997).

Twaite shad have only been confirmed in Barrow, with anecdotal reports pointing to a decline of population in the Slaney River Valley SAC of which twaite shad is a qualifying interest (QI). The twaite shad has been categorised under the EU Habitats Directive as an Annex II and V species and Vulnerable on the Ireland Red List (King *et al.*, 2011).

3.2.5 Freshwater pearl mussel

The freshwater pearl mussel is an endangered species of freshwater mussel. Freshwater pearl mussels are similar in shape to common marine mussels but grow much larger and live far longer. They can grow as large as 20 cm and live for more than 100 years, making them one of the longest-lived invertebrates (Skinner *et al.,* 2003). These mussels live on the beds of clean, fast-flowing rivers, where they can be buried partly or wholly in coarse sand or fine gravel. Mussels have a complex life cycle, living on the gills of young Atlantic salmon or brown trout, for their first year, without causing harm to the fish (Skinner *et al.,* 2003). The NPWS publish a map of sensitive catchment areas for freshwater pearl mussel, along the east coast of Ireland these include the Avoca, Vartry and Slaney (NPWS, 2017). Freshwater pearl mussels are a QI feature of the Slaney River SAC and since there is some evidence of a northerly migration of salmon from the Slaney (Ó Maoiléidigh *et al.,* 2018), it is possible that juveniles may transfer to the Fish and Shellfish Ecology Study Area during salmon migration.

4 KEY PARAMETERS FOR ASSESSMENT

4.1 Project design parameters

The project description is provided in section 2 of the NIS. Table 4-1 outlines the project design parameters that have been used to inform the assessment of potential impacts of the construction, operational and maintenance and decommissioning phases of the Project on fish and shellfish ecology.

Due to the potential for unexpected ground conditions and obstructions, the final route and length of the offshore export cable and offshore inter array cables will be confirmed during construction (see design flexibility in section 2 of the NIS). For the purposes of the assessment in section 6, the maximum length of cables has been considered to ensure the potential for maximum impact is identified. Should the lengths of cables be less than those specified, then the potential for effects will not change the assessment outlined in section 6. An alternative route within the offshore wind farm area of offshore cable corridor will also not change the potential impacts presented in section 6.

Table 4-1: Project design parameters considered for the identification of potential impacts on fish and shellfish ecology.

Potential impact	Phase[1] C	O	D	Project design parameters	Justification
Temporary subtidal habitat loss/disturbance	✓	✓	✓	**Construction phase** 709,500 m² of temporary habitat loss/disturbance due to: • 54,000 m² due to the use of jack-up vessels during foundation installation, with two jack-up events per wind turbine generator (WTG) and four jack-up events for the offshore substation (OSS); • 570,000 m² due to the installation of 41 km inter-array cables and 16 km offshore cable with seabed disturbance width of 10 m; and • 85,500 m² due to sand wave clearance for 10% of inter-array cables and 10% of the offshore cable. Offshore construction phase duration of 15 months. **Operational and maintenance phase** 387,000 m² of temporary habitat loss/disturbance due to: • 51,000 m² due to component replacement activities using jack-up vessel associated with 25 WTGs and OSS; • 210,000 m² due to inter-array cables: seven repair events and seven reburial events over the lifetime of the Project; and • 126,000 m² due to offshore cable: three repair events and three reburial events over the lifetime of the Project (three intertidal and three subtidal). Operational phase of 40 years. **Decommissioning phase** 624,000 m² of temporary habitat loss/disturbance. Parameters are assumed to be the same as for the construction phase with the exception that that there will be no sand wave clearance or seabed clearance associated with foundation installation.	The accounted number of WTGs and OSS and the maximum length of cables resulting in greatest extent of temporary habitat loss.

Potential impact	Phase[1] C	O	D	Project design parameters	Justification
Injury and/or disturbance to fish from underwater noise during pile-driving	✓	✗	✗	**Construction Phase** • 26 monopiles (WTGs and OSS) of 9.6 m diameter; • Average maximum hammer energy of 2,500 kJ (absolute maximum of up to 3,500 kJ); • Average five hours piling per pile (maximum of eight hours) with one pile expected to be installed in each 24-hour period; • Maximum of 208 hours piling over a total of 26 days.	The assessment of potential impacts considers the maximum hammer energies and maximum piling duration for monopile installation. In many cases, monopile installation will require lower hammer energies and shorter piling durations.
Increased suspended sediment concentrations and associated sediment deposition	✓	✓	✓	**Construction phase** WTGs and OSS installed on monopile foundations: • Drilled installation of 9.6 m diameter pile. Installation of inter-array cables and offshore cable: • Disturbance of seabed material from a 1 m wide trench for inter-array cables, 3 m wide trench for offshore cable and 3 m deep trench; and • Modelled cable lengths over areas of sand and muddy sand. **Operational and maintenance phase** Cable repair/reburial activities: • Inter-array cables: seven repair events and seven reburial events; and • Offshore cable: three repair events and three reburial events (three subtidal and three intertidal). **Decommissioning phase** WTGs and OSS on monopile foundations: • Cutting and removal of monopile foundations to approximately 2 m below seabed. Removal of inter-array cables and offshore cable: • Disturbance of seabed material from a 1 m wide trench for inter array cables, 3 m wide trench for offshore cable and 3 m deep trench.	Greatest volume of sediment released into the water column. See appendix B: Marine Processes Technical Report for further justification.
Long-term subtidal habitat loss	✗	✓	✗	**Operational and maintenance phase** 332,060 m^2 of long-term habitat loss due to: • Presence of 26 (i.e. 25 x WTG + 1 x OSS) monopile foundations with base diameter of 9.6 m and associated scour protection; and • Presence of cable protection associated with 41 km inter-array cables and 16 km offshore cable. Assumes 50% of inter-array cable route and 50% of offshore cable may require cable protection. Operational phase 40 years.	The accounted number of WTG and OSS foundation type and associated scour protection; maximum length of cables and cable protection resulting in greatest extent of habitat loss.
Electromagnetic Fields (EMF) from subsea electrical cabling	✗	✓	✗	**Operational and maintenance phase** Presence of inter-array cables and offshore cable: • 41 km of 66 kV AC inter-array cables; • 16 km of 220 kV offshore cable; • Burial depths of between 0.5 m and 3 m; and • 50% of inter-array cable route and 50% of offshore cable corridor may require cable protection. Operational phase of 40 years.	Maximum length of cables and minimum burial depth (the greater the depth the more the EMF is attenuated).

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

4.2 Measures included in the Project

As part of the project design process, a number of measures have been proposed to prevent or reduce the potential for impacts on Fish and Shellfish Ecology (see Table 4-2). These measures include designed-in and management measures (controls).

These measures were not taken into account in section 4 of the Stage 1 screening appraisal to inform screening for appropriate assessment (see appendix A: Report to Inform Screening for Appropriate Assessment) in accordance with guidance and prevailing case law but can lawfully be taken into account for the Stage 2 appraisal.

As there is a commitment to implement these measures, they are considered inherently part of the design of the Project and have therefore been considered in the assessment of potential impacts presented in section 6 below (i.e. the determination of magnitude assumes implementation of these measures). These measures are considered standard industry practice for this type of development.

Table 4-2: Measures included in the Project.

Measures included in the Project	Justification
An Environmental Management Plan (EMP) (see appendix K: Management Plans) will be implemented during the construction, operational and maintenance and decommissioning phases of the Project. The EMP includes project specific measures and commitments and a Marine Pollution Contingency Plan (MPCP). Measures also include: designated areas for refuelling where spillages can be easily contained, storage of chemicals in secure designated areas in line with appropriate regulations and guidelines, double skinning of pipes and tanks containing hazardous substances, and storage of these substances in impenetrable bunds.	To ensure that the potential for release of pollutants from construction, operational and maintenance and decommissioning plant is minimised. In this manner, accidental release of contaminants from vessels will be strictly controlled, thus providing protection for marine life across all phases of the Project.
Burial and protection of cables - The cables will be buried below the seabed wherever possible, to a minimum burial depth of 0.5 m and a maximum burial depth of 3 m. The appointed contractor will be required prior to the construction phase to submit details on the cable specification and installation methodology. This will include details on the cable laying, including geotechnical data, cable laying techniques and a cable burial risk assessment. Also, in advance of any cable repair, the contractor will be required to submit details on the parameters of the repair or reburial activities and the proposed methodology.	While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and marine mammal and megafauna (and fish and shellfish) receptors, thereby potentially reducing the effect on those receptors.
During piling operations, soft starts will be used (in accordance with international best practices for underwater noise, which includes the 'Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters' (DAHG, 2014)). This will involve the implementation of lower hammer energies (i.e. approximately 10-15% of the maximum hammer energy; see section 6.2 below) at the beginning of the piling sequence before energy input is 'ramped up' (increased) over time to required higher levels.	This measure will minimise the risk of injury to fish species in the immediate vicinity of piling operations, allowing individuals to flee the area before noise levels reach a level at which injury may occur.

4.3 Impacts scoped out of the assessment

On the basis of the baseline environment and the project description outlined in section 2 of the NIS, a number of impacts are proposed to be scoped out of the assessment for fish and shellfish ecology. These impacts are outlined, together with a justification for the scoping out decision, in Table 4-3.

Table 4-3: Impacts scoped out of the assessment for fish and shellfish ecology.

Potential impact	Justification
Seabed disturbance leading to the release of sediment contaminants and resulting potential effects on fish and shellfish ecology	Site specific sediment sampling for contaminants will be carried out prior to construction of the Project. Although site specific sediment contamination levels are unknown at this time, it is considered unlikely that sources of contamination will be present in any greater concentrations than trace amounts. There is limited potential of contamination to sediments from anthropogenic activities. In addition, sediments at the offshore wind farm area and offshore cable corridor contain sand and coarse sediment which will not retain contamination substances as coarser sediments are harder to combine with and any contamination will be washed away and diluted to negligible levels. Assessment of any possible contamination on benthic ecology receptors considered the impact to be negligible (see appendix D: Benthic Subtidal and Intertidal Ecology – Supporting Information). As such, there is no potential for effects on fish and shellfish receptors from this impact and this impact has therefore been scoped out of the assessment.
Accidental release of pollutants	The measures included in the Project, as set out in Table 4-2, will minimise the likelihood of accidental release of pollutants (e.g. spillage of chemicals) and in the unlikely event that such an incident occurs, they will limit the severity of any such release. The offshore wind farm area is relatively close to operational port facilities and as such offshore refuelling will not occur. All offshore operations will be subject to the measures set out in a MPCP and intertidal works will be subject to an EMP (see appendix K: Management Plans). As such, potential effects on fish and shellfish receptors from this impact are unlikely and this impact has therefore been scoped out of the assessment.
Disturbance to fish from underwater noise generated by vessels during construction, operation and decommissioning	Underwater noise modelling presented in appendix C: Subsea Noise Technical Report showed that underwater noise generated from vessels will be low and effects from noise emissions would only occur if fish species remained within immediate vicinity of the vessel (i.e. within metres) for a period longer than 12 hours which is highly unlikely. As such, there is no potential for effects on fish and shellfish receptors from this impact and this impact has therefore been scoped out of the assessment.
Disturbance to fish from underwater noise generated by wind turbines during operation	Noise generated by operational wind turbines is of a very low frequency and low sound pressure level (Andersson *et al.,* 2011). Studies have found that sound levels are only high enough to possibly cause a behavioural reaction within metres from a wind turbine (Sigray and Andersson, 2011; Andersson *et al.,* 2011) and therefore such levels are not considered to have potential effects on fish and shellfish receptors. This impact has therefore been scoped out of the assessment.
Colonisation of hard structures	There is the potential for subsurface structures to provide suitable substrate for colonisation of some mollusc species. However the increase in surface area suitable for colonisation would be extremely small in the context of hard and soft sediment habitats in the Fish and Shellfish Ecology Study Area and therefore this would not have a potential effect on the diversity or population levels associated with shellfish receptors within the Fish and Shellfish Ecology Study Area. This impact has therefore been scoped out of the assessment.
Impacts (injury and behavioural effects) to fish from geophysical survey noise generated during operational and maintenance surveys.	Injury ranges associated with geophysical surveys would be orders of magnitude smaller than those associated with piling activities. For geophysical surveys, injury has the potential to occur in very close proximity to geophysical survey equipment (i.e. within metres, if injury occurs at all), however injury will be avoided through the use of a ramp up procedure (i.e. where energy levels of survey equipment are slowly increased to the maximum to allow time for receptors to move away from noise levels that may cause injury). Temporary and reversible behavioural responses to geophysical

Potential impact	Justification
	surveys would be limited to tens to low hundreds of metres from the mobile geophysical survey vessel (again, where these occur at all). These impacts has therefore been scoped out of the assessment.
Temperature rises from the subsea cables causing a barrier effect	Warming of subsea cables may cause an increase in temperature of the seabed habitats (i.e. sands and gravels). All cables will be buried either beneath surface sediments or cable protection and as such, any increases in temperature at the sediment surface will be very small and highly localised in extent (i.e. any temperature increase would only occur in the immediate vicinity of the buried cable, i.e. within ~1 m). Due to the small changes predicted at the seabed and the highly localised nature of the change, it is not predicted to affect fish and shellfish receptors.

5 IMPACT METHODOLOGY

5.1.1 Overview

This report takes account of the following guidance documents and legislation:

- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2022);
- Guidance on Marine Baseline Ecological Assessments & Monitoring Activities for Offshore Renewable Energy Projects Parts 1 and 2 (Department of Communications, Climate Action and Environment (DCCAE), 2018);
- Marine Strategy Framework Directive (EU, 2008);
- Ireland's National Biodiversity Plan 2023-2030 (Department of Housing, Local Government and Heritage (DHLGH), 2024);
- Ireland's Integrated Marine Plan 2012;
- The Habitats Directive 92/43/EEC; and
- European Communities (Birds and Natural Habitats) Regulations 2011, as amended.

5.1.2 Impact assessment criteria

This section describes the criteria applied in this assessment to assign values to the magnitude of potential impacts and the sensitivity of the receptors.

The criteria for defining impact magnitude in this report are outlined in Table 5-1 below.

Table 5-1: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition
High	Loss of resource and/or quality and integrity of resource; severe damage to key characteristics, features or elements (Adverse)
	Large scale or major improvement of resource quality; extensive restoration or enhancement; major improvement of attribute quality (Beneficial)
Medium	Loss of resource, but not adversely affecting integrity of resource; partial loss of/damage to key characteristics, features or elements (Adverse)
	Benefit to, or addition of, key characteristics, features or elements; improvement of attribute quality (Beneficial)
Low	Some measurable change in attributes, quality or vulnerability, minor loss or, or alteration to, one (maybe more) key characteristics, features or elements (Adverse)
	Minor benefit to, or addition of, one (maybe more) key characteristics, features or elements; some beneficial impact on attribute or a reduced risk of negative impact occurring (Beneficial)
Negligible	Very minor loss or detrimental alteration to one or more characteristics, features or elements (Adverse)
	Very minor benefit to, or positive addition of one or more characteristics, features or elements (Beneficial)

The sensitivity of fish and shellfish qualifying features has been defined by an assessment of the combined vulnerability of the receptor to a given impact and the likely rate of recoverability to pre-impact conditions. Vulnerability is defined as the susceptibility of a species to disturbance, damage or death, from a specific external factor. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. Recoverability is dependent on a receptor's ability to recover or recruit subject to the extent of disturbance/damage incurred. Information on these aspects of sensitivity of the fish and shellfish qualifying features to given impacts has been informed by the best available evidence following environmental impact or experimental manipulation in the field and evidence from the offshore wind industry and analogous activities such as those associated with aggregate extraction, electrical cabling, and oil and gas industries. These assessments have been combined with the assessed conservation status (i.e. the level of designation/importance) of the affected receptor as defined in section 3.2.

The criteria for defining receptor sensitivity in this report are outlined in Table 5-2 below.

Table 5-2: Definition of terms relating to the sensitivity of the receptor.

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

5.1.3 European sites

Where Natura 2000 sites (i.e. internationally designated European sites) are considered, this report summarises the potential impacts on the QIs of internationally designated sites as described within section 3.1. The complete assessment of adverse effects on European sites is contained in the NIS for the Project.

6 POTENTIAL IMPACTS

The potential impacts arising from the construction, operational and maintenance and decommissioning phases of the Project are listed in Table 4-1, along with the project design parameters against which each impact has been assessed.

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

6.1 Temporary subtidal habitat loss/disturbance

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

6.1.1 Construction phase

Magnitude of impact

The installation of infrastructure within the offshore wind farm area and offshore cable corridor may lead to temporary subtidal habitat loss/disturbance. The project design parameters is for 709,500 m^2 of temporary habitat loss/disturbance during the construction phase (Table 4-1). This equates to 1.3% of the offshore wind farm area and offshore cable corridor and as such represents a very small proportion of the Project.

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

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

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

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

Sensitivity of the receptor

In general, mobile fish species are able to avoid areas subject to temporary habitat disturbance (EMU, 2004). Migratory fish are only expected to pass through the Fish and Shellfish Ecology Study Area on their way to/from spawning grounds, and therefore are not likely to be sensitive to this impact. The sensitivity of the relevant fish and shellfish receptors is therefore considered to be low.

6.1.2 Operational and maintenance phase

Magnitude of impact

Operational and maintenance activities within the offshore wind farm area and offshore cable corridor may lead to temporary subtidal habitat loss/disturbance. The project design parameters is for 387,000 m^2 of temporary habitat loss/disturbance during the operational and maintenance phase (Table 4-1). This equates to 0.7% of the offshore wind farm area and offshore cable corridor combined (see appendix D: Benthic Subtidal and Intertidal Ecology – Supporting Information), therefore this represents a very small proportion of the offshore wind farm area and offshore cable corridor combined. It should also be noted that only a small proportion of the total habitat loss/disturbance is likely to be occurring at any one time over the 40-year operational phase of the Project.

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

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

Sensitivity of the receptor

The sensitivity of the receptor can be found in section 6.1.1 above.

6.1.3 Decommissioning phase

Magnitude of impact

Decommissioning activities within the offshore wind farm area and offshore cable corridor may lead to temporary subtidal habitat loss/disturbance. The project design parameters are for up to 624,000 m^2 of temporary habitat loss/disturbance during the decommissioning phase (Table 4-1). This equates to 1.2% of the offshore wind farm area and offshore cable corridor combined, which represents a very small proportion of the offshore wind farm area and offshore cable corridor combined. For the purposes of this assessment, the impacts of decommissioning are predicted to be similar to those for the construction phase, as set out above.

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

Sensitivity of the receptor

The sensitivity of the receptor can be found in section 6.1.1 above.

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

6.2.1 Construction phase

Magnitude of impact

The installation of foundations within the offshore wind farm area may lead to injury and/or disturbance to fish from underwater noise during pile driving. As outlined in Table 4-1, the parameter assessed considers the maximum hammer energy and maximum piling duration, with 26 monopiles (WTGs and OSS), with each monopile installed via impact/percussive piling with an average maximum hammer energy of 2,500 kJ and absolute maximum hammer energy of up to 3,500 kJ. A maximum duration of 208 hours of piling activity, over a maximum 26-day period, may take place during the construction phase.

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

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

Sensitivity of the receptor

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

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

although they also detect particle motion. These species have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3.

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

Injury

Table 6-1 summarises the fish injury criteria recommended for pile driving based on the Popper *et al*. (2014) guidelines, noting that dual criteria are adopted in these guidelines to account for the uncertainties associated with effects of underwater noise on fish.

Table 6-1: Criteria for onset of injury to fish due to impulsive piling (Popper *et al.*, 2014).

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

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

The full results of the underwater noise modelling are presented in appendix C: Subsea Noise Technical Report. In order to inform this assessment, Table 6-2 and Table 6-3 display the predicted injury ranges associated with the installation of one 9.6 m diameter monopile at the east of the offshore wind farm area, for peak sound pressure levels (SPL_{pk}) and cumulative sound exposure level (SEL_{cum}) respectively. This modelled event resulted in the greatest predicted injury ranges and therefore forms the focus of the assessment for injury[2].

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

For peak pressure noise levels when piling energy is at its maximum (i.e. 3,500 kJ), recoverable injury to fish may occur within approximately 357 m of the piling activity. The potential for mortality or mortal injury to fish eggs would also occur at distances of up to 357 m (Table 6-2). It should be noted that these ranges are the maximum ranges for the maximum hammer energy, and it is unlikely that injury will occur in this range due to the implementation of soft starts during piling operations (see Table 4-2), which will allow fish to move away from the areas of highest noise levels, before they reach a level that would cause an injury. As outlined in

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

Table 6-2 below, the initial injury ranges for soft start initiation are considerably lower (i.e. approximately 118 m to approximately 172 m, depending on the fish species considered).

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

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

Table 6-2: Summary of peak pressure maximum injury ranges for fish due to installation of one 9.6 m diameter monopile at the east of the offshore wind farm area (assuming hammer energy of 3,500 KJ).

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

Table 6-3: Summary of cumulative SEL injury ranges for fish due to installation of one 9.6 m diameter monopile at the east of the offshore wind farm area (N/E = threshold not exceeded).

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

Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity caused by exposure to intense sound. Normal hearing ability returns following cessation of the noise causing TTS, though the recovery period is variable. When experiencing TTS, fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment. Table 6-4 presents the ranges at which TTS in fish may occur as a result of piling for one 9.6 m diameter monopile. This indicates that effects of TTS may occur to maximum ranges of up to 690 m.

Behaviour

Behavioural effects in response to construction related underwater noise include a wide variety of responses including startle responses (also known as C-turn responses), strong avoidance behaviour, changes in swimming or schooling behaviour or changes of position in the water column. The Popper *et al*. (2014) guidelines provide qualitative behavioural criteria for fish from a range of noise sources. These categorise the risks of effects in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. tens of metres), “intermediate” (i.e. hundreds of metres) or “far” (i.e. thousands of metres). The behavioural criteria for piling operations are summarised in Table 6-4 for the four fish groupings.

Table 6-4: Potential risk for the onset of behavioural effects in fish from piling (Popper *et al.*, 2014)[a].

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

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

Group 1 Fish (e.g. flatfish and elasmobranchs) and Group 2 Fish (e.g. salmonids) are less sensitive to sound pressure, with these species detecting sound in the environment through particle motion. However, sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al.,* 2010; Hawkins *et al*., 2014). Group 3 (including gadoids such as cod and whiting) and Group 4 fish (sprat and shad) are more sensitive to the sound pressure component of underwater noise and, as indicated in Table 6-4, the risk of behavioural effects in the intermediate and far fields are therefore greater for these species.

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

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

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

The authors did point out that any potential seismic effects on fish may not necessarily translate to population scale effect or disruption to fisheries and McCauley *et al*. (2000) show that caged fish experiments can lead to variable results. While these studies are informative to some degree, these, and other similar studies, do not provide an evidence base that is sufficiently robust to propose quantitative criteria for behavioural effects (Hawkins and Popper, 2016; Popper *et al.,* 2014) and as such the qualitative criteria outlined in Table 6-4 are proposed.

Figure 6-1 shows the modelled underwater noise levels based on the results from appendix C: Subsea Noise Technical Report, relative to fish spawning habitats for a number of marine species in the vicinity of the offshore wind farm area. The modelled outputs show that noise attenuation is rapid with distance from foundation location. They also indicate that, based on a behavioural response occurring at levels in excess of 160 dB re 1 μPa SPL_{peak}, fish may exhibit behavioural responses within approximately 7 km from the source. It should be noted, however, that this noise level is considerably lower than the levels reported by the existing studies on the effect of noise on fish behaviour outlined above. These results broadly align with qualitative thresholds for behavioural effects on fish as set out in Table 6-4, with moderate risk of behavioural effects in the range of hundreds to thousands of metres from the piling activity, depending on the species.

As set out above, increased tolerance (and decreased sensitivity) to underwater sound may occur for some fish and shellfish during key life history stages, such as spawning or migration. This was demonstrated in an investigation into the impact of impulsive seismic air gun surveys on feeding herring schools, which found a slight but not significant reduction in swimming speed when exposed to the sound impact (Peña *et al.*, 2013). The findings of this survey indicated that feeding herring did not display avoidance responses to seismic sound sources, even when the vessel came into close proximity to herring, which indicated an awareness of and response to impulsive anthropogenic sound, which would be expected in response to piling, but not a significant response when fish were highly motivated to remain within an area – in this case during feeding.

The behavioural effects from the underwater noise, at the levels expected as a result of the pile driving for the Project, are likely to be limited for diadromous fish species. As noted in the paragraph above, Figure 6-1 shows noise contours associated with piling operations. Noise levels in excess of 160 dB re 1 μPa SPL_{peak} are expected to lead to behavioural effects on fish, including diadromous fish. Broadly, the range at which these behavioural responses are likely to occur is approximately 7 km from the noise source and as demonstrated in Figure 6-1, this does not extend to the coast, even at the greatest hammer energies. Therefore, there is a large area for fish to navigate along the coast, whilst avoiding the noise source when migrating to and from rivers in which these species may spawn (e.g. River Boyne and River Blackwater SAC). As such, there is no potential for diadromous species to experience barriers to migration when moving from freshwater systems into and within the marine environment.

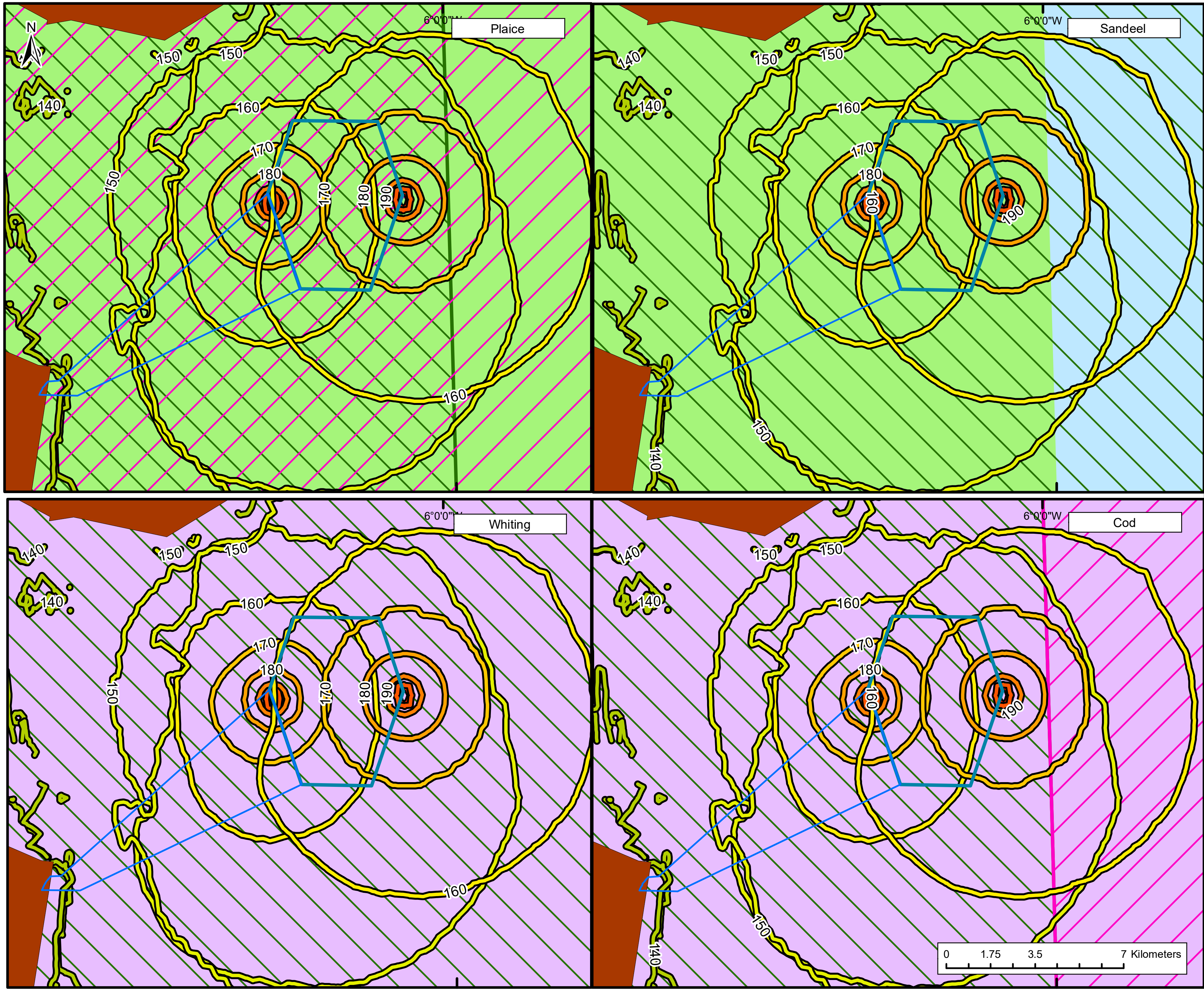
Group 1 Fish (e.g. flatfish, elasmobranchs, and lamprey), Group 2 Fish (e.g. salmonids) and aquatic decapod crustaceans are less sensitive to sound pressure, with these species typically detecting sound in the environment through particle motion. Group 1 elasmobranch species do not possess a swim bladder, and thus will be most impacted by particle motion. There is evidence of startle and fleeing responses to piling sounds at a minimum of 20-30 dB above background conditions due to increased particle motion (Casper *et al.,* 2012). However, sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al.,* 2010; Hawkins *et al.,* 2014). Particle motion is hard to quantify in the same way as sound pressure. It is likely that the designed-in soft start procedure will allow any individuals near the construction activities to avoid damage by fleeing the immediate area, suggesting low vulnerability overall to this impact. Furthermore, it is likely the area within which behavioural effects for sound pressure may occur is large enough and conservative enough to account for any potential behavioural responses and physical effects from particle motion as a result of piling.

Summary

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

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

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



Offshore Wind Farm Area
Offshore Cable Corridor

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

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

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

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

Client
ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project
Oriel Wind Farm Project

Title **Figure 6-1 Modelled underwater noise levels (peak pressure) associated with installation of monopiles within the offshore wind farm area and identified key fish spawning and nursery areas**

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Issue Details

Drawn By:	NG	Project No.	EOR0822 (MDR1520B)
Checked By:	NG	File Ref:	
Approved By:	AOS		EOR0822_FAS_E_1202_FINAL
Scale:	1:200,000 @A4	Projection:	ITM (IRENET95)
Date:	07/03/2024		Geographic Co-ordinates: ETRS89

6.3 Increased suspended sediment concentrations and associated sediment deposition

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

6.3.1 Construction phase

Magnitude of impact

The installation of infrastructure within the offshore wind farm area and offshore cable corridor may lead to increases in suspended sediment concentrations (SSC) and associated sediment deposition. The project design parameter for foundation installation assumes all wind turbine and offshore substation foundations will be installed by drilling 9.6 m diameter piles (Table 4-1).

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

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

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

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

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

Sensitivity of the receptor

In terms of SSC, adult fish species are more mobile than many of the other fish and shellfish receptors, and therefore may show avoidance behaviour within areas affected by increased SSC (EMU, 2004), making them less susceptible to physiological effects of this impact. Juvenile fish are more likely to be affected by habitat disturbances such as increased SSC than adult fish. This is due to the decreased mobility of juvenile fish and these animals are therefore less able to avoid impacts.

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

All migratory fish receptors within the Fish and Shellfish Ecology Study Area are deemed to be of low vulnerability, high recoverability and of international importance. The sensitivity of the receptor is therefore, considered to be low.

6.3.2 Operational and maintenance phase

Magnitude of impact

Operational and maintenance activities within the offshore wind farm area and offshore cable corridor may lead to increases in suspended sediment concentrations and associated sediment deposition. The project design parameter is for seven inter-array cable repair, seven reburial events, three offshore cable repair events and three reburial events over the Project lifetime (Table 4-1), using similar methods as those for cable installation activities (i.e. trenching/jetting).

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

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

Sensitivity of the receptor

The sensitivity of the fish and shellfish receptors can be found in section 6.3.1 above.

6.3.3 Decommissioning phase

Magnitude of impact

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

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

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

Sensitivity of the receptor

The sensitivity of the fish and shellfish receptors can be found in section 6.3.1 above.

6.4 Long-term subtidal habitat loss

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

6.4.1 Operational and maintenance phase

Magnitude of impact

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

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

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

Sensitivity of the receptor

Fish and shellfish species that are reliant upon the presence of suitable sediment/habitat for their survival are considered to be more vulnerable to change depending on the availability of habitat within the wider geographical region. However, migratory fish are only expected to pass through the Fish and Shellfish Study Area on their way to/from spawning grounds, and therefore are not likely to be sensitive to this impact. The sensitivity of these fish and shellfish receptors is therefore, considered to be low.

6.5 Electromagnetic Fields (EMF) from subsea electrical cabling

The installation of inter-array cables and offshore cable will conduct an AC current (see Table 4-1). The conduction of electricity through subsea power cables has the potential to emit a localised EMF which could potentially affect the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species (including elasmobranchs) and migratory fish species (CMACS, 2003).

6.5.1 Operational and maintenance phase

Magnitude of impact

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

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

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

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

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

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

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

Sensitivity of the receptor

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

Studies examining the effects of EMF from AC undersea power cables on fish behaviours have been conducted to determine the thresholds for detection and response to EMF. Table 6-5 provides a summary of the scientific studies conducted to assess sensitivity of EMF on varying fish species.

Table 6-5: Relationship between geomagnetic field detection, electrosensitivity, and the ability to detect 50/60-Hz AC fields in common marine fish and shellfish species (adapted from CSA, 2019).

Species Group	Detect Geomagnetic Field	Detect Electric Fields	Evidence from Laboratory Studies of 50/60-Hz EMF from AC Power Cables	Evidence from Field Studies of AC Power Cables
Skates	Yes, multiple species (Normandeau *et al.*, 2011)	Yes, multiple species (Normandeau *et al.,* 2011)	No responses expected at 60 Hz (Kempster *et al.*, 2013)	No attraction at California AC cable sites operating at up to 914 mG (Love *et al.*, 2016).
Flounders	Potentially, due to observed orientation behaviours (Metcalf *et al.*, 1993)	Not tested	Not tested	No population-level effects, but some evidence of delayed cable crossing. It is unclear whether effect was due to cable EMF or prior sediment disturbance (Vattenfall, 2006).
Tunas and mackerels	Yes, for some species (Walker, 1984)	Not tested (Normandeau *et al.*, 2011)	Not tested	Some evidence of attraction of mackerel to monopile structure, but no effect from cables (Bouma, 2008).
American/European Eels	Yes, for multiple species (Normandeau *et al.*, 2011)	Mixed evidence (Normandeau *et al.*, 2011)	No effect of 950 mG magnetic field at 50 Hz on swim behaviour or orientation (Orpwood *et al.,* 2015)	Unburied AC cable did not prevent migration of eels (Westerberg *et al.*, 2008).
Salmon	Yes, for multiple species (Yano *et al.*, 1997, Putman *et al.*, 2014)	Not tested (Normandeau *et al* 2011)	No effect of 950 mG magnetic field at 50 Hz on swim behaviour (Armstrong *et al.*, 2015)	Not surveyed.

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

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

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

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

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

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

7 IN-COMBINATION EFFECTS

7.1 Methodology

The in-combination assessment (ICA) takes into account the impact associated with the Project together with other projects. The projects selected as relevant to the in-combination assessment have based upon the results of a screening exercise (see appendix J: Screening – In-combination Effects). Each project has been considered on a case-by-case basis for screening in or out of this assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

The approach to in-combination examines the potential for effects associated with the Project alongside the following projects if they fall within the Zone of Influence (ZoI) for relevant European sites:

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

The specific projects screened into the in-combination assessment, are outlined in Table 7-1 and Figure 7-1.

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

Table 7-1: List of other projects considered with regards to in-combination effects.

Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction	Dates of operation	Overlap with the Project
Offshore Wind Farms							
North Irish Sea Array (NISA)	Maritime Area Consent	16.2	18.1	EIA Scoping Report (2021) refers to the construction of an offshore wind farm of up to 500 MW, consisting of 36 turbines with a maximum height of 320 m and rotor diameter of up to 290 m. Offshore substation platforms may be required. [3]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.
Dublin Array	Maritime Area Consent	61.2	56.9	EIA Scoping report (2020) refers to the construction of Bray and Kish offshore wind farm of up to 900 MW, consisting of up to 61 turbines with a maximum height of 308 m and rotor diameter of up to 285 m and up to three offshore substation platforms. [4]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.
Codling Wind Park	Maritime Area Consent	61.4	57.1	EIA Scoping report (2020) refers to the construction of up to 140 turbines with a maximum height of 320 m and rotor diameter of up to 288 m (up to 1500 MW). The project will also contain up to five offshore substation platforms.[5]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.

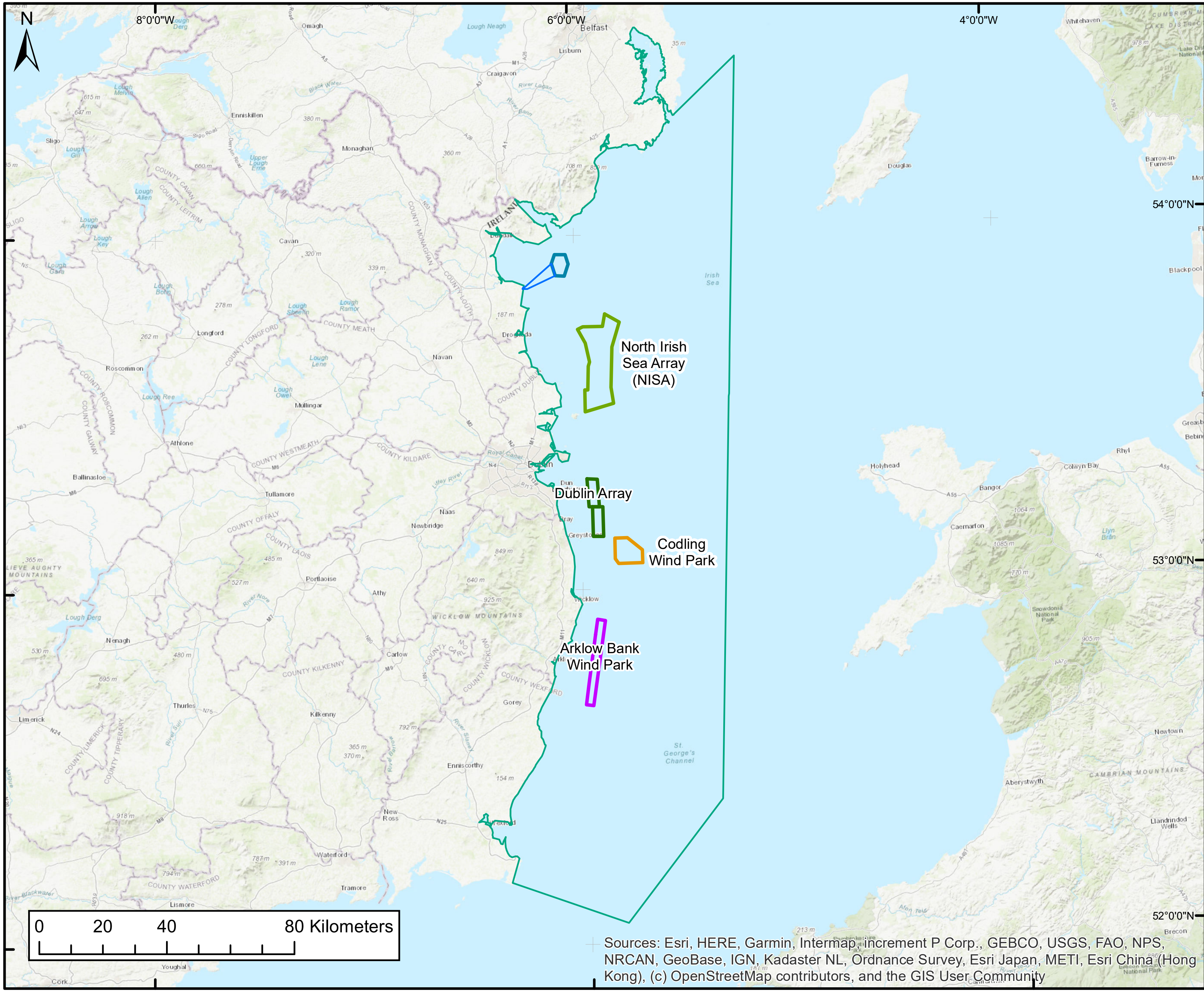
[3] Project website https://northirishseaarray.ie/: states that wind farm will consist of 35 to 46 turbines.

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

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

Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction	Dates of operation	Overlap with the Project
Arklow Bank Wind Park	Maritime Area Consent	107.1	104.6	EIA Scoping Report (2023): The project will include between 37 & 56 turbines and up to two OSS and foundation substructures. The area in which the proposed wind turbines, inter-array cables and OSS will be located on Arklow Bank covers an area of seabed approximately 64 km^2.[6]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Spatial overlap unlikely for impacts such as SSC, habitat loss and EMF. Potential for spatial overlap associated with underwater noise emissions.

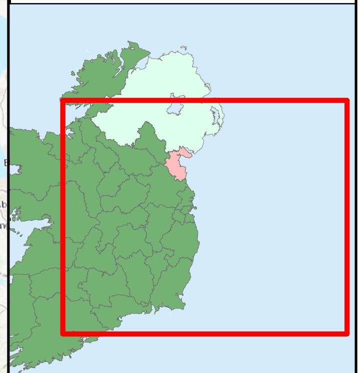
[6] Project website https://www.sserenewables.com/: states between 36 and 60 turbines (up to 800MW) along with one to two OSS and foundation substructures, a network of inter-array cabling and two offshore export cables.



Legend

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

Data Sources: Client



Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title **Figure 7-1**

Offshore projects screened into the in-combination assessment - fish and shellfish

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Issue Details

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

Table 7-2 presents the relevant project design parameters from Table 4-1, which are used to assess the potential in-combination effects of the Project with the other projects identified in Table 7-1 (where information is available).

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

Table 7-2: Project design parameters considered for the in-combination assessment of potential cumulative impacts on Fish and Shellfish Ecology.

Potential impact	Phase C	Phase O	Phase D	Project design parameters	Justification
Injury and/or disturbance to fish from underwater noise during pile-driving	✓	✗	✗	Project design parameter as described for the Project (Table 4-1) assessed in-combination with the following other projects: • NISA; • Codling Wind Park; • Dublin Array (Bray Bank and Kish Banks); and • Arklow Bank Wind Park.	Maximum potential for in-combination effects from underwater noise from construction operations within the Western Irish Sea Fish and Shellfish Ecology Study Area.

7.1.1 In-combination assessment

A description of the in-combination effects upon Fish and Shellfish Ecology receptors arising from the identified impact is given below.

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

Construction phase

Magnitude of impact

The installation of foundations within the offshore wind farm area, together with the projects identified in Table 7-2, may lead to injury and/or disturbance to fish from underwater noise during pile driving. Other projects screened into the assessment within the Western Irish Sea Fish and Shellfish Ecology Study Area include the NISA, Codling Wind Park, Dublin Array and Arklow Bank Wind Park offshore wind farms.

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

Piling operations will represent intermittent occurrences at these offshore wind farm sites, with each individual piling event likely to be similar in duration to those proposed for the Project. The project design parameter (temporal) for piling duration for the Project is for monopile foundations with on average five hours piling per pile (up to a maximum of eight hours per pile) (see Table 4-1). For other offshore wind farm projects monopile foundations have been assumed to represent the maximum design parameter. Therefore, given the intermittent nature of identified piling events the potential for temporal overlap is therefore minimised even when construction phases overlap which, as outlined in Table 7-1, is subject to change as construction phases are indicative.

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

Each of the impact assessments consider the project design parameters for hammer energy and/or the largest pile diameter and therefore result in the greatest propagation ranges. It should be noted, however, that the project specific assessments may have used behavioural response criteria which differ from the approach used for this Project and from the other projects. The project specific assessments were undertaken using the best scientific evidence available at the time that the assessments were drafted. As such, it is not appropriate to make direct comparisons between the behavioural response ranges across projects, however the following paragraphs do give an indication of the extents of behavioural responses from fish and shellfish to support this in-combination assessment.

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

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

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

Sensitivity of receptor

Sensitivities of fish and shellfish receptors to underwater noise are fully detailed in section 6.2.1. Fish injury as a result of piling noise would only be expected in the immediate vicinity of piling operations, and the area within which effects on fish larvae would be expected is similarly small, though it is unclear whether effects on fish larvae would include injury or mortality.

Behavioural effects on fish species as a result of piling noise are predicted to be dependent on the nature of the fish and shellfish receptors, with larger impact ranges predicted for pelagic fish than for demersal fish species. A detailed description of sensitivity of fish to underwater noise emissions is described in section 6.2.1.

The spread of behavioural impact ranges predicted for the identified projects reflects some of the uncertainty associated with behavioural effects criteria, with any behavioural effects also dependent on factors such as type of fish, its sex, age and condition, stressors to which the fish is or has been exposed or the reasons and drivers for the fish being in the area.

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

Therefore, given the varying levels of sensitivity associated with identified fish qualifying features, salmonids and shad (Group 2 and 4 fish) are deemed to be of medium to high vulnerability, medium recoverability and of international importance within the Western Irish Sea Fish and Shellfish Ecology Study Area. The sensitivity of these fish receptors is therefore considered to be medium.

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

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