Pentland floating offshore wind farm

Volume 2: Offshore EIAR

Chapter 10: Fish and Shellfish Ecology

PENTLAND FLOATING OFFSHORE WIND FARM

OFFSHORE EIAR (VOLUME 2): MAIN REPORT

CHAPTER 10: FISH AND SHELLFISH ECOLOGY

Document Title:	Pentland Floating Offshore Wind Farm Offshore EIAR
Document no.	GBPNTD-ENV-XOD-RP-00005
Project:	Pentland Floating Offshore Wind Farm
Originator Company	Xodus Group Ltd
Revision	01
Originator	Sinead Petersen
Date	27.07.2022

Revision History:

Revision	Date	Status	Originator	Reviewed	Approved
01	27.07.2022	Final	SP	TW/RM	PM

CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF PROJECT TERMS

Key Terms	Definition
Dounreay Trì Floating Wind Demonstration Project (the 'Dounreay Trì Project')	The 2017 consented project that was previously owned by Dounreay Trì Limited (in administration) and acquired by Highland Wind Limited (HWL) in 2020. The Dounreay Trì Project consent was for two demonstrator floating Wind Turbine Generators (WTGs) with a marine licence that overlaps with the Offshore Development, as defined. The offshore components of the Dounreay Trì Project consent are no longer being implemented.
Highland Wind Limited	The Developer of the Project (defined below) and the Applicant for the associated consents and licences.
Landfall	The point where the Offshore Export Cable(s) from the PFOWF Array, as defined, will be brought ashore.
Offshore Export Cable(s)	The cable(s) that transmits electricity produced by the WTGs to landfall.
Offshore Export Cable Corridor (OECC)	The area within which the Offshore Export Cable(s) will be located.
Offshore Site	The area encompassing the PFOWF Array and OECC, as defined.
Onshore Site	The area encompassing the PFOWF Onshore Transmission Infrastructure, as defined.
Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s) (the 'Offshore Development')	All offshore components of the Project (WTGs, inter-array and Offshore Export Cable(s), floating substructures, and all other associated offshore infrastructure) required during operation of the Project, for which HWL are seeking consent. The Offshore Development is the focus of this Environmental Impact Assessment Report.
PFOWF Array	All WTGs, inter-array cables, mooring lines, floating sub-structures and supporting subsea infrastructure within the PFOWF Array Area, as defined, excluding the Offshore Export Cable(s).
PFOWF Array Area	The area where the WTGs will be located within the Offshore Site, as defined.
PFOWF Onshore Transmission Infrastructure (the 'Onshore Development')	All onshore components of the Project, including horizontal directional drilling, onshore cables (i.e. those above mean low water springs), transition joint bay, cable joint bays, substation, construction compound, and access (and all other associated infrastructure) across all project phases from development to decommissioning, for which HWL are seeking consent from The Highland Council.
PFOWF Project (the 'Project')	The combined Offshore Development and Onshore Development, as defined.

ACRONYMS AND ABBREVIATIONS

AC	Alternating Currents
AIS	Automatic Identification System
CBRA	Cable Burial Risk Assessment
CEFAS	Centre for Environment Fisheries and Aquaculture Science
CEMP	Construction Environmental Management Plan
CMS	Construction Method Statement
DC	Direct Current
DSFB	District Salmon Fisheries Board
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMF	Electromagnetic Fields
EPS	European Protected Species
EU	European Union
EUNIS	European Union Nature Information System
FAD	Fish Aggregation Device
FMS	Fisheries Management Scotland
GIS	Geographic Information System
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Appraisal
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
Hz	Hertz
ICES	International Council for the Exploration of the Sea
INSPIRE	Impulse Noise Sound Propagation and Impact Range Estimator
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
Km	Kilometre
kV	Kilovolt
m	Metre
m/s	Metres per second
MarLIN	Marine Life Information Network
MARPOL	The International Convention for the Prevention of Pollution from Ships
MHWS	Mean High Water Springs
MPA	Marine Protected Area
MMO	Marine Maritime Organisation
MS-LOT	Marine Scotland - Licensing Operations Team
MSS	Marine Scotland Science
mT	Millitesla
MW	Megawatts
NCA	Nature Conservation Appraisal
NCMPA	Nature Conservation Marine Protected Area
NMPI	National Marine Plan Interactive
NOAA	National Oceanic and Atmospheric Administration
OEMP	Operational Environmental Management Plan
OSPAR	Oslo / Paris Convention
OWF	Offshore Wind Farms
PFOWF	Pentland Floating Offshore Wind Farm
PMF	Priority Marine Feature
PO	Plan Option
PTS	Permanent Threshold Shift
ROV	Remotely Operated Vehicles
RIAA	Report to Inform the Appropriate Assessment
SAC	Special Area of Conservation

SEL	Sound Exposure Level
SFF	Scottish Fishermen's Federation
SHEPD	Scottish Hydro Electric Power Distribution
SMP	Sectorial Marine Plan
SNH	Scottish Natural Heritage
SSSI	Sites of Special Scientific Interest
TLP	Tension Leg Platform
TTS	Temporary Threshold Shift
UK	United Kingdom
UKBAP	UK Biodiversity Action Plan
UXO	Unexploded ordnance
μV	Microvolts
μT	Microtesla
WTG	Wind Turbine Generators
ZoI	Zone of Influence

10 FISH AND SHELLFISH ECOLOGY

10.1 Introduction

The potential effects of the Pentland Floating Offshore Wind Farm (PFOWF) Array and Offshore Export Cable(s), hereafter referred to as the 'Offshore Development', during the construction, operation and maintenance, and decommissioning phases on Fish and Shellfish Ecology are assessed in this chapter. The Chapter also includes an assessment of the potential cumulative effects with other relevant projects.

Physical conditions such as sediments, water quality and physical processes are considered in Chapter 7: Physical Processes and Chapter 8: Water and Sediment Quality. Commercially important fish and shellfish species have a cross over with Chapter 13: Commercial Fisheries, and vessel activity has been cross referenced with Chapter 14: Shipping and Navigation.

Xodus Group Limited have drafted and carried out the impact assessment. Further competency details of the Project Team, including the lead authors for each chapter, are provided in Volume 3: Appendix 1.1: Details of the Project Team of this Offshore Environmental Impact Assessment Report (Offshore EIAR).

Table 10.1 below provides a list of all the supporting studies which relate to the Fish and Shellfish Ecology impact assessment. All supporting studies are appended to this Offshore EIAR.

Table 10.1 Supporting studies

Details of study	Locations of supporting studies
Pentland Floating Offshore Wind Farm (PFOWF): Underwater noise modelling – Subacoustech Environmental Report No. P296R0103	Offshore EIAR (Volume 3): Technical Appendix 10.1: Underwater Noise Modelling
Environmental Baseline Report – MMT Pentland Floating Offshore Wind Farm, Geophysical & Environmental Survey 2021- 103760-HWL-MMT-SUR-REP-ENVEBSRE.	Offshore EIAR (Volume 3): Technical Appendix 9.1: Environmental Baseline Report

Effects on migratory fish receptors are also further addressed where identified as a qualifying interest of screened in Special Areas of Conservation (SACs) in the Report to Inform the Appropriate Assessment (RIAA). This is submitted alongside this Offshore EIAR as part of the overall application.

10.2 Legislation, Policy and Guidance

In addition to those described in Chapter 3: Policy and Legislative Context of this Offshore EIAR, the following relevant legislation and guidance documents relating to Fish and Shellfish Ecology were used in the preparation of this Chapter:

10.2.1 Legislation

- The Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention) 1992: Are a series of Annexes put in place for the prevention and elimination of pollution from land based sources, by dumping or incineration, and from offshore sources, and assessment of the quality of the marine environment, and on the protection and conservation of the ecosystems and biological diversity of the maritime area;
- The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention; 1979) outlines legal commitments for contracting parties on the conservation of engendered and vulnerable species specified in the appendices of this instrument;

- The Convention on the Conservation of Migratory Species of Wild Animals ('the Bonn Convention'): Outlines legal commitments for contracting parties on the conservation of endangered migratory species and their habitats;
- United Kingdom (UK) Biodiversity Action (UKBAP) was the UK government's response to the Convention on Biological Diversity, opened for signature at the Rio Earth Summit in 1992;
- Wildlife & Countryside Act 1981 (as amended) is the primary legislation which protects animals, plants and habitats in the UK;
- Nature Conservation (Scotland) Act 2004 ensures public bodies in Scotland have a duty to further the conservation of biodiversity;
- Wildlife and Natural Environment (Scotland) Act 2011 provides various protections to certain wild animals in Scotland, and makes amendments to the Nature Conservation (Scotland) Act 2004; and
- The Conservation (Natural Habitats, &c.) Regulations 1994 (Habitats Regulations) and the Conservation of Marine Habitats and Species Regulations 2017 (Habitats Regulations) – implement the protection requirements of the Habitats and Birds Directive in Scottish waters and underpin the Habitats Regulations Appraisal (HRA) process.

10.2.2 Policy and Strategy

- Priority Marine Features (PMFs) is a list of 81 PMFs adopted by Scottish Ministers many of which are features characteristic of the Scottish marine environment;
- Scotland's National Marine Plan (Marine Scotland, 2015), prepared in accordance with the UK Marine Policy Statement, which outlines the framework for marine plans for the UK marine environment. Policies GEN 9, GEN 13 and WILD FISH 1 are considered relevant to fish and shellfish receptors;
- International Union for Conservation of Nature (IUCN) Red List of Threatened Species was established in 1964 and is the world's most comprehensive information source on the global extinction risk status of animal, fungus and plant species;
- Scottish Biodiversity Strategy is made up of two documents: Scotland's Biodiversity: It's in Your Hands and the 2020 Challenge for Scotland's Biodiversity. The aims of the strategy are to: protect and restore biodiversity on land and in our seas, and to support healthy ecosystems, connect people with the natural world, for their health and well-being, and to involve them more in decision making and maximise the benefits for Scotland of a diverse natural environment and the services it provides, contributing to sustainable economic growth; and
- Caithness Biodiversity Action Plan forms part of a suite of Local Biodiversity Action Plans produced for the Highland Council area by the Highland Biodiversity Project.

10.2.3 Guidance

- The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) have developed a guidance document for Environmental Impact Assessment for the licensing of offshore windfarms (CEFAS, 2004); and
- CEFAS (2012), Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects.

10.3 Scoping and Consultation

Scoping and consultation have been ongoing throughout the Environmental Impact Assessment (EIA) process and have played an important part in ensuring the scopes of the baseline characterisation and impact assessment are appropriate with respect to the Offshore Development and the requirements of the regulators and their advisors.

Relevant comments from the EIA Scoping Opinion and the Scoping Opinion Addendum specific to Fish and Shellfish Ecology provided by Marine Scotland Licensing Operations Team (MS-LOT) on behalf of Scottish Ministers, Marine Scotland Science (MSS), Fisheries Management Scotland, NatureScot, Northern District Salmon Fisheries Board, Scottish Fishermen's Federation (SFF), and Caithness District Salmon Fishery Board are summarised in Table 10.2 below, which provides a high-level response on how these comments have been addressed within this Offshore EIAR.

Table 10.2 Summary of consultation responses specific to Fish and Shellfish Ecology

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
Scoping Opinion		
MS-LOT (on behalf of Scottish Ministers)	*With regards to the baseline data, the Scottish Ministers are broadly content with the existing data on fish and shellfish resources listed in the Scoping Report however, highlight the additional studies, reports and current data sources available as recommended by MSS, FMS, Caithness DSFB and Northern DSFB. The Scottish Minsters advise that these must be included and fully considered in the EIA Report. In addition, the Scottish Ministers highlight the recommendation by MSS regarding the presentation of some of the data. Please note that diadromous fish will now be considered separately from marine fish and the Scottish Ministers advice is detailed in paragraphs 5.5.7 to 5.5.10.*	The additional data sources have been taken into consideration. These are listed in Section 10.4.2 and considered within this assessment. Impacts on diadromous fish and marine fish have been considered separately within Section 10.6 where relevant.
	Within Table 8-3 of the Scoping Report, the Developer identifies marine fish species which are proposed to be considered within the EIA Report for further assessment. The Scottish Ministers agree with the species identified and direct the Developer to MSS advice that Table 8-3 is updated to reflect those species which are PMFs. The EIA Report must include quantification, where possible, of the likely impacts to key PMFs (those that are important prey for marine predators such as seabirds and marine mammals including, but not limited to, herring, sandeels and sprat) and consider whether this could lead to a significant impact on their national status and the implications for predator/prey interactions. This view is supported by both NatureScot and MSS representations.	Table 10.4 shows the conservation importance of all the species listed (including PMF). These sensitive species have been assessed for the impacts identified where relevant.
	Potential impacts on fish and shellfish ecology receptors during all phases of the Offshore Proposed Development are considered by the Developer within Table 8-4 of the Scoping Report. The Scottish Ministers agree with the potential impacts which have been identified for marine fish and shellfish ecology however, advise that the potential impacts from EMF from subsea and dynamic cables; fish aggregation around floating structures and associated infrastructure; and habitat loss and disturbance must also be scoped in and fully addressed by the Developer in the EIA Report. The representations from MSS and NatureScot both agree with this view.	The potential impacts due to Electromagnetic Fields (EMF) during the operational phase has been scoped in for assessment, see Section 10.6.2.2. The potential impact of fish aggregation around floating structures and associated infrastructure has also been assessed, see Section 10.6.2.3. The potential impacts associated with habitat loss include direct habitat loss in the construction phase and habitat loss due to the

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
		presence of anchors and Offshore Export Cable(s) on the seabed during the operational phase.
	With regards to impacts from EMF, the Scottish Ministers highlight the MSS advice that consideration must also be given to pelagic fish species that may come into contact with dynamic cables which are free hanging in the water column.	The potential impacts due to EMF during the operation and maintenacne phase, including an assessment of the dynamic cable sections, have been scoped in for assessment, see Section 10.6.2.2.
	In relation to habitat disturbance, the Scottish Ministers agree with NatureScot that both temporary and long term habitat loss and disturbance from the Offshore Proposed Development on prey species is a key impact that must be considered across their life history stages. In addition, the Scottish Ministers advise that the Developer considers technical designs that minimise seabed disturbance and footprint, such as the shared anchor point and steep wave mooring system in the EIA Report, as highlighted by MSS.	The potential impacts on prey species have been taken into consideration within the impact assessments related to habitat loss and disturbance. See Sections 10.6.1.1.3 and 10.6.2.1. The developer has considered designs that reduce seabed disturbance and footprint, such as a reduction in the number of Wind Turbine Generators (WTGs), moorings and anchors. The worst case Design Envelope for the assessment is detailed in Section 10.5.4.
	Within Table 8-5 the Developer details the principle methods of assessment to be employed within the EIA Report. With regards to the proposed assessment to be undertaken to identify suitable habitat for sandeel spawning and nursery grounds, the Developer proposes a desk based assessment to review seabed images collected in the Study Area. The Scottish Ministers agree that further confirmation and refinement of sandeel spawning and nursery grounds is required; however, direct the Developer to the MSS advice that seabed images to determine suitability of sediments present for sandeel spawning is not an accurate method. Therefore, the Scottish Ministers recommend that the Developer must undertake surveys and use sediment analysis as a more accurate method to determine whether spawning is likely within an area in line with the MSS advice.	Benthic surveys took place in 2021 that included grab samples that were used to identify potential sediment habitats favoured by fish and shellfish (Offshore EIAR [Volume 3]: Technical Appendix 9.1). This is detailed within Section 10.4.4.2.
	The Scottish Ministers agree with the Developer that the main diadromous fish likely to occur at the site are Atlantic salmon, sea trout and eel. With regards to the proposed study area, the Scottish Ministers highlight the MSS advice that diadromous fish should be considered over a larger study area than defined in Section 8.3.5 of the Scoping Report. The Scottish Ministers agree and advise that the Developer must consider and include the potential impacts of the salmon populations of the Rivers Borgie, Naver and Thurso Special Area of Conservation ("SACs") within the EIA Report.	Diadromous fish have been considered separately to marine fish where relevant, see Section 10.4.4.4 and 10.6. For Atlantic salmon, the Rivers Borgie, Naver and Thurso SACs have been considered, see Section 10.4.4.1. Further assessments of these SACs are provided in the RIAA (HWL, 2022).

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	For the avoidance of doubt, all additional impacts scoped in above in paragraph 5.5.3 for marine fish and shellfish must also be scoped in for diadromous fish. With regards to the impact of fish aggregation, the Scottish Ministers agree with MSS that this must be expanded on in relation to diadromous fish to include the potential for the structures to attract and offer shelter and favourable predation opportunities to predatory birds, mammals and larger fish. This must be considered in the EIA Report. Furthermore, the Scottish Ministers advise that all types of marine renewables development are considered in the cumulative assessment, in addition to those developments listed in Table 8-4 of the Scoping Report.	Diadromous fish have been considered separately to marine fish where relevant, see Section 10.4.4.4 and 10.6. The potential impact of fish aggregation around floating structures and associated infrastructure has also been assessed, as well as potential predator prey impacts (see Section 10.6.2.3). The developments listed within the cumulative effects Section have been expanded to include all types of marine development with potential connectivity to the Offshore Development (see Section 10.7).
	Finally, the Scottish Ministers highlight the representations by Northern DSFB, Caithness DSFB and FMS and request the Developer fully considers these comments in the EIA Report. For the avoidance of doubt, barrier effects do not require to be scoped in to the EIA Report. The Scottish Ministers note that the EIA Report must evidence consultation input from the local fishery board(s), where relevant, in line with the representation from the Highland Council. In this respect, the Scottish Ministers highlight MSS advice that the Association of Salmon Fishery Boards is now Fisheries Management Scotland and that the Developer should consult Orkney Trout Fishing Association in relation to the sea trout rod fishery in Orkney waters.	Consideration and a response to these comments from Northern DSFB, Caithness District Salmon Fisheries Board (DSFB) and Fisheries Management Scotland (FMS) are provided within this table and taken forward into the assessment where appropriate. Initial contact has been made with the Orkney Trout Fishing Association, and further consultation is planned during July / August 2022. HWL will continue to engage with the Orkney Trout Fishing Association as required throughout the project development process.
	MSS advised that the matter of adequacy of knowledge of diadromous fish populations from SAC rivers which could be impacted should be considered in the EIA Report as well as the HRA. The Scottish Ministers agree with MSS and request that an assessment is included in the EIA Report as well as the HRA.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR see Section 10.4.4.1. Further assessments of these SACs are provided in the RIAA (HWL, 2022).
MSS	***Marine Fish Ecology*** *Data, survey work and EIAR assessment methodology MSS are content that most of the existing data on fish and shellfish resources have been listed, however MSS advise that the developer refers to a report which provides a modelled spatial representation of the probability of the presence of 0 age group fish (fish in the first year of their life) and the probability of aggregations of 0 age group fish (Aires et al. 2014). It is recommended these data are presented visually in conjunction with the*	The Aires *et al*. 2014 data has been included within Figure 10.7. Other sources such as Coull *et al.* (1998) and Ellis *et al.* (2012) are also provided within Section 10.4.4.3.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	Coull et al. (1998) and Ellis et al. (2012) nursery maps, as there are certain limitations with the data. Further details are available here: *(https://www2.gov.scot/Topics/marine/science/MSInteractive/Themes/fish-fisheries/fsm)*	
	In addition to the Coull et al. (1998), Ellis et al. (2010) and Aires et al. (2014) data, new information is available regarding the spawning areas of cod, haddock and whiting (González-Irusta and Wright 2016; González-Irusta and Wright 2016; González-Irusta and Wright 2017). The whiting paper is available but the associated GIS layers are not available as yet. The three papers contain the new information however they are not yet available on NMPi. We hope that these will be available online shortly to enable their use	The sources outlined by MSS have been included in Table 10.3 and referenced where applicable within this Offshore EIAR.
	MSS advise that it would be helpful to include the results of the ICES International Herring Larvae Survey (IHLS), due to the proximity of the study area to herring spawning grounds. These data provide quantitative estimates of herring larval abundance which are used as a relative index of changes in herring spawning stock biomass in the assessment.	The source outlined by MSS has been included in Table 10.3 and referenced where applicable within this Offshore EIAR.
	MSS also advise referencing the ORJIP study on 'Impacts on fish from piling at offshore wind farm sites: collating population information, gap analysis and appraisal of mitigation options' which was published in 2018 (Boyle and New 2018).	The source outlined by MSS has been included in Table 10.3 and referenced where applicable within this Offshore EIAR.
	As stated in this Scoping Report, predicted EUNIS habitat data suggests there may be suitable seabed habitat for sandeels within the Study Area. The developer states that this would need to be confirmed by benthic grab samples and geophysical and geotechnical site investigation surveys. In section 8.3.10 (Method of Assessments) the developer proposes a desk based assessment to review seabed images collected in the area to determine suitability of sediments present for spawning and nursery grounds. MSS agree that further confirmation and refinement of sandeel spawning areas is required and therefore MSS advise that surveys should be undertaken to identify suitable habitat for sandeel spawning to inform impact assessment and the need for mitigation. Reviewing seabed images to determine suitability of sediments present for sandeel spawning is not an accurate method. MSS recommend sediment analysis as a more accurate method to judge whether spawning is likely within an area. Sandeels prefer spawning substrate with a low clay	Benthic surveys took place in 2021 that included grab samples that were used to identify potential fish and shellfish favourable sediment habitats (Offshore EIAR [Volume 3]: Technical Appendix 9.1). The sources suggested by MSS have been included in Table 10.3 and referenced where applicable.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	silt fraction (<10%) and typical sandeel habitat is within the 20 – 100 m water depth range (Mazik et al. 2015 and Lancaster et al. 2014).	
	MSS is content with the fish species identified in Table 8-3 but recommend that the table is updated to reflect those fish species which are Priority Marine Features (PMFs), to highlight the importance of those species. MSS also recommend that the EIAR should consider those fish species which provide an important function as a key prey resource (such as herring, sandeels and sprat) and the implications for predator/prey interactions.	Table 10.4 shows the conservation importance of all the species listed (including PMF). The impact section takes into account the potential impact on prey species where applicable (see Sections 10.6.1.2 and 10.6.2.1).
	Impacts *MSS agree with the potential impacts which have been identified for fish and shellfish ecology however MSS have some further points for consideration.* *EMF - MSS agrees with NatureScot and advise that the potential effects of EMFs (from subsea and dynamic cables) on sensitive species are scoped in. Floating offshore wind farms have dynamic cables which are free-hanging in the water column and therefore consideration should also be given to pelagic fish species that might come into contact with these cables.*	The potential impacts due to EMF during the operational phase, including those from the dynamic cable sections, have been scoped in for assessment (see Section 10.6.2.2).
	Fish aggregation around the floating structure and associated infrastructure MSS agrees with NatureScot and advise that fish aggregation around the floating structure and associated infrastructure should be scoped in. Floating offshore wind farms may act as a fish aggregation device and this may have wider ecological implications such as attracting marine predators.	The potential impact of fish aggregation around floating structures and associated infrastructure has also been assessed (see Section 10.6.2.3).
	Habitat disturbance *MSS welcome any technical designs that minimise seabed disturbance and footprint such as the shared anchor point and steep wave mooring system*	Refinement of the Offshore Development parameters has taken place and these refinements are presented in Chapter 3: Site Selection and Alternatives and Chapter 5 Project Description. These relevant refinements are reflected within each of the impact assessments, as presented in Section 10.5.4 of this Chapter.
	Diadromous fish *MSS agree that the main diadromous fish likely to occur at the site are Atlantic salmon, sea trout and eel. Malcolm et al. (2010) provided a comprehensive review of information on the coastal migration of returning adult salmon and emigrating salmon smolts, and sea trout. However, new material has shed additional light on*	The sources suggested by MSS have been included in Table 10.3 and referenced where applicable. The Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR (see Section 10.4.4.1).

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	various topics - notably, in this part of Scotland, in relation to returning adult salmon. Tagging studies and some genetic assignment of salmon caught at sea off the north coast of Scotland to their rivers of origin show that fish destined for north coast and more distant rivers, particularly Scottish east coast rivers, are present (Malcolm et al. 2010, Cauwelier et al. 2015, Godfrey et al. 2015, Godfrey et al. 2014, Downie et al. 2018). Of the rivers on the north coast with populations of salmon, the three with the largest populations are the Rivers Borgie, Naver and Thurso, and all are designated as salmon SACs and all with valuable rod fisheries for salmon.	
	Diadromous fish are mobile and should be considered over a larger study area than that defined in Section 8.3.5. Certainly, the potential impacts on the salmon populations of the Rivers Borgie, Naver and Thurso should all be included for consideration in the EIAR. An annual grading of Scottish salmon rivers is carried out by Marine Scotland Science using catch, counter and juvenile survey data, to assess the resilience of the salmon population of each Scottish salmon river to any additional mortality. The latest assessment is at Consultation and application of conservation limits on salmon - gov.scot (www.gov.scot). This approach now forms the basis of assessing the state of the salmon populations in SACs.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR (see Section 10.4.4.1). Further assessments of these SACs are provided in the RIAA (HWL, 2022). Annual grading of Scottish salmon rivers data has been added to Section 10.4.4.1 Designated sites.
	In relation to diadromous fish, MSS are generally content with what is proposed in Table 8-4 to be scoped in and out. However, MSS agree with NatureScot that the effects of EMFs from subsea and dynamic cables on sensitive species should be scoped in. There is published information for Pacific salmon (Putman et al. 2013, 2014), which is also likely to apply to Atlantic salmon, on the importance of geomagnetic navigation both to post-smolts in migrating to marine feeding grounds and to returning adult salmon in homing to their natal rivers. Such navigation makes use of very small differences in the ambient magnetic fields which should be considered in relation to the magnetic fields associated with cables. Emigrating smolts and returning adults both mainly migrate close to the sea surface (many references are now available) which may increase the potential for the migration of geomagnetically navigating salmon to be impaired or delayed through interaction with EMF associated with mid water to surface cables. Hutchison et al. (2020) have recently reviewed the potential for interaction between resource species, including fish, and electromagnetic fields associated with electricity production by offshore wind farms.	The potential impacts due to EMF effects during the operational phase, including EMF effects from the dynamic cable sections, have been scoped in for assessment (see Section 10.6.2.2) The sources suggested by MSS have been included in Table 10.3 and referenced where applicable within this Offshore EIAR.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	MSS agree with NatureScot that fish aggregation effects around the floating structure and associated infrastructure should be scoped in, and this potential impact needs expanded in relation to diadromous fish to include the potential for the structures to attract and offer shelter and favourable predation opportunities to predatory birds, mammals and larger fish. The available relevant information which includes papers by Dannheim et al. (2019), Degraer et al. (2020) and Russell et al. (2014), albeit not on floating wind developments, should be reviewed to inform the impact assessment in the context of diadromous fish.	The potential effect of fish aggregation effects around the floating substructures and associated infrastructure during the operational phase have been scoped in for assessment (see Section 10.6.2.3). The sources suggested by MSS have been included in Table 10.3 and referenced where applicable within this Offshore EIAR.
	Regarding statutory sites, the justification of the statement in Table 11-6 in relation to the Rivers Borgie, Naver and Thurso that "As the Project will have no direct or indirect impact on the site or adjacent habitat, there is no pathway for impact as identified in this report." is not clear and requires further consideration.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR (see Section 10.4.4.1). Further assessments of these SACs are provided in the RIAA (HWL, 2022).
	MSS welcome (in Section 4) that the Northern and Caithness District Salmon Fishery Boards will be consulted. Although there is no District Salmon Fishery Board for Orkney, we recommend consulting with the Orkney Trout Fishing Association in relation to the important, although poorly documented, sea trout rod fishery in Orkney waters.	Initial contact has been made with the Orkney Trout Fishing Association, and further consultation is planned during July / August 2022. HWL will continue to engage with the Orkney Trout Fishing Association as required throughout the project development process.
	MSS highlight that the Association of Salmon Fishery Boards is now Fisheries Management Scotland.	Noted.
	In their consultation response to LOT of 18 February 2021, NatureScot state that "We recognise the continued lack of knowledge on individual river populations for diadromous species which are SAC qualifying interests, and so currently we continue to advise that the assessment of these should be covered within the EIAR rather than the HRA." MSS advise that the matter of the adequacy of knowledge of diadromous fish populations from SAC rivers which could be impacted should be considered both in the EIAR and in the screening report.	All 17 SACs were assessed within the Nature Conservation Appraisal (NCA) Screening Report (A-100671-S01-REPT-006), and those screened in have been assessed for connectivity within the RIAA (HWL, 2022). As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR (see Section 10.4.4.1)
	Marine fish ecology *We have considered the request and have no further comments to provide*	Noted.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	Diadromous fish *MSS do not advise that the possible barrier effects from floating platform and associated infrastructure and the effects of operational noise should be scoped in. These are at present speculative impact pathways with no hard evidence, although a literature-based study to review the impact of shadow flicker or pulsating shadow effect, caused by onshore wind turbines blades, on Atlantic salmon (Salmo salar) is currently being carried out by Scotland's Centre of Expertise for Waters (CREW).*	The potential impact on fish and shellfish associated with operational noise will not be assessed within the Offshore EIAR. See explanation in Section 10.5.2. As per MS-LOT's response on behalf of Scottish Minister's, the potential impacts associated with barrier effects will not be considered within the Offshore EIAR. See explanation in Section 10.5.2.
	MSS advise that all types of marine renewables development should be considered in the cumulative assessment.	The developments listed within the cumulative effects Section have been expanded to include all types of marine renewables development with potential for connectivity to the Offshore Development See Section 10.7.
Fisheries Management Scotland	*The Scoping Report cites the report by Malcom et al. 2010 regarding the importance of the development area for salmon, sea trout and eels. However, since that time further work and identification of evidence gaps has been undertaken, including the ScotMER Diadromous Fish Evidence Map. The Scoping Report should be updated to fully incorporate this process. It should also be updated to include more recent work undertaken by Marine Scotland Science (e.g. https://marine.gov.scot/data/application-acoustic-tagging-satellite-tracking-and-genetics-assessmixed-stock-nature-coastal).*	The chapter considers the ScotMER Diadromous Fish Evidence Map as well as other recent work undertaken by Marine Scotland as suggested. Additional sources have been taken into consideration as shown in Table 10.3, including the suggested source in this comment. This source has been referenced where appropriate within this Offshore EIAR.
	As highlighted in the response from the Northern District Salmon Fishery Board, Atlantic salmon use the Pentland Firth as a major migratory route for adult salmon returning to Scottish rivers from the northern ocean and possibly also some of the outward routes for salmon smolts leaving the northern rivers for the sea. The work undertaken by Marine Scotland Science (reference above) demonstrates that salmon for a wide range of Scottish rivers, specifically including the Spey SAC, utilise the Pentland Firth. We do not consider that it is possible to scope out any of the 17 SACs in Scotland, and should the developer wish to do so, a clearly evidenced justification will be necessary.	All 17 SACs were assessed within the NCA Screening Report (A-100671-S01-REPT-006), and those screened in have been assessed for connectivity within the RIAA (HWL, 2022).
	We consider that table 8.4 is inadequate and we wish to see a full consideration of the potential effects of the proposed development on salmon leaving and returning to Scotland's rivers, taking into account the strategic importance of the Pentland Firth	Additional information on potential salmon migratory routes has been included in Section 10.4.4.4.1.1. Potential effects to migratory fish at a local and wider level have been considered as part of this Offshore

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	as a major migratory route. This should include a full consideration of the cumulative effect of the development with existing and proposed developments across Scotland.	EIAR. This will include consideration of relevant projects with the potential to act cumulatively (see Section 10.6 and 10.7). The developments listed within the cumulative effects section have been expanded to include all types of marine renewables development with connectivity to the Offshore Development. See Section 10.7.
	We would make the following specific points about table 8.4: *Scoped out: Effects of EMFs from subsea and dynamic cables on sensitive species.* *We do not agree that EMFs can be scoped out as this stage. Indeed, we note that the HRA Screening Report for the proposed Berwick Bank Offshore Wind Farm, concluded that underwater noise, EMFs, accidental pollution and in-combination effects could not be discounted as likely significant effects for any of the SAC rivers identified in that report.* *EMFs in relation to floating windfarms were discussed at the MASTS floating wind workshop in October 2020. Concern was expressed that because the cables arising from the turbines are present in the water column and cannot be shielded, that this was an issue of particular importance.*	The potential impacts due to EMF effects during the operation and maintenance phase, including EMF effects from the dynamic cable sections, have been scoped in for assessment, see Section 10.6.2.2.
	Scoped out: Barrier effects on migratory fish from the presence of the floating platform and associated infrastructure. *In recent months, concerns have been raised by some of our members about the possibility of displacement effects arising from offshore wind farms – essentially the concern is that they may act as 'artificial islands' that migratory fish chose to avoid due to visual disturbance. The impacts of such avoidance activity, should it occur, are unknown. This issue was discussed at the most recent meeting of the ScotMER Diadromous Fish Group.*	As per MS-LOT and MSS comments on barrier effects, it has been advised that the potential impacts associated with barrier effects are not required to be scoped into this Offshore EIAR and as such these effects are not assessed. See explanation in Section 10.5.2.
	By way of explanation, little consideration has been given to the way in which fish may perceive and react to their aerial surroundings as viewed through the water surface. Light passing through the air/ water interface surface is refracted due to the difference in the optical densities of the two mediums. Only light passing vertically through the interface is not refracted and as the angle of incident light moves away from the vertical, the extent of refraction increases. The overall effect of this is that, within the water column, all the visual information passing into the water space from	As per MS-LOT and MSS comments on barrier effects, it has been advised that the potential impacts associated with barrier effects, caused by turbine blades, are not required to be scoped into this Offshore EIAR and as such these effects are not assessed. See explanation in Section 10.5.2.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	the full 180° arc of the sky and from all around its 360° horizon is compressed within a 97° cone. Fish swimming within the cone view their external surroundings through a relatively small surface window in the form of a disc that varies in size, while continuing to contain all the same information, depending on the fish's depth within the cone. *Under most conditions the fish's surface window on the world is essentially devoid of notable information (e.g. at sea) or the window's visual content is static (e.g. where a forest or mountain overlooks a river or lake). However, a fish swimming in close proximity to a wind turbine, will not see the lower part of the turbine column in the surface window due to reflectance. The more elevated features, such as the moving turbine blades, are potentially more prominent features in the fish's view of the surrounding landscape than might otherwise be expected.* *From the fish's point of view, any aerial object seen to move into the surface window across the static background is a potentially mortal threat and a response of proportionate intensity is expected. The so-called non-consumptive effects of predation modify the behaviour of prey species, alter performance of individuals and adversely affect populations. It is not likely that fish assess the threat of avian predation based on identification of specific predator species because the overhead image observed by fish is often distorted when the air-water interface becomes nonplanar due to the effects of wind or currents. However, the visual system of fish is reported to be highly sensitive to movement and predation risk is probably assessed non-specifically on this basis. Therefore, it will be necessary to consider how fish react to a highly dynamic image of turbine blades as represented in the surface window and whether this is likely to affect their performance and/ or their use of aquatic habitat.*	
	Scoped out: Effects of operational noise on sensitive species. *See above - the HRA Screening Report for the proposed Berwick Bank Offshore Wind Farm, concluded that underwater noise could not be discounted as a likely significant effect for any of the SAC rivers identified in that report.*	As agreed with statutory consultees, the potential impacts associated with operational noise are not required to be scoped into this Offshore EIAR. See explanation in Section 10.5.2
	Scoped out: Fish aggregation around the floating structure and associated infrastructure.	The potential impact of fish aggregation around floating structures and associated infrastructure is considered in Section 10.6.2.3.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	We consider that there is a significant risk of increased predation, if fish of any species aggregate around the turbines. There is evidence from England of offshore wind turbines attracting predators such as seals and given that the location of the proposed development lies within a major migratory route for wild salmonids, the impact of any increased predation should be fully considered. This issue has been identified by the ScotMER Diadromous fish group and is included in the Marine Scotland Evidence Map for diadromous fish.	The likelihood of a significant change in the distribution, density or diversity of fish and shellfish species as a result of the installation of the Offshore Development has been considered within the Offshore EIAR (see Section 10.6). If from the preliminary assessment, based on existing studies and regional data, there is understood to be a likely change in fish aggregation, the potential impacts of this in relation to fish and shellfish species have been considered within the Offshore EIAR. The potential impacts that this may have on marine mammal or ornithological predator presence are considered in Chapter 12: Marine Ornithology and Chapter 11: Marine Mammals and Other Megafauna.
NatureScot	***Fish and shellfish interests*** *Advice on fish and shellfish interests is provided in Appendix D. Key species to be assessed include diadromous fish as well as PMFs which are ecologically important as a key prey species – this will help inform the impact assessment for seabirds and marine mammals. Habitat loss and disturbance (both temporary and long term) from the wind farm on these prey species is a key impact that should be considered across their life history stages*	Fish and shellfish PMF species have been included in the assessment of potential impacts either by way of the HRA process in order to ensure protection of conservation objectives, or as part of the assessment of potential impacts in the Offshore EIAR. Section 10.4.4.4 provides a summary of the key fish and shellfish species which are expected to require detailed consideration within the EIA. Potential impacts on prey species have been taken into consideration for impacts relating to habitat damage/ disturbance. See Section 10.6.1.1.3 and 10.6.2.1
	We recognise the continued lack of knowledge on individual river populations for diadromous species which are SAC qualifying interests, and so currently we continue to advise that the assessment of these should be covered within the EIAR rather than the HRA.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR see Section 10.4.4.1. Further assessments of these SACs are provided in the RIAA (HWL, 2022).
	Key species and habitats *We agree with the species identified in section 8.3.8 but advise that potential impacts be considered at all life stages.* *We also advise that Priority Marine Features (PMFs) which are ecologically important as a key prey species should be considered.*	Fish and shellfish PMF species have been included in the assessment of potential impacts either by way of the HRA process in order to ensure protection of conservation objectives, or as part of the assessment of potential impacts in the Offshore EIAR. Section 10.4.4.4 provides a summary of the key fish and shellfish species which are expected to require detailed consideration within the EIA, the consideration of the impacts to different life stages will depend on the species in question as there is dramatic variety in habitat use for

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
		some species from egg to adult phase. In any case, all potentially impacted species of fish and shellfish at all relevant life stages have been included in the assessment of impacts.
	Marine fish *In order to inform impact assessment for seabirds and marine mammals, the EIAR should consider those fish species which provide an important function as a key prey resource, noting many of these are PMFs. Relevant species are likely to include herring, sandeels and sprat.*	Table 10.4 outlines the conservation importance of all the species known to potentially utilise the Offshore Development area (including PMF). Potential impacts on prey species have been taken into consideration for impacts relating to habitat damage/ disturbance. See Section 10.6.1.1.3 and 10.6.2.1.
	Key impact pathways to consider *We broadly agree with the impact pathways listed in Table 8.4 and provide the following information.*	Noted.
	EMF *We advise that potential impacts from EMF are scoped in. This is particularly relevant for floating wind farms where the inter-array cables are within the water column.*	The potential impacts due to EMF during the operational phase, including EMF from the dynamic cable sections, have been scoped in for assessment (see Section 10.6.2.2).
	Fish aggregation around the floating structures and associated infrastructures *Offshore infrastructure may act as a fish aggregation device (FAD) and may attract larger predators. As little is known regarding the FAD effect of floating offshore wind farms, and the potential impacts to other receptors, we advise that this should be scoped in.*	The potential impact associated with fish aggregation around the floating structures and associated infrastructures has been scoped in. See Section 10.6.2.3. The likelihood of a significant change in the distribution, density or diversity of fish and shellfish species as a result of the installation of this project has been considered within this Offshore EIAR. If from the preliminary assessment, based on existing studies and regional data, there is understood to be a likely change in fish aggregation, the potential impacts of this in relation to fish and shellfish species have been considered within this Offshore EIAR. The potential impacts that this may have on marine mammal or ornithological predator presence are considered in Chapter 12: Marine Ornithology and Chapter 11: Marine Mammals and Other Megafauna.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	Approach to impact assessment *We advise that the assessment should quantify where possible the likely impacts to key PMFs and consider whether this could lead to a significant impact on the national status of the PMFs being considered*	Table 10.4 outlines the conservation importance of all the species known to potentially utilise the Offshore Development area (including PMF). These species have been split into diadromous and marine fish and have been assessed accordingly.
	In relation to Fish & Shellfish Ecology, you note that consideration should be given to Priority Marine Features (PMFs) which are ecologically important as a key prey species. Could you please clarify which PMFs you are expecting to be scoped into the EIA Report. *These are any PMF fish species that are important prey for marine predators such as seabirds and marine mammals. So species such as sandeel, herring and sprat.*	Table 10.4 outlines the conservation importance of all the species known to potentially utilise the Offshore Development area (including PMF). Potential impacts on prey species have been taken into consideration for impacts relating to habitat damage/ disturbance (see Section 10.6.1.1.3 and 10.6.2.1).
	Fish and shellfish interests *Advice on fish and shellfish interests is provided in Appendix D. Key species to be assessed include diadromous fish as well as PMFs which are ecologically important as a key prey species – this will help inform the impact assessment for seabirds and marine mammals. Habitat loss and disturbance (both temporary and long term) from the wind farm on these prey species is a key impact that should be considered across their life history stages.*	Fish and shellfish PMF species have been included in the assessment of potential impacts either by way of the HRA process in order to ensure protection of conservation objectives, or as part of the assessment of potential impacts in this Offshore EIAR. Section 10.4.4.4 provides a summary of the key fish and shellfish species. Potential impacts on prey species have been taken into consideration for impacts relating to habitat damage/ disturbance. See Section 10.6.1.2 and 10.6.2.1.
	We recognise the continued lack of knowledge on individual river populations for diadromous species which are SAC qualifying interests, and so currently we continue to advise that the assessment of these should be covered within the EIAR rather than the HRA.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR see Section 10.4.4.1. Further assessments of these SACs are provided in the RIAA (HWL, 2022).
Northern District Salmon Fisheries Board	*Highland Wind Limited for an area 6km offshore near Dounreay in northern Caithness.* *A number of the Northern area's rivers are likely to be affected by the proposed development because the WRG Site and the Export Cable Corridor sit astride the major route for adult salmon returning to Scottish rivers from the northern ocean and*	A full assessment of all relevant waterways has been undertaken in this Offshore EIAR. Additional information on potential salmon migratory routes has been included in Section 10.4.4.4.1.1 and Figure 10.9.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	possibly also some of the outward routes for salmon smolts leaving the northern rivers for the sea.	
	The Scoping Report cites Malcom et al.'s report of 2010 on the importance of the development area for salmon, sea-trout and eels. However, this consideration work should be updated in the Scoping Report to include studies completed since 2010, particularly by Marine Scotland Science.	Additional sources have been taken into consideration, including the suggested source in this comment. See Table 10.3.
	In addition, a report by the Flow Country Rivers Trust "Fishermen's Knowledge: Salmon in the Pentland Firth" can be downloaded at https://caithness.dsfb.org.uk/publications/). The report shows that the WTG Site and the Export Cable Corridor span the major throughway for adult salmon returning from the ocean to salmon rivers in the Northern area (including the Rivers Naver and Borgie SACs) but also including all the other rivers of the Northern area. Furthermore, many (or perhaps most) of the salmon returning to all the rivers of the east and west coasts of Scotland traverse the proposed development area and this is the general context in which regional should be considered.	This source has been taken into consideration and has been used where applicable within this Offshore EIAR. See Table 10.3.
	Because the Scoping Report lacks substance, the Board considers that Table 8.4 is defective. The table scopes out all categories of potential effects of the development (construction and operation) on salmon on the flimsiest of grounds. Instead, the Board wishes to see a full consideration of the potential effects of the proposed development on salmon leaving and returning to the Northern area's rivers, including the Rivers Naver and Borgie SACs.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR see Section 10.4.4.1. Further assessments of these SACs are provided in the RIAA (HWL, 2022). Salmon migratory routes have been discussed in Section 10.4.4.4.1.1. Potential effects to migratory fish at a local and wider level have been considered as part of this Offshore EIAR. This will include consideration of relevant projects with the potential to act cumulatively (see Section 10.6 and 10.7).
	Furthermore, Table 8.4 scopes in cumulative impacts associated with future development of additional offshore windfarms of the North coast. This also is not good enough. In the case of salmon, at least, the potential interactions of the proposed windfarm extend to existing and planned non-wind renewables installations. The Board therefore wishes to see a full consideration of interactions with other marine renewables developments - extant and proposed - and the cumulative effects of development.	The developments listed within the cumulative effects section have been expanded to include all types of marine renewables development with potential connectivity to the Offshore Development (see Section 10.7). A cumulative impact assessment has been undertaken as part of the EIA process. The projects considered in each assessment have been relevant to that topic (see Section 10.7). The cumulative impact

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
		assessment for fish and shellfish ecology considers other projects within 50 km of the Offshore Site for underwater noise impacts, and 20 km for other impact pathways (Section 10.7.1).
SFF	*Table 8.4 scopes out EMF, the SFF would contend that there is insufficient evidence to do so, therefore scope in. It gives Aggregations on Turbines as minor impact, which seems to be contradictory to other lines, so should be scoped in. Then we have the scoping in of Ghost Fishing, which will be interesting to see the justification and the outputs.*	The potential impacts due to EMF during the operational phase have been scoped in for assessment (see Section 10.6.2.2). The potential effect of fish aggregation effects around the floating structure and associated infrastructure during the operational phase has been scoped in for assessment (see Section 10.6.2.3). The potential impact of gear entanglement, which could potentially lead to ghost fishing, is assessed in Chapter 13: Commercial Fisheries.
	Table 13.1 seems to underplay the "wave regime" it will also impact on construction and decommissioning. As there is little real evidence available EMF/Heat should be scoped in. And, finally, fish aggregation should be scoped in so that it can be assessed against the claims made for its benefits.	The potential impacts of the Offshore Development on the wave and tidal regime are discussed in Chapter 7: Marine and Physical Processes. The potential impacts due to EMF during the operational phase have been scoped in for assessment (see Section 10.6.2.2). The potential effect of fish aggregation effects around the floating structure and associated infrastructure during the operational phase has been scoped in for assessment (see Section 10.6.2.3).
Caithness District Salmon Fishery Board	*You requested an opinion from the Board re. the floating windfarm development proposed by Highland Wind Limited for an area 6km offshore near Dounreay in northern Caithness.* *A number of the Caithness rivers are obviously likely to be affected by the proposed development because the WRG Site and the Export Cable Corridor sit astride the major route for adult salmon returning to Scottish rivers from the northern ocean and probably also some of the outward routes for salmon smolts leaving the northern rivers for the sea.*	A full assessment of all relevant waterways has been undertaken in the Offshore EIAR. Additional information on potential salmon migratory routes has been included in Section 10.4.4.4.1.1 and Figure 10.9.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	The Scoping Report cites Malcom et al.'s report of 2010 on the importance of the development area for salmon, sea-trout and eels. However, several studies of the use by adult salmon of the general area around the windfarm have been completed and published since 2010 by Marine Scotland Science and these should also have been used to inform the Scoping Report.	Additional sources have been taken into consideration, including the suggested source in this comment. See Table 10.3.
	In addition, a report by the Flow Country Rivers Trust "Fishermen's Knowledge: Salmon in the Pentland Firth" can be downloaded at https://caithness.dsfb.org.uk/publications/). The report shows that the WTG Site and the Export Cable Corridor span the major throughway for adult salmon returning from the ocean to salmon rivers in Caithness (including the River Thurso SAC) but also including all the other rivers of the North Coast and all the rivers of the east and west coasts of Scotland. Indeed, some fish passing through the proposed development area prove to travel even further.	This source has been taken into consideration and has been used where applicable within this Offshore EIAR. See Table 10.3.
	Because the Scoping Report lacks substance in this respect, the Board considers that Table 8.4 is defective. The table scopes out all categories of potential effects of the development (construction and operation) on salmon on the very flimsiest of grounds. The Board wishes to see a full consideration of the potential effects of the development on salmon leaving and returning to the local northern rivers, set in the wider context of potential effects on the full range of rivers (including many SACs) that may be impacted elsewhere.	As suggested, the Rivers Borgie, Naver and Thurso have been included within this Offshore EIAR see Section 10.4.4.1. Further assessments of these SACs are provided in the RIAA (HWL, 2022). Salmon migratory routes have been discussed in Section 10.4.4.4.1.1. Potential effects to migratory fish at a local and wider level have been considered as part of the EIAR. This will include consideration of relevant projects with the potential to act cumulatively (see Section 10.6 and 10.7).
	Furthermore, Table 8.4 scopes in cumulative impacts associated with future development of additional offshore windfarms in the same general area. This also is not good enough. In the case of salmon, at least, the potential interactions of the proposed windfarm extend to existing and planned non-wind renewables installations. The Board therefore wishes to see a full consideration of interactions with other developments especially, but not confined to, tidal energy facilities located or planned within the confines of the Pentland Firth to the east of the proposed windfarm.	The developments listed within the cumulative effects section have been expanded to include all types of marine renewables development with potential connectivity to the Offshore Development (see Section 10.7). A cumulative impact assessment has been undertaken as part of the EIA process. The projects considered in each assessment have been relevant to that topic (see Section 10.7). The cumulative impact assessment for Fish and Shellfish Ecology considers other projects

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
		within 50 km of the Offshore Site for underwater noise impacts, and 20 km for other impact pathways (Section 10.7.1).
The Highland Council (THC)	*The EIAR needs to address the aquatic interests that may be affected by the development, for example benthic impacts, increases in silt and sediment loads resulting from construction works; pollution risk / incidents during construction; obstruction to upstream and downstream migration both during and after construction; disturbance of spawning beds / timing of works; and other drainage issues. The EIAR should evidence consultation input from the local fishery board(s) where relevant.*	Pollution risk / incidents during construction have been considered (see Section 10.6.1.5). Barrier effects associated with obstruction to upstream and downstream migration both during and after construction has been scoped out, in line with comments received from MSS. See explanation in Section 10.5.2. Disturbance of spawning beds / timing of works have been considered. See Section 10.6.1.1.3.
Scoping Opinion Addendum		
MS-LOT, on behalf of Scottish Ministers	*Within table 4.1 of the Scoping Report the Developer summarises the potential impacts to fish and shellfish ecology associated with the change in parameters. The Scottish Ministers broadly agree with the impacts to be scoped in however, advise that the NatureScot representation and advice from MSS must be fully addressed by the Developer. In particular, the greater area of seabed to be impacted must be considered in the EIA Report in terms of disturbance and loss of habitat supporting fish and shellfish.*	The potential disturbance and loss of habitat supporting fish and shellfish has been assessed in Section 10.6.1.1.3 of this chapter, in line with the advice received.
	Section 4.2 of the Scoping Report summarises the changes to method of assessment proposed by the Developer due to the introduction of pile driving activities which involves underwater noise propagation modelling and a comparative exercise. The Scottish Ministers agree with the method proposed but advise that the modelling should follow a precautionary approach to determine the worst case scenario where fish do not flee from the noise, in line with the MSS advice.	The modelling of underwater noise propagation on fish ecology receptors is presented in Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling Report. Both fleeing animals and stationary animal models have been used within the assessment on piling activities as presented in Section 10.6.1.1 of this chapter
	In relation to diadromous fish, the Scottish Ministers advise that the advice from MSS must be fully addressed by the Developer, including the scoping in of foraging areas to cover, for example, sea trout. For the avoidance of doubt, all impacts scoped in, in relation to marine fish and shellfish must also be scoped in for diadromous fish.	Impacts on diadromous fish and marine fish have been considered separately within Section 10.6 where relevant. Baseline information on sea trout has been outlined in Section 10.4.4.4.1 and has been considered in Section 10.6 where relevant.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	The Scottish Ministers also highlight the MSS advice which directs the Developer to the proposed river gradings for salmon rivers for 2022 which are now available.	This source has been taken into consideration and has been used where applicable within this EIAR. See Table 10.3.
MSS	*MSS agree with the method to assess marine fish and shellfish impacts from underwater noise caused by pile driving. In addition to this, MSS recommend that the modelling follows a precautionary approach as there is evidence that some species of fish fail to display avoidance or fleeing behaviour such as a startle response to underwater noise and therefore may remain stationary when exposed to underwater noise and may not flee (Harding et al. 2016). Therefore, this consideration should be taken into account in the modelling to determine the worst-case scenario where fish do not flee from the noise.* *MSS also recommend that underwater noise impacts to fish from possible UXO clearance should be included in the EIAR.*	See Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling Report. The potential impacts associated with underwater noise from piling activities have been scoped in for assessment (see Section 10.6.1.1). As discussed in Chapter 5: Project Description, based on an initial desk-based unexploded ordnance (UXO) assessment undertaken by Ordtek (Ordtek, 2021) it is assumed that it will be possible to avoid any UXO encountered. Following future planned surveys, should it become apparent that any further mitigation is required, such as clearance or detonation, this would be subject to separate assessment and licence applications. Nonetheless, an initial assessment of the underwater noise from UXO clearance on fish and shellfish is presented in 10.6.1.1.3.
	The Scoping Opinion http://marine.gov.scot/data/scoping-opinion-pentland-floating-offshore-windfarm and the accompanying information from Marine Scotland Science (same link) provide advice and information regarding diadromous fish, prior to the revised project details as in Table 2.1 of the Addendum. Insofar as the potential impacts listed in Table 4.1 apply to diadromous fish, MSS is content with what is now scoped in and out, but "and foraging areas" should be inserted after "spawning and nursery grounds" in "Direct habitat loss due to disturbance of spawning and nursery grounds" to cover, for example, foraging sea trout. However, it is unclear from the wording in Section 4.1 of the Addendum whether the potential impacts from Electromagnetic Fields (EMFs) from subsea and dynamic cables and Fish aggregation around floating structures and associated infrastructure are to be kept scoped in. MSS advise that these potential impacts should be scoped in for diadromous fish. *As with our previous advice on the scoping report for this project, comments made on marine fish ecology should also be applied to diadromous fish, where relevant.*	Impacts on diadromous fish and marine fish have been considered separately within Section 10.6 where relevant. The potential disturbance and loss of habitat supporting fish and shellfish has been assessed in Section 10.6.1.1.3. The associated impact on predatory species, such as sea trout is also considered where relevant. The potential impacts due to EMF during the operational phase have been scoped in for assessment (see Section 10.6.2.2). The potential impact of fish aggregation around floating structures and associated infrastructure has also been assessed as well as potential predator prey impacts (see Section 10.6.2.3).

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	MSS also note that the proposed river gradings for salmon rivers for 2022 are now available. *https://www.gov.scot/publications/salmon-fishing-proposed-river-gradings-for-2022-season/*	This source has been taken into consideration and has been used where applicable within this Offshore EIAR. See Table 10.3.
	The Northern District Salmon Fishery Board (DSFB) response refers to the potential for visual effects from an array of wind turbines with rotating blades (direct visual impact of moving turbine blades and the related shadow flicker cast by moving blades) to be a spatial barrier to the migration of salmon. Fisheries Management Scotland (FMS) do not specifically mention visual effects in their response, but say that they are disappointed that possible barrier effects have not been scoped in.	The potential impacts associated with barrier effects have not been scoped into this Offshore EIAR. See explanation in Section 10.5.2
	The topic of shadow flicker insofar as it applies in fresh waters has recently been reviewed by Dodd and Briers (2021). Most of what they say is also likely to apply to the potential for direct visual impact. Dodd and Briers (2021) concluded that, 'While there is some information available about the response of Atlantic salmon to changes in light intensity (e.g., responses to strobe light or artificial light at night), there is no published information about the responses (biological or behavioural) of Atlantic salmon, or any fish species, to artificial light patterns of the characteristics associated with shadow flicker'; and that, 'shadow flicker is unlikely to result in a change at the population level'. They also recommended further research into the effects of shadow flicker/changes in light pattern/intensity on Atlantic salmon. *MSS would largely accept these conclusions as also applying to the salmon life-stages in the marine context and endorse that information from further research would also be useful in a marine context.* *However, on the basis of present information, MSS would not consider it to be a high priority need for marine renewables assessments, and the MSS position remains that barrier effects do not require assessment in the EIA Report for Pentland Floating Offshore Wind Farm.*	In accordance with this response, the potential impacts associated with barrier effects have not been scoped into this Offshore EIAR. See explanation in Section 10.5.2

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
FMS	*As you are aware, Fisheries Management Scotland, and our members, the Caithness and Northern DSFBs have previously commented. Fisheries Management Scotland are also members of the ScotMER Diadromous Fish Specialist Receptor Group, which have identified a number of evidence gaps related to the health, distribution, and impacts on Diadromous fish. We are concerned that the planning system for marine renewables is not leading to these evidence gaps being closed – in our view this is a symptom of the wider failings of the EIA system in Scotland.*	Noted.
	We have reviewed the Scoping Opinion adopted by the Scottish Ministers on 28 September 2021. We welcome the fact that the input of FMS, Caithness DSFB and Northern DSFB are specifically highlighted and must be fully considered in the EIA report. We also welcome the following points: *- Diadromous fish should be considered separately from marine fish.* *- EMFs from subsea and dynamic cables should be considered in relation to pelagic fish species (we hope that this includes diadromous fish) That the developer should consider and include potential impacts over a larger study area to include the Rivers Borgie, Naver and Thurso SACs. However, we remain of the view that this study area is not sufficiently wide. In 2017 Marine Scotland Science tagged fish from the Armadale netting station on the north coast of Scotland in order to assess the 'mixed stock' nature of the net fishery in operation at that time. The report is available on the Scottish Government website. A combination of tracking and genetic assignation demonstrated that adult salmon on the north coast of Scotland were from rivers as far afield as the Spey SAC and the Outer Hebrides. The strategic nature of many of the sites being considered for marine renewable energy, and the wide range of rivers that potentially could be affected, is the primary reason that Fisheries Management Scotland, in addition to our members, respond to these developments.* *- Reference to SAC rivers for diadromous fish in section 5.5.8. and the fact that all additional impacts scoped in above in paragraph 5.5.3 for marine fish and shellfish must also be scoped in for diadromous fish. The requirement for the impact of fish aggregation to be expanded on in relation to diadromous fish to include the potential for the structures to attract and offer shelter and favourable predation opportunities to predatory birds, mammals and larger fish.*	Impacts on diadromous fish and marine fish have been considered separately within Section 10.6 where relevant. The potential impacts due to EMF during the operational phase has been scoped in for assessment (see Section 10.6.2.2). The potential impact of fish aggregation around the floating substructures and associated infrastructure has also been assessed as well as potential predator prey impacts (see Section 10.6.2.3).

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
	We are disappointed that possible barrier effects do not need to be scoped in to the EIA Report. *We were contacted by Xodus Group in late December, where they confirmed that barrier effects had been scoped out on the basis of the small scale and offshore location of the development, citing the limited (and not fully accessible) literature on this impact. Whilst we accept that the responsibility to understand and assess any impacts arising from this issue should not necessarily fall on an individual development, we do need to understand how these evidence gaps will be understood in future, including the contribution from the renewable energy sector into assessing these issues. It is not acceptable at a national, strategic level to accept that there is no information available and therefore ignore the issue. Xodus also stated that they 'hope' not to have to assess the impact for the development to act like an artificial reef, attracting fish to the area. We maintain that it is important that this is scoped in for diadromous fish, as artificial reef structures also run the risk of aggregating predators – an important concern for wild fish interests, particularly in such a strategically important area for migratory salmonids from a wide range of Scotland's rivers.*	The potential impacts associated with barrier effects have not been scoped into this Offshore EIAR. See explanation in Section 10.5.2. The potential impact of fish aggregation around floating structures and associated infrastructure has been assessed as well as potential predator prey impacts (see Section 10.6.2.3).
SFF	*If there are piles going in, the grounds lost to fishing must be scoped, if any. Given the lack of robust science we don't believe desk top modelling is sufficient for noise or EMF, why not take the opportunity to gather real time data?*	The potential impacts associated with underwater noise from piling activities have been scoped in for assessment (see Section 10.6.1.1). Lost fishing grounds due to Offshore Site infrastructure have been assessed in Chapter 13: Commercial Fisheries. The potential impacts due to EMF during the operational phase have been scoped in for assessment (see Section 10.6.2.2). It is agreed that direct measurements of underwater noise are beneficial in providing confidence in the assessment outputs. However, it depends on the type of underwater noise measurements, of which two could be carried out in relation to offshore wind farm consents, so it is important to be clear what is being considered. The first is underwater noise baseline for the region, the second is measurements of piling noise and its propagation through the water column.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
		An underwater noise baseline is rarely required during the consents phase. This is because the thresholds used in underwater noise assessments are generally based on absolute noise thresholds that are well in excess of any baseline, so the baseline does not influence the noise exposure. Occasionally there is a specific concern for disturbance where the background noise can be important, but this is not common and it is believed that almost all, if not all, recent EIARs in Scotland are submitted without underwater noise baseline data. Monitoring of piling is certainly of benefit, in theory, and this is especially true based on the type of subsea piling proposed for the Offshore Development and the deep water that is present there. Significant extrapolations from other data are necessary in modelling. However, this is standard practice in offshore wind farm underwater noise assessments. Monitoring of piling invariably takes place during the beginning of the construction phase for assessment and modelling verification. To date, the Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model that is being used for the assessment has been very reliable and there has been no need to revise or revisit the model due to inaccuracies found on site, so confidence is relatively high. The potential for monitoring of impacts will be considered in the post-consent phase and captured within the Project Environmental Monitoring Programme (PEMP).
THC	*Fish and Shellfish Ecology; Marine Mammal and Other Mega Fauna; and Ornithology:* *The Highland Council do not have any comment to offer on these sections of the EIAR Scoping Report Addendum but anticipate that Marine Scotland Science, Scottish Environment Protection Agency and NatureScot will be offering comments.*	Noted.
The Northern District Salmon Fishery Board	*Thank you for emailing through the addendum to the above scoping report. I can confirm that the Northern District Salmon Fishery Board has no further comment to make at this stage.*	Noted.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
NatureScot	*The new worst case parameters include potentially up to 12 moorings and anchors per wind turbine, a spread radius of up to 1,250m, and potentially up to 12 driven piles per wind turbine with each pile being approximately 8m in diameter. Although we agree the potential impacts that may result from these increases are not new impacts from those presented in the Scoping Report, and the approach to assessing them will not alter, the new worst case parameters will result in a much greater area of the seabed being impacted. This should be considered in the EIA Report in terms of disturbance and loss of benthic habitat and habitat supporting fish and shellfish.*	Since the submission of the Scoping Report Addendum, the Applicant has further refined the Offshore Development infrastructure which has reduced the number of mooring lines to a maximum of 9 per WTG. This has also reduced a number of other parameters with the Design Envelope. The worst case parameters for the refined Design Envelope have been used for this assessment. See Table 10.12 for worst case design parameters and worst case seabed footprints.
SEPA	*The Scoping Addendum Report concludes that the proposed changes to some of the turbine parameters (rotor diameter, hub height and overall tip height) do not materially alter the position of the original Scoping Opinion as the methodologies of assessment will remain the same. The decision to include pile driving however requires additional assessments and modelling to assess the impact of underwater noise on marine mammals and other megafauna, and fish and shellfish ecology.* *In relation to SEPA's interests, we do not consider that any further matters require assessment within an EIA in relation to the Offshore EIA Report and we have no comments on proposed assessments and modelling methodologies.*	Noted. The modelling of underwater noise propagation on fish ecology receptors is presented in Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling Report. An assessment of the underwater noise associated with piling activities on Fish and Shellfish Ecology is presented in Section 10.6.1.1.
THC	*Fish and Shellfish Ecology; Marine Mammal and Other Mega Fauna; and Ornithology* *The Highland Council do not have any comment to offer on these sections of the EIAR Scoping Report Addendum but anticipate that Marine Scotland Science, Scottish Environment Protection Agency and NatureScot will be offering comments.*	Noted. Comments from MSS, SEPA and NatureScot have been considered within this Chapter and the following assessment.

Consultee	Comment / Issue Raised	Offshore Development Approach and Section ID
Cumulative Project List		
THC	*Having reviewed the submitted document, I would suggest the following projects are also included in the cumulative assessment:* > *Space Hub Sutherland (in all chapters of the EIAR not just the SLVIA section).*	The Space Hub Sutherland project is approximately 38 km south-west of the Offshore Site. Considering the intervening distance between the Offshore Site and the Space Hub Sutherland Project, as well as the very short duration of the launch exclusion zones and that the EIAR for the project noted no significant effects on aquatic ecology during operations, there is no potential for a cumulative impact with the Offshore Development with respect to Fish and Shellfish Ecology receptors. The Space Hub Sutherland Project is considered in Chapter 18: Other Users of the Marine Environment.

10.4 Baseline Characterisation

The purpose of this Section is to provide a description of fish and shellfish species of conservation importance, economic value and those which are particularly abundant in the Study Area, as defined in Section 10.4.1 and in Figure 10.1 below. The characterisation of the current environment is established from a combination of a site-specific survey, desk-based study and consultation with key stakeholders.

The objective of this Section is to present the best available understanding of the current baseline for fish and shellfish species including key spawning and nursery grounds, migration routes and their contribution to local biodiversity and wider food webs.

10.4.1 Study Area

The focus of the impact assessment is the potential impacts on fish and shellfish species that utilise the Study Area and adjacent waters. There is variation in species' behaviour and the range over which their populations can be found. Potential impacts have therefore been set in the context of a wider study area over which fish and shellfish species identified as present in the Study Area are thought to range and in the context of the regional populations to which those species belong. For example, Atlantic Salmon migratory routes to river SACs in Scotland.

The following areas are referred to in this impact assessment:

> Offshore Site: Area encompassing the PFOWF Array Area and Offshore Export Cable Corridor (OECC), as defined below;

> PFOWF Array Area: The area where the WTGs will be located within the Offshore Site, as defined;

> OECC: The area within which the Offshore Export Cable(s) will be located; and

> The Study Area: The study area for Fish and Shellfish Ecology receptors is identified as International Council for the Exploration of the Sea (ICES) sub-area rectangle 46E6 boundary which extends over 1 degree longitude by 30' latitude; which at the Offshore Development latitude, is an area of approximately 3,240 km^2, plus the inclusion of the rivers which have been identified as having potential connectivity to the Offshore Site, and adjacent ICES rectangles to correlate with the commercial fisheries study area and provide perspective on overall habitat usage and extent of species which are present in waters relevant to the Offshore Development.

The Study Area is shown in Figure 10.1 below:

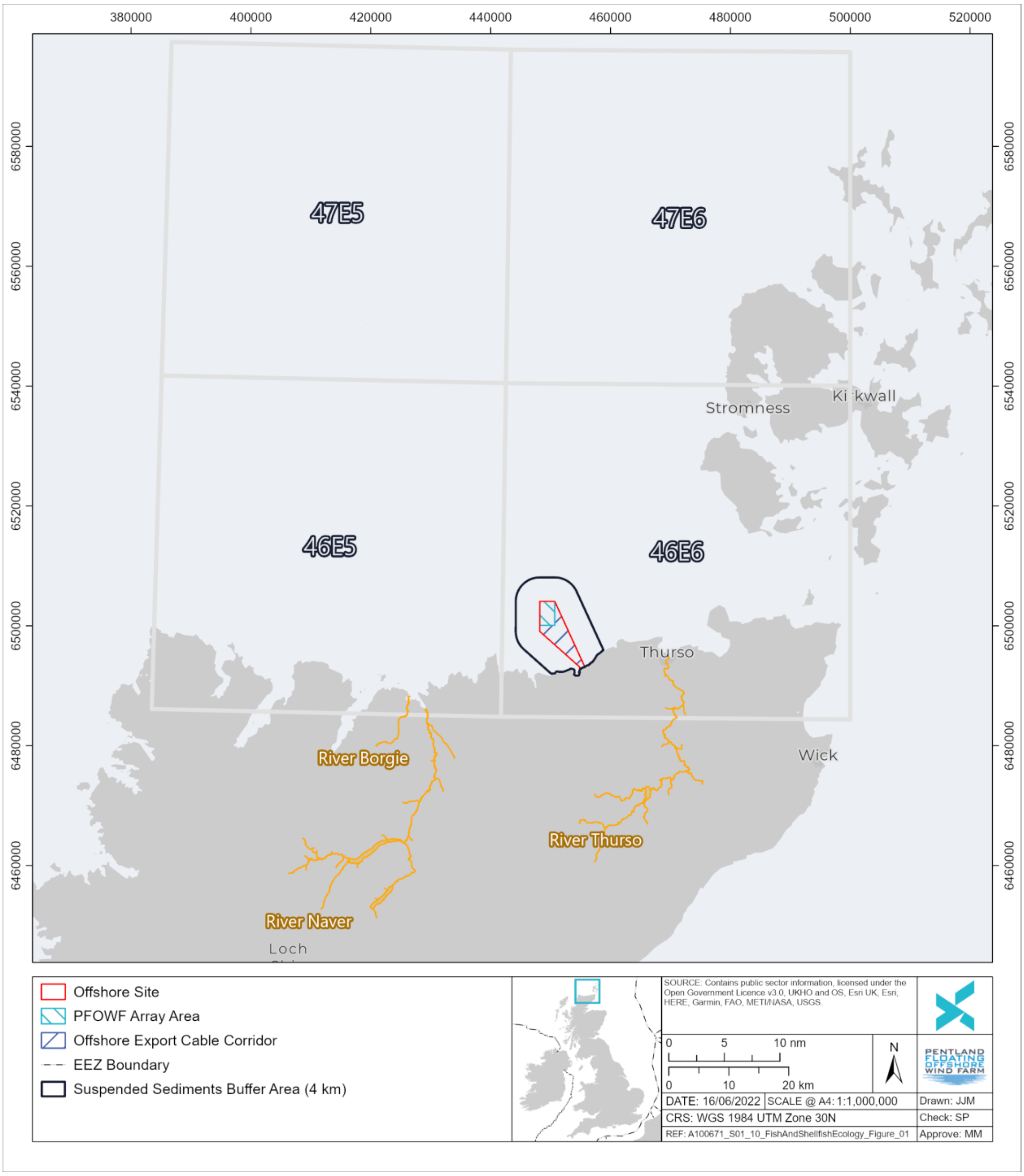

Figure 10.1 Fish and Shellfish Ecology Study Area

10.4.2 Sources of Information

A review was undertaken of the literature and data relevant to this assessment relating to Fish and Shellfish Ecology and was used to give an overview of the existing environment. The primary data sources used in the preparation of this chapter are listed below in Table 10.3.

Table 10.3 Summary of key sources of information pertaining to Fish and Shellfish Ecology

Title	Source	Year	Author
Fisheries sensitivity maps in British waters	https://www.cefas.co.uk/media/o0fgfobd/sensi_maps.pdf	1998	Coull *et al.*
Spawning and nursery grounds of selected fish species in UK waters	https://www.cefas.co.uk/publications/techrep/TechRep147.pdf	2012	Ellis *et al.*
Fish and Shellfish Stocks: 2016 Edition	https://data.marine.gov.scot/dataset/fish-and-shellfish-stocks-2016	2016	Marine Scotland Science
The Marine Life Information Network	https://www.marlin.ac.uk/	2022	MarLIN
National Biodiversity Network (NBN) Atlas	https://nbn.org.uk/content-block/nbn-gateway/	2015	National Biodiversity Network (NBN)
Confirmation of presence, absence and seasonality from fisheries statistics per ICEs rectangle	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920679/UK_Sea_Fisheries_Statistics_2019_-_access_checked-002.pdf	2019	Marine Maritime Organisation (MMO)
Joint Nature Conservation Committee (JNCC) SAC information	https://sac.jncc.gov.uk/	2020	JNCC
Scottish Biodiversity Strategy	https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy	2020	NatureScot
International Bottom Trawl Survey	https://www.ices.dk/community/groups/pages/ibtswg.aspx	2021	North Sea
IUCN Red List of Threatened Species	https://www.iucnredlist.org/	2021	IUCN
Sectoral Marine Plan for Offshore Wind Energy	https://www.gov.scot/publications/sectoral-marine-plan-offshore-wind-energy/documents/	2020	Scottish Government
ScotMER Diadromous Fish Evidence Map	https://www.nsrac.org/wp-content/uploads/2020/06/ScotMER-Presentation.pdf https://www.gov.scot/publications/streamlined-scotmer-evidence-map/	2019 2020	MSS Scottish Government

Title	Source	Year	Author
Fishermen's Knowledge: Salmon in the Pentland Firth	https://caithness.dsfb.org.uk/publications/	2017	FCRT
Application of acoustic tagging, satellite tracking and genetics to assess the mixed stock nature of coastal net fisheries	https://marine.gov.scot/data/application-acoustic-tagging-satellite-tracking-and-genetics-assess-mixed-stock-nature-coastal	2019	MSS
Salmon fishing: proposed river gradings for 2022 season	https://www.gov.scot/publications/salmon-fishing-proposed-river-gradings-for-2022-season/	2021	Scottish Government
Update to the Fisheries Sensitivity Maps for British Waters	https://www2.gov.scot/Topics/marine/science/MSInteractive/Themes/fish-fisheries/fsm	2015	Scottish Government
Spawning grounds of Atlantic cod (*Gadus morhua*) in the North Sea	https://academic.oup.com/icesjms/article/73/2/304/2614292	2016	González-Irusta and Wright
Spawning grounds of whiting (*Merlangius merlangus*)	https://pubag.nal.usda.gov/catalog/5733845	2016	González-Irusta and Wright
Spawning grounds of haddock (*Melanogrammus aeglefinus*) in the North Sea and West of Scotland	https://www.semanticscholar.org/paper/Spawning-grounds-of-haddock-(Melanogrammus-in-the-Gonz%C3%A1lez%E2%80%90Irusta-Wright/0fa1b31e88279ec02efc47f5afa82ea287d3d35e https://research-scotland.ac.uk/handle/20.500.12594/10859?show=full	2017	González-Irusta and Wright
The International Herring Larvae Surveys	https://obis.org/dataset/94829f49-bab5-48a5-9a64-38425f8ec640	2015	IHLS
ORJIP Impacts on fish from piling at offshore wind farm sites: collating population information, gap analysis and appraisal of mitigation options	https://prod-drupal-files.storage.googleapis.com/documents/resource/public/ORJIP%20Piling%20Study%20Final%20Report%20Aug%202018%20%28PDF%29.pdf	2018	Boyle and New
Nutrients from salmon parents alter selection pressures on their offspring	https://onlinelibrary.wiley.com/doi/full/10.1111/ele.12894	2018	Downie *et al.*
Updating Fisheries Sensitivity Maps in British Waters.	https://www.gov.scot/publications/scottish-marine-freshwater-science-volume-5-number-10-updatingfisheries/.	2014	Aires *et al.*
Development of detailed ecological guidance to support the application of the	https://www.nature.scot/sites/default/files/2017-07/Publication%202014%20-%20SNH%20Commissioned%20Report%20491%20-%20Development%20of%20detailed%20ecological%20gui	2014	Lancaster *et al.*

Title	Source	Year	Author
Scottish Marine Protected Area (MPA) selection guidelines in Scotland's seas.	dance%20to%20support%20the%20application%20of%20the%20Scottish%20MPA%20selection%20guidelines%20in%20Scotland%27s%20seas.pdf		
A review of the recovery potential and influencing factors of relevance to the management of habitats and species within Marine Protected Areas around Scotland	http://www.snh.org.uk/pdfs/publications/commissioned_reports/771.pdf	2015	Mazik *et al.*
Genetic assignment of marine-caught adult salmon at Armadale to region of origin	https://www.gov.scot/publications/scottish-marine-freshwater-science-vol-6-16-genetic-assignment-marine/	2015	Cauwelier *et al.*
Using historic tag data to infer the geographic range of salmon river stocks likely to be taken by a coastal fishery	https://data.marine.gov.scot/sites/default/files//SMFS%200906.pdf	2018	Downie *et al*.
Depth use and migratory behaviour of homing Atlantic salmon (Salmo salar) in Scottish coastal waters	http://icesjms.oxfordjournals.org/content/early/2014/07/16/icesjms.fsu118.full.pdf?keytype=ref&ijkey=y9lmPDRLdC04n7B	2015	Godfrey *et al.*
Depth use and movements of homing Atlantic salmon (Salmo salar) in Scottish coastal waters in relation to marine renewable energy development.	http://www.gov.scot/Resource/0046/00466487.pdf	2014	Godfrey *et al.*
Evidence for Geomagnetic Imprinting as a Homing Mechanism in Pacific Salmon	https://www.sciencedirect.com/science/article/pii/S0960982213000031	2013	Patman *et al.*
An Inherited Magnetic Map Guides Ocean Navigation in Juvenile Pacific Salmon	https://www.sciencedirect.com/science/article/pii/S0960982214000189	2014	Putman *et al.*
Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species	https://www.nature.com/articles/s41598-020-60793-x	2020	Hutchison *et al.*

Title	Source	Year	Author
Offshore wind farm artificial reefs affect ecosystem structure and functioning	https://tos.org/oceanography/assets/docs/33-4_degraer.pdf	2020	Degraer *et al.*
Marine mammals trace anthropogenic structures at sea	https://www.cell.com/current-biology/fulltext/S0960-9822(14)00749-0?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0960982214007490%3Fshowall%3Dtrue	2014	Russell *et al.*

10.4.3 Site-specific Surveys

No specific Fish and Shellfish Ecology site surveys have been carried out to inform this chapter. However, grab sample surveys have been undertaken to inform seabed sediment characteristics across the Offshore Site and these have been used to identify potential fish and shellfish favourable sediment habitats (Offshore EIAR [Volume 3]: Technical Appendix 9.1).

10.4.3.1 Noise Modelling

Noise modelling and analysis of potential impacts from pilling operations at the Offshore Development was undertaken by Subacoustech Environmental. The modelling was undertaken using INSPIRE (Version 5.1) and shows the range at which different fish species are affected by underwater sounds from, in this case, piling activity, by calculating the noise contours (Offshore EIAR [Volume 3]: Technical Appendix 10.1 Underwater Noise Modelling Report).

The model is designed to calculate the propagation of noise in shallow, mixed water, typical of the conditions around the UK, and is very well suited to the region around Pentland Firth. The model has been tuned for accuracy using over 80 datasets of underwater noise propagation from monitoring around offshore piling activities. Calculations are made along 180 equally spaced radial transects (one every two degrees).

The model results should be considered conservative as maximum design parameters and worst case assumptions have been selected for modelling, including:

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

10.4.4 Baseline Description

10.4.4.1 Designated sites

There are no SACs for fish or shellfish features located within the area immediately adjacent to the Offshore Site. The closest relevant SACs to the Offshore Site are the rivers Thurso, Naver and Borgie, located 13 km, 23 km and 24 km from the Offshore Site (Figure 10.2), respectively. These are all SACs designated for their importance to Atlantic salmon (*Salmo salar*) (JNCC, 2020a; 2020b; 2020c). Atlantic salmon may use the Pentland Firth as a migratory route (Malcolm *et al*., 2010) between the rivers and ocean prior to maturation and spawning.

The River Thurso SAC is designated primarily for Atlantic salmon; the river supports a high proportion of multi sea-winter salmon (JNCC, 2020a). Whereas the River Naver SAC is primarily designated for freshwater pearl mussel (*Margaritifera margaritifera*) and Atlantic salmon. Atlantic salmon are also host species for freshwater pearl mussel, which is a feature of several designated sites in Scotland including the River Naver SAC and River Borgie SAC (JNCC, 2020b; 2020c). The River Borgie SAC is primarily designated for freshwater pearl mussels, with Atlantic salmon and otters (*Lutra lutra*) also being present as Annex II species, however otters are not a primary reason for designating the site.

Rivers Thurso, Naver and Borgie SACs between 2017-2021 have consistently retained a good conservation status (Grade 1) for Atlantic salmon, with no change anticipated for 2022 (Scottish Government, 2021).

The North-West Orkney Nature Conservation Marine Protected Area (NCMPA) is located 33 km to the north of the Offshore Site. This NCMPA is an area of importance for sandeels (*Ammodytes sp*.). Sandeels spend the majority of their life in the sandy substrate of the seabed on which they depend, except when feeding and spawning, and are therefore vulnerable to disturbance and habitat loss. Sandeels are a key source of food for a range of marine wildlife, including many types of larger fish and seabirds, along with being commercially important to the European Union (EU) nations (e.g. Denmark). Newly hatched sandeel larvae from the North-West Orkney NCMPA are transported by currents to sandeel grounds around Shetland and south of the Moray Firth (JNCC, 2020d).

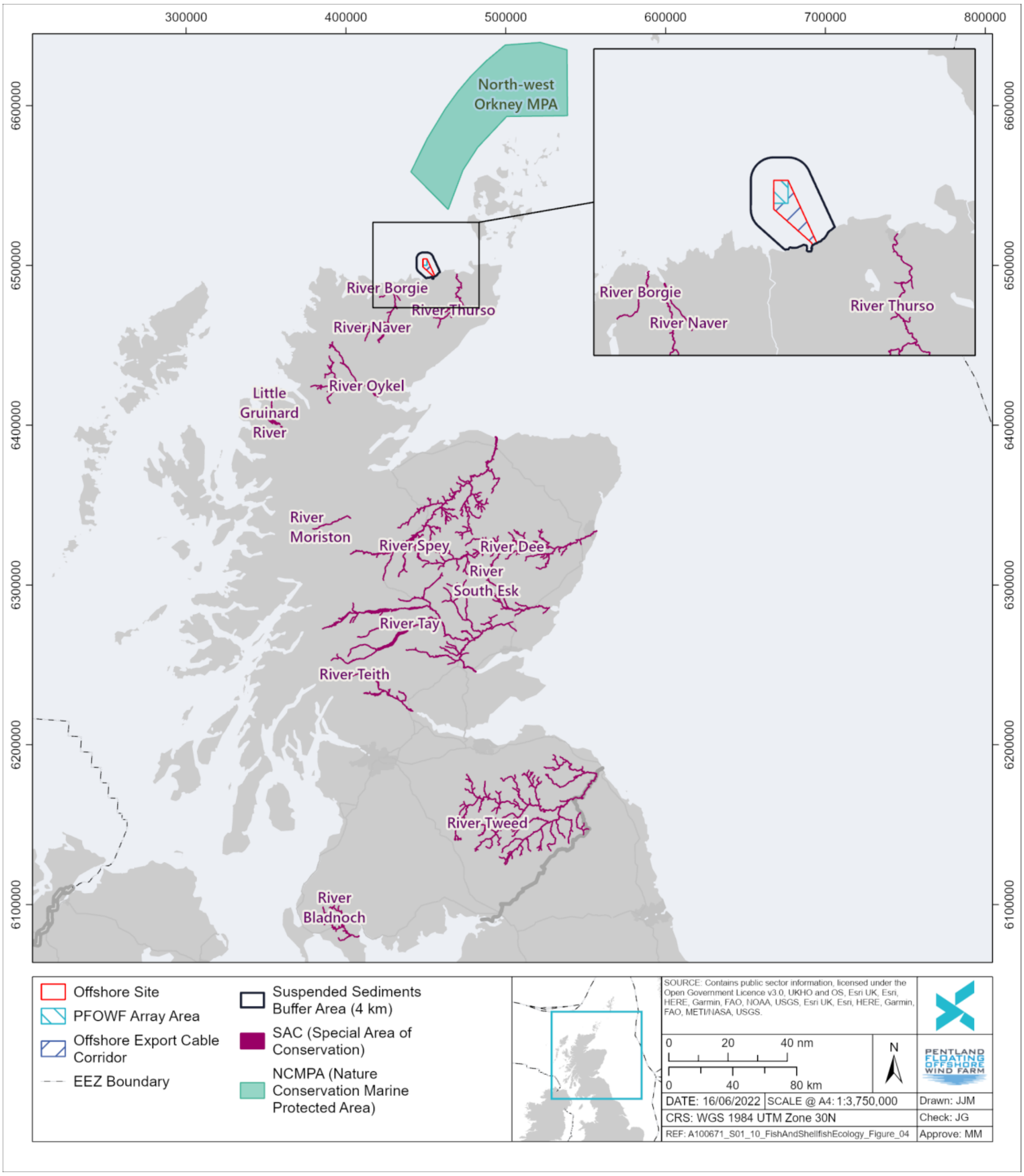

Figure 10.2 Protected sites designated for fish ecology features

10.4.4.2 Overview of seabed habitat and sediments

The European Union Nature Information System (EUNIS) habitat classifications throughout and in the vicinity of the Study Area are shown in Figure 10.3. Predicted EUNIS habitat data (McBreen *et al*., 2010) suggests there may be seabed which comprises suitable habitat for sandeels within the Study Area.

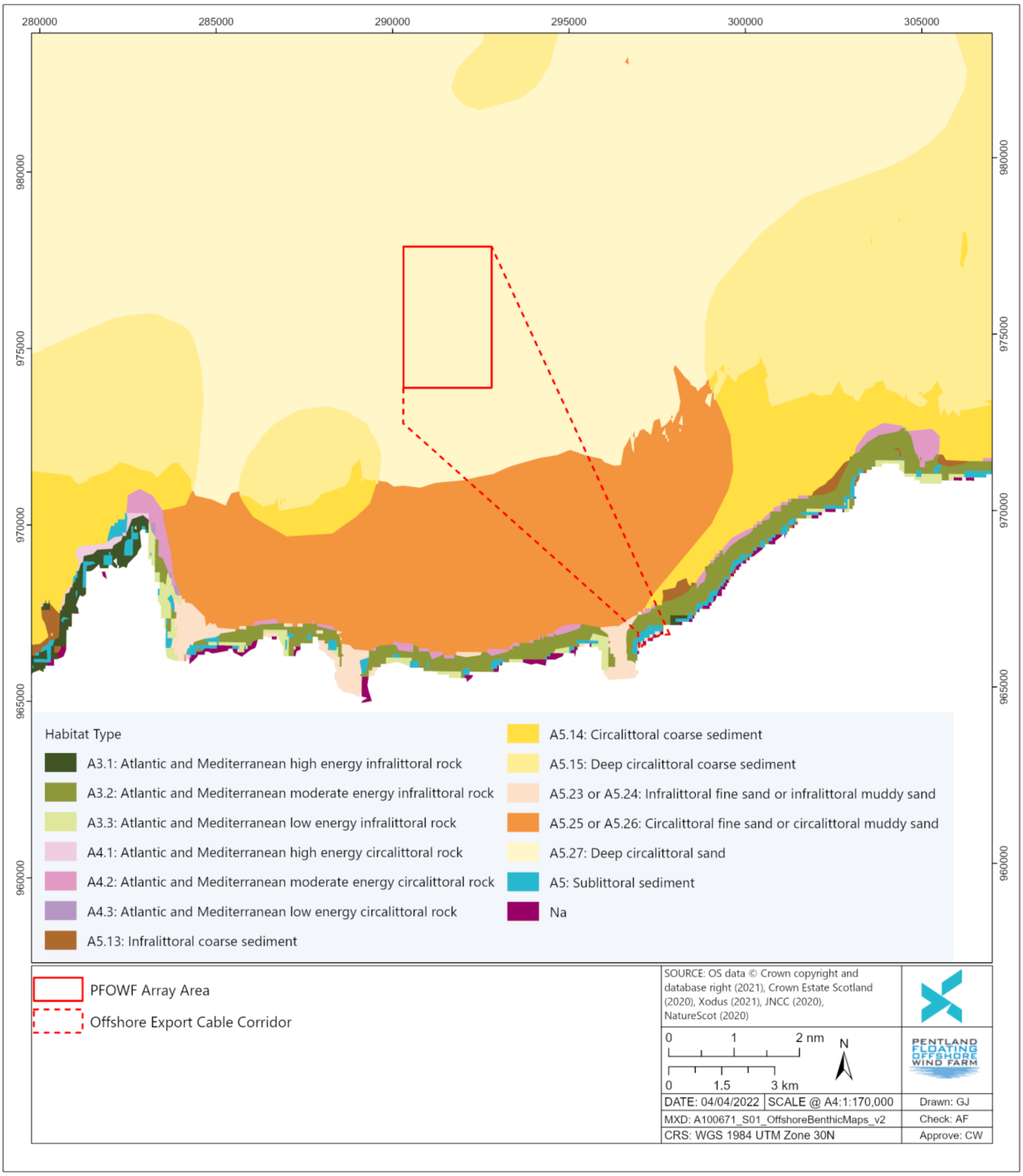

Figure 10.3 Sediment types in the vicinity of the Offshore Site

Note: Na is listed as *"Atlantic infralittoral sediment"* where no EUNIS classification is classified.

The MMT surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1) identified four fish species of conservation importance within the survey area, which encompassed the PFOWF Array Area and OECC (as shown in Figure 8.2). These were sandeel, ling (*Molva molva*), skate (*Dipturus sp*) complex and European plaice (*Pleuronectes platessa*):

- A juvenile ling was identified along transect T007. Ling is listed as a PMF and is on the Scottish Biodiversity List. The survey area is also located within a previously known nursing area for ling (Table 10.4 Ellis *et al.,* 2012; Offshore EIAR [Volume 3]: Technical Appendix 9.1);
- Skate, that was most likely to be common skate (*Dipturus batis*) complex, was identified at grab sample site S007 located outside of the PFOWF Array Area to the north-east (Offshore EIAR [Volume 3]: Technical Appendix 9.1). Common skate is listed as a PMF as well as in the Scottish Biodiversity List. Further, common skate is also listed as critically endangered by the IUCN Red List of Threatened Species (IUCN, 2021). The survey area is also located within a previously identified nursery ground for common skate (Table 10.4; Ellis *et al.,* 2012);
- The European plaice was identified along transects T001A located within the nearshore area of the OECC and T006 located to the south-east of the PFOWF Array Area. European plaice is listed in the Scottish Biodiversity List (Offshore EIAR [Volume 3]: Technical Appendix 9.1); and
- Sandeel, that was most likely to be lesser sandeel (*Ammodytes tobianus*), was identified in a grab sample collected at site S016 (MTT, 2021a). Lesser sandeel is listed as a PMF, in the Scottish Biodiversity List and as data deficient by the IUCN Red List of Threatened Species (IUCN, 2021).

10.4.4.3 Fish and shellfish spawning and nursery grounds

The waters off the north coast of Scotland, including the Study Area, are potential spawning and nursery areas for a number of species of commercial and conservation importance (see Table 10.4 and Figure 10.4 to Figure 10.6). It should be noted that the spawning and nursery grounds identified by Coull *et al.* (1998) and Ellis *et al.* (2012) are based on predictions, and therefore may be spatially and temporally variable.

Aries *et al.* (2014) use the findings of Ellis *et al.* (2012) and Coull *et al.* (1998) together with data from the National and International Bottom Trawl Surveys, the Beam Trawl Survey, International Herring Larvae Surveys (IHLS) and other standalone surveys to summarise the probability of aggregations of 0 group fish (i.e. those in the first year of their life) and/or larvae of key commercial species. The probability of aggregations of 0-group-fish occurring in the area is low for sprat (*Sprattus sprattus*), sole (*Solea solea*), mackerel (*Scomber scombrus*), hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*) and anglerfish (*Lophiiformes*), low to moderate for whiting (*Merlangius merlangus*), plaice (*Pleuronectes platessa*) and Norway pout (*Trisopterus esmarkii*), low further offshore and moderate near shore for herring and cod, moderate to high nearshore for horse mackerel (*Trachurus trachurus*), and moderate for haddock (*Melanogrammus aeglefinus*).

Whilst most species spawn into the water column of moving water masses over extensive areas, demersal spawners (e.g. sandeel and herring) have habitat suitability requirements (i.e. they are seabed dependent), and as a consequence, their spawning grounds are typically more spatially limited than pelagic spawners. Certain fish species are also sensitive to underwater sound, depending on their physiology (e.g. presence or absence or of a swim bladder) (Popper *et al.,* 2014). The Study Area may overlap with suitable habitat for spawning grounds for sandeel and nursery grounds for sandeel, cod (*Gadus morhua*) and herring (*Clupea harengus*) – all of which are potentially sensitive to impacts caused by the installation, operation and maintenance or decommissioning of Offshore Wind Farms (OWFs) due to seabed dependence (sandeel, herring) or noise sensitivity (herring, cod).

As noted above, herring are demersal spawners and are also sensitive to underwater noise. As herring larvae are demersal, they are considered as stationary receptors as larvae and mobile receptors as adults. Herring were not identified in the 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1) and the IHLS estimates of herring larvae abundance are predicted to be low in the Study Area (IHLS, 2015). Ellis *et al*. (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds and overlaps with low intensity nursery ground. Due to this, herring larvae and eggs are not expected to be in the vicinity of the Offshore Site in high numbers.

As herring and sandeels are demersal spawners with spawning grounds that are considered to be more spatially limited than pelagic spawners, they have been considered separately within the impact assessment for underwater noise and habitat loss/ disturbance to spawning and nursery grounds. All other species are pelagic spawners, and therefore, their spawning grounds will not be directly affected by the Offshore Development.

Table 10.4 Spawning and nursery grounds of fish and shellfish species within ICES rectangle 46E6 (Coull *et al.*, 1998 and Ellis *et al.*, 2012)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Conservation Importance (IUCN, 2021; OSPAR Commission, 2021; JNCC, 2019)
Monkfish (Anglerfish)	N	N	N	N	N	N	N	N	N	N	N	N	UK List of Priority Habitats and Species Scottish Biodiversity List
Blue whiting	N	N	N	N	N	N	N	N	N	N	N	N	UK List of Priority Habitats and Species Scottish Biodiversity List Scottish Priority Marine Features
Cod	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (vulnerable) OSPAR List of Threatened and/or Declining Species and Habitats UK List of Priority Habitats and Species Scottish Biodiversity List Scottish Priority Marine Features
Common Skate	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (critically Endangered) Scottish Priority Marine Features OSPAR List of Threatened and/or Declining Species and Habitats UK List of Priority Habitats and Species Scottish Biodiversity List
European Hake	N	N	N	N	N	N	N	N	N	N	N	N	UK List of Priority Habitats and Species Scottish Biodiversity List
Haddock	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (vulnerable)
Herring	N	N	N	N	N	N	N	N	N	N	N	N	Scottish Priority Marine Features Scottish Biodiversity List
Lemon Sole	N	N	N	SN	SN	SN	SN	SN	SN	N	N	N	-
Ling	N	N	N	N	N	N	N	N	N	N	N	N	UK List of Priority Habitats and Species Scottish Biodiversity List Scottish Priority Marine Features
Mackerel	N	N	N	N	N	N	N	N	N	N	N	N	Scottish Priority Marine Features Scottish Biodiversity List
Plaice	N	N	N	N	N	N	N	N	N	N	N	N	UK List of Priority Habitats and Species Scottish Biodiversity List
Saithe	N	N	N	N	N	N	N	N	N	N	N	N	Scottish Priority Marine Features

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Conservation Importance (IUCN, 2021; OSPAR Commission, 2021; JNCC, 2019)
Sandeel	SN	SN	N	N	N	N	N	N	N	N	SN	SN	UK List of Priority Habitats and Species Scottish Biodiversity List Scottish Priority Marine Features
Sprat	N	N	N	N	S*N	S*N	SN	SN	N	N	N	N	-
Spotted Ray	N	N	N	N	N	N	N	N	N	N	N	N	OSPAR List of Threatened and/or Declining Species and Habitats
Spurdog	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (vulnerable) Scottish Priority Marine Features OSPAR List of Threatened and/or Declining Species and Habitats UK List of Priority Habitats and Species
Thornback Ray	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (near Threatened) OSPAR List of Threatened and/or Declining Species and Habitats Scottish Biodiversity List
Tope Shark	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (vulnerable) UK List of Priority Habitats and Species
Whiting	N	N	N	N	N	N	N	N	N	N	N	N	Scottish Priority Marine Features UK List of Priority Habitats and Species Scottish Biodiversity List
S = Spawning, N = Nursery, SN = Spawning and Nursery; * = peak spawning; Species = High nursery intensity as per Ellis *et al*., 2012.													

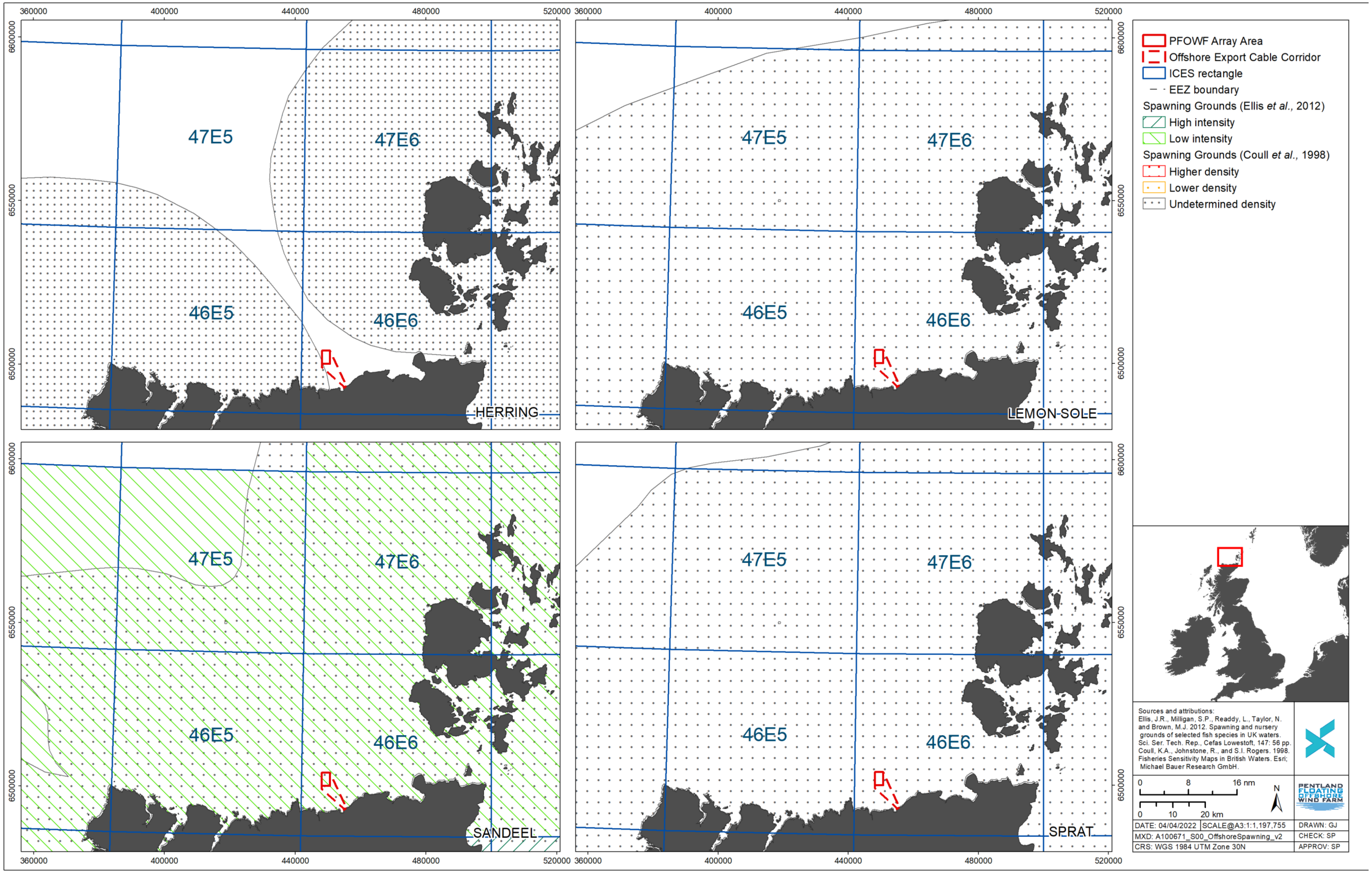

Figure 10.4 Spawning Grounds (Ellis *et al.*, 2012 and Coull *et al.*, 1998)

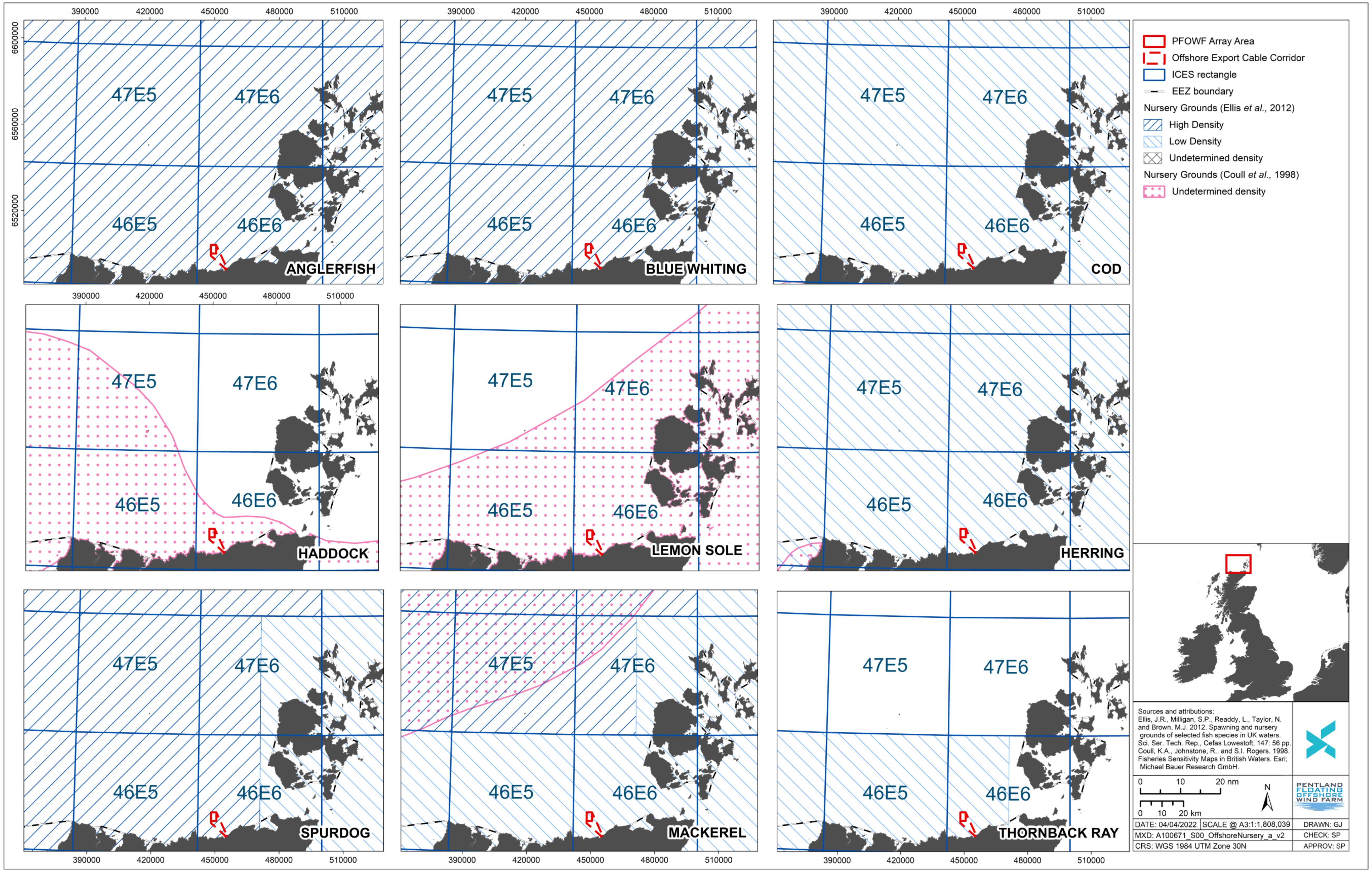

Figure 10.5 Nursery Grounds (part 1) (Ellis *et al.*, 2012 and Coull *et al.*, 1998)

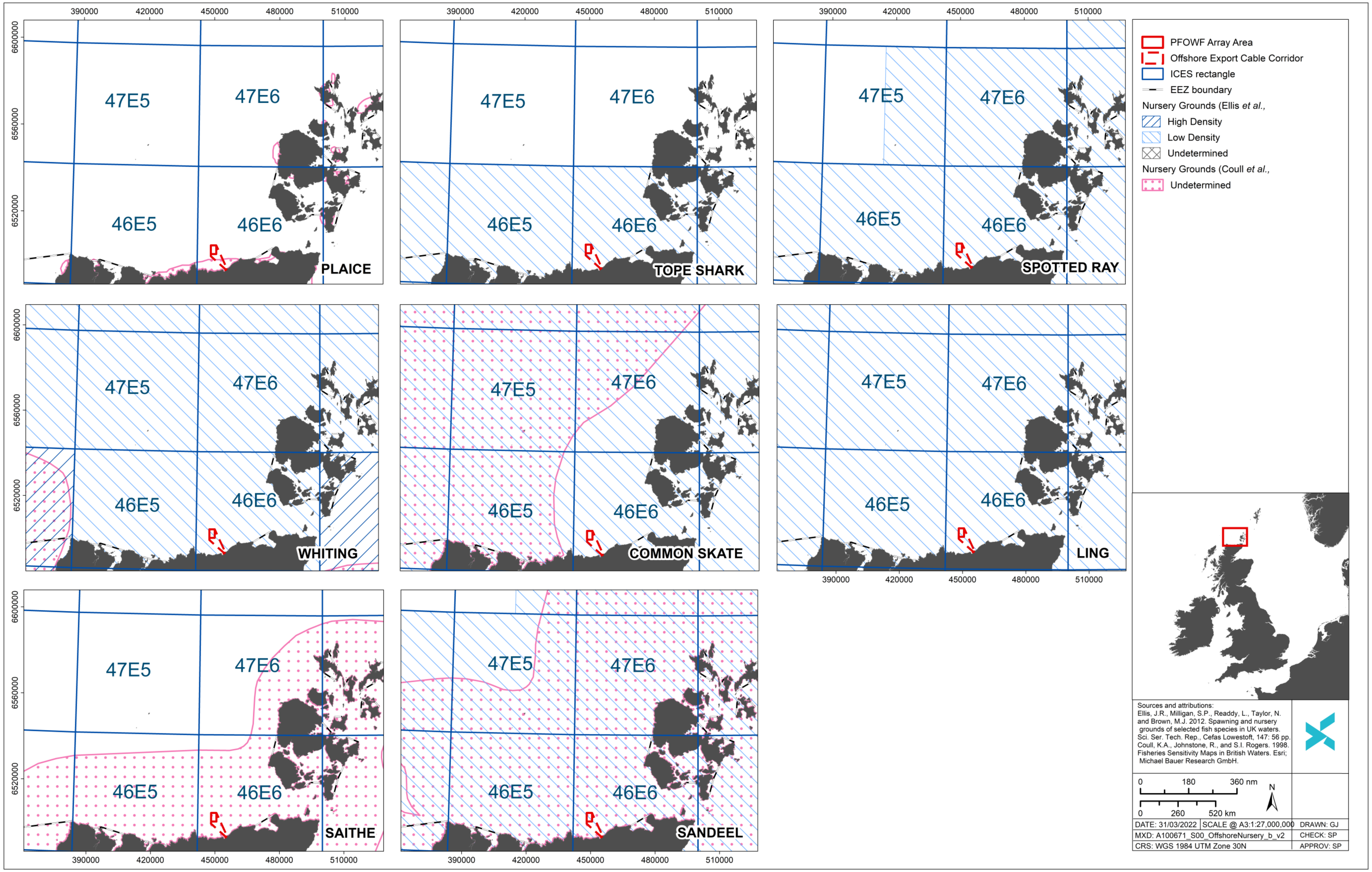

Figure 10.6 Nursery Grounds (part 2) (Ellis *et al.*, 2012 and Coull *et al.*, 1998)

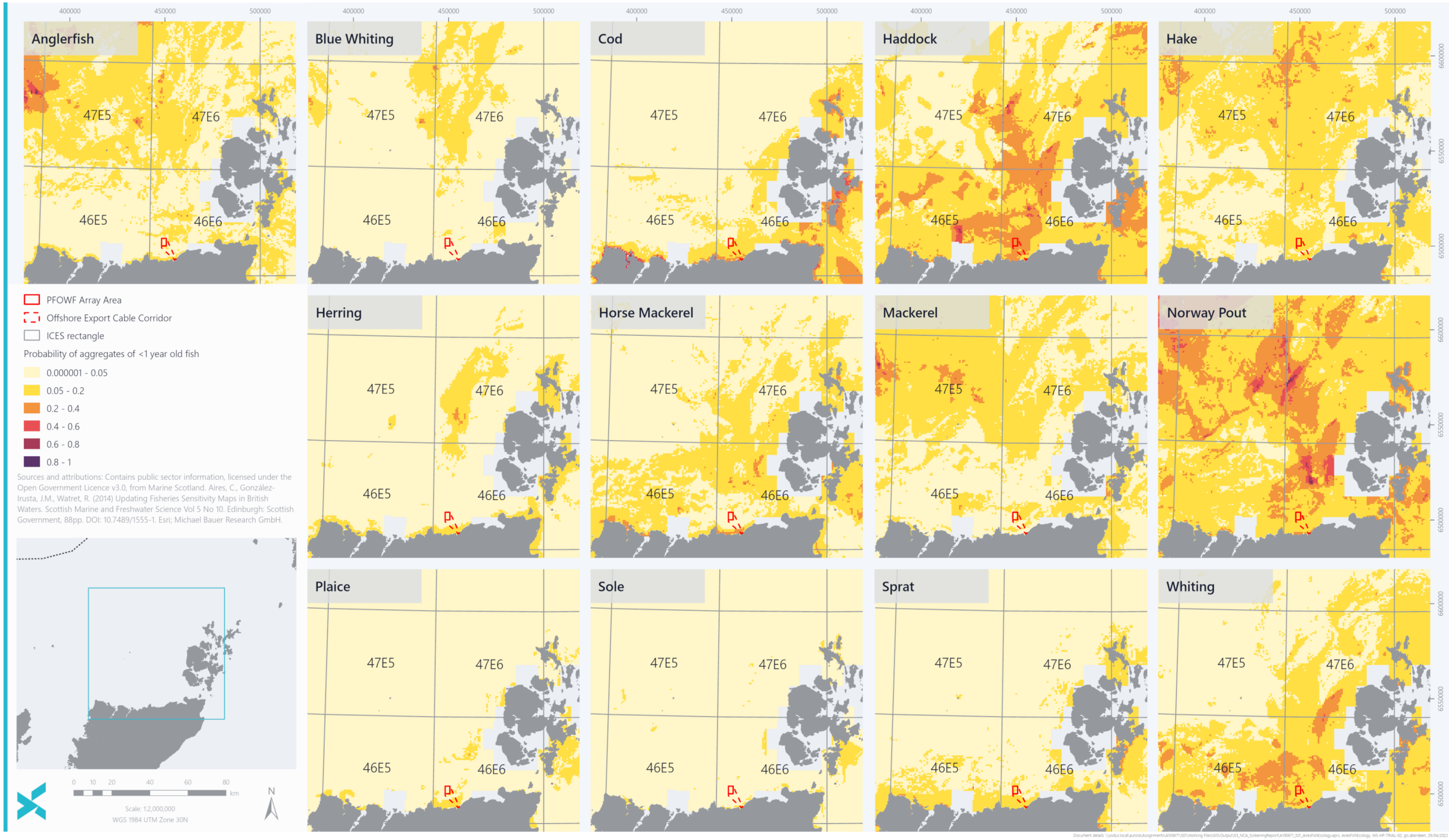

Figure 10.7 Probability of aggregations of 0 group fish and/or larvae of key commercial species (Aries *et al.,* 2014)

10.4.4.4 Species of conservation importance

This section details both marine fish and diadromous fish of conservation importance. Impacts scoped into the assessment are assessed separately for marine fish and diadromous fish within Section 10.6.

10.4.4.4.1 **Diadromous**

A number of diadromous species are anticipated to use the area in the vicinity of the Offshore Development. This includes Atlantic salmon, European eels (*Anguilla anguilla*) and sea trout (*Salmo trutta*).

10.4.4.4.1.1 Atlantic salmon

Atlantic salmon is an Annex II species under the Habitat Directive, a Scottish Biodiversity Species, a Scottish PMF species, and is of cultural, recreational and commercial importance in Scotland. Atlantic salmon are diadromous spending most of their adult lives at sea, returning to freshwater rivers during autumn/ winter to spawn (MarLin, 2022a). After maturing to approximately 12 cm in length at around two years old as they undergo a physiological change to enable them to live in sea water, Atlantic salmon migrate to deep-sea feeding grounds, mostly located in the North Atlantic (NatureScot, 2020a). Deposited eggs tend to hatch the following spring, and the hatched salmon remain in the riverbed feeding on the attached yolk sac. Within the Scottish river systems, salmon tend to remain in the rivers for two to three years whilst they grow and transform to allow them to adapt to salt water.

A tagging data analysis study of salmon in Scotland, which consisted of tagging juvenile in-river salmon and recovering tagged adults on their return migration, indicated that coastal fisheries may exploit fish which originate from rivers located considerable distances from where they operate. In summary, half of all recovered tags were recovered in rivers within tens of kilometres of tagging sites; 90% of tags were recovered within hundreds of kilometres and 100% of tags were recovered within several hundreds of kilometres of coastal fishery tagging sites (Downie *et al*., 2018).

The Sectoral Marine Plan (SMP) (2020) identified Atlantic salmon are likely to be present in the region of the Northern Plan Option (POs) areas. This is due to the multiple rivers with known salmon populations with connectivity to the northern region of Scotland. In addition, the Pentland Firth is a major throughway for Atlantic salmon returning from ocean feeding grounds to rivers within north and east Scotland (FCRT, 2017). Figure 10.8 and Figure 10.9 show the possible migratory routes of adult salmon returning to Scottish rivers (FCRT, 2017).

Caithness has multiple rivers protected for Atlantic salmon. Due to the location of the Offshore Development, there is potential to affect the migratory routes of adult salmon returning to Scottish rivers from the northern Atlantic Ocean and for smolts of salmon leaving the rivers and entering the ocean. The Caithness District Salmon Fishery Board publish yearly electrofishing reports surveying juvenile salmonids (2013-2021) (Youngson, 2022). The River Thurso is included within these reports. In 2020, the River Thurso was found to be heavily populated with salmon fry (at this stage the salmon has consumed all the yolk sac, has grown slightly in size and will emerge from the gravel), as the density of fry exceeded 0.8 fry per m^2 target at all six of the survey sites (Youngson, 2022). In 2021, the fry density at one of the survey sites was also lower than the 0.8 fry per m^2 target, potentially as a result of poor recruitment in 2018. However, it is expected that the status of juvenile salmon in the River Thurso will remain as favourable for 2022 (Youngson, 2022).

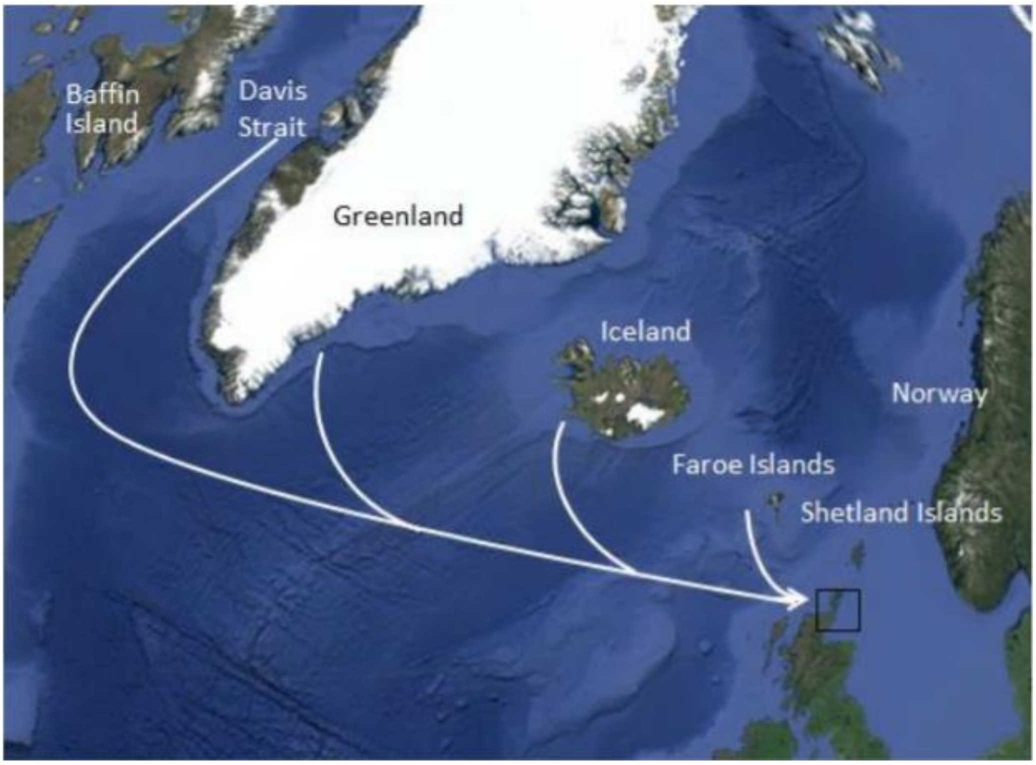

Figure 10.8 Indicative routes for retuning migration of adult salmon to Scottish rivers (as shown by the arrows; FCRT, 2017)

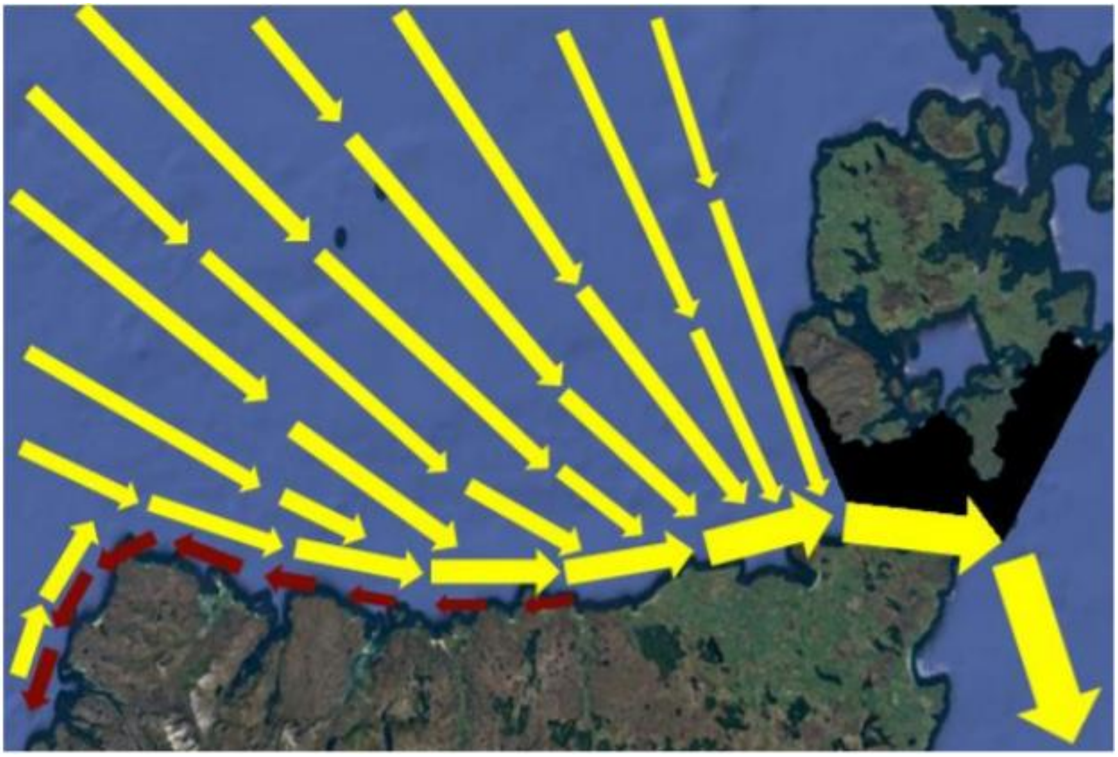

Figure 10.9 Possible pattens of migratory salmon on the north coast of Scotland (FCRT, 2017)

10.4.4.4.1.2 European eel

European eels are critically endangered according to IUCN (2021), a Scottish Biodiversity Species, a UK BAP species, an OSPAR Annex V species, and a PMF species. European eels are also diadromous; migrating to sea to spawn in the Sargasso Sea, with the larvae using Atlantic Ocean currents to make their return journey back to freshwater (Malcolm *et al*., 2010). European eel remain in freshwater for more than 20 years before migrating to the Sargasso Sea to spawn (NatureScot, 2020b). European eel may use the Study Area as a migratory route, and the nearshore areas as habitat.

10.4.4.4.1.3 Sea trout

Sea trout are also likely to be present in the Study Area and are also species of conservation concern as they are on the IUCN Red List (least concern) and a PMF species. Sea trout are a diadromous species predominately found in shallow coastal waters of the oceans and estuaries where they feed and grow, before returning to freshwater to spawn when they have reached maturity (Malcolm *et al*, 2010). Unlike Atlantic salmon, sea trout do not travel to far-off feeding grounds and tend to stay in coastal areas (NatureScot, 2022). Sea trout may use the Study Area as a migratory route, and the nearshore areas as habitat.

The lifecycle of sea trout is similar to Atlantic salmon, with sea trout smolts leaving rivers during spring/ early summer to the sea and returning to rivers to spawn during autumn/ winter months (AST, 2018). Female sea trout return to the rivers they were born in to lay their eggs in gravel depressions (NatureScot, 2022). Juvenile and young sea trout feed on insects such as mayflies as well as invertebrates. As they mature sea trout continue to feed on these species but also feed on crustaceans and smaller fish such as herring and sprat (British Sea fishing, 2022).

10.4.4.4.2 **Marine fish**

10.4.4.4.2.1 Sandeels

The North West Orkney NCMPA is designated for the protection of sandeel. This NCMPA is 33 km to the north of the Offshore Site and overlaps with the Study Area within ICES rectangle 46E6. The predicted EUNIS habitat data also suggests there is suitable habitat for sandeels within the Offshore Site (McBreen *et al.*, 2010). A recent species distribution model, available through National Marine Plan Interactive (NMPI), also predicts that buried sandeel are likely to be present at the Offshore Site, predominantly within the OECC (Langton *et al.,* 2021). As well as being a protected species, sandeels are also considered to be an important prey species.

Sandeel are seabed-dependent for almost their entire life-cycle (except feeding and spawning), inhabiting medium to coarse grained sandy substrates of sandbanks into which they bury to protect themselves from predators (Holland *et al*, 2005; NatureScot, 2021). Once settled, studies have shown that sandeel are mostly resident, rarely travelling over 20 miles. It is understood that sandeel rarely emerge from the seabed between September and March, except to spawn. Some species of sandeel can live for as long as 10 years, reaching maturity at around two years of age.

10.4.4.4.2.2 Herring

Herring is a PMF, Scottish Biodiversity List species and is known to be commercially exploited throughout the UK. They are also considered to be a key prey species. Herring stocks are categorised regionally and have varying spawning/nursery periods at different locations. Herring migrate considerable distances in large shoals to feeding and spawning grounds (Munro *et al.,* 1998), and juvenile herring will remain typically for up to two years within the nursery area, before joining the migrating shoal of adult herring. The International Herring Larvae Surveys (IHLS) estimates herring larvae abundance in the North Sea and adjacent waters. Low numbers of herring larvae are predicted to be within the Study Area (IHLS, 2015).

10.4.4.4.2.3 Sprat

Sprat is a pelagic fish usually found in inshore waters in depths up to 150 m. Sprat is not listed as a species of conservation importance, however, they are considered an important prey species. Sprat migrate between winter feeding grounds and summer spawning grounds and they move to the surface at night to feed on planktonic crustaceans. They tend to spawn at depths of 10 to 20 m, producing pelagic eggs within 100 km of the shore (Whitehead, 1985). Sprat eggs are pelagic and are therefore potentially vulnerable to impacts from suspended sediment (Keller *et al*., 2006; Robertson *et al*., 2006). Additionally, because sprat have swim bladders that are connected to the inner ear, and have relatively sensitive hearing, they may be vulnerable to increased noise from the Offshore Development activities (Popper *et al*., 2014).

10.4.4.4.3 **Other protected species**

10.4.4.4.3.1 Freshwater pearl mussel

As mentioned in Section 10.4.4.1, freshwater pearl mussels are a designated feature of the River Naver SAC and River Borgie SAC. They live partially buried typically in coarse sands and fine gravel within rivers. Freshwater pearl mussels are rare in Scotland and are under threat due to poor water quality, illegal pearl fishing and damage to their habitat. There has been a decline in the number of rivers in Scotland that can support freshwater pearl mussels, and the species is now on the brink of extinction in several rivers. They are a similar shape to common marine mussels, but can grow much larger and live for more than 100 years (NatureScot, 2020c).

The Study Area does not directly overlap with the SACs with known freshwater pearl mussels, with the closest river SAC being 13 km away. Freshwater pearl mussel live on the gills of Atlantic salmon and sea trout in the first year of their lives, during the glochidial stage of their life cycle, and therefore rely on these anadromous fish during this stage (Skinner *et al*., 2003). Consequently, if there is a significant impact on salmon and salmon migration there is potential for this to have an indirect impact on freshwater pearl mussel populations.

10.4.4.5 Commercially important species

Table 10.5 details the top ten commercially important fish and shellfish species in terms of the average annual landing value across the ICES rectangles overlapping, and in the vicinity of, the Study Area between 2016 and 2020. The potential impacts of the Offshore Development on commercial fisheries is assessed in detail within Chapter 13: Commercial Fisheries.

Table 10.5 Species of commercial importance within ICES rectangles 46E5, 46E6, 47E5 and 47E6 (MMO, 2021)

Species	Average Annual Landing value (£) 2016 - 2020			
	46E5	46E6	47E5	47E6
Crabs C.P. Mix	£2,989,395	£4,808,248	£3,881,577	£5,414,406
Haddock	£991,853	£1,292,819	£416,525	£918,875
Mackerel	£355,409	£691,864	£639,775	£571,057
Cod	£39,969	£587,726	£138,441	£958,265
Monkfish (*Lophius*) or Anglerfish	£15,525	£285,885	£233,289	£1,053,668
Lobsters	£124,768	£643,102	£3,443	£126,298
Herring	£608,327	£52	£0	£281,789
Scallops	£274,384	£444,644	£39,990	£33,722
Crabs – Velvet (Swim)	£355,409	£691,864	£639,775	£571,057
Squid (*Decabrachia*)	£113,570	£9,084	£1,678,553	£371,978

The three most economically important commercial shellfish species from the area include brown crab (*Cancer pagurus)*, European lobster (*Homarus gammarus)* and king scallop (*Pecten maximus)*. Velvet crab (*Necora puber)* is also commercially fished in this area, as is periwinkle (*Littorina littorea)* and green crab (*Carcinus maenus)* (MSS, 2014b; See Chapter 13: Commercial Fisheries).

10.4.4.6 Shellfish

The commercially important shellfish species listed in Section 10.4.4.5 are not protected by conservation legislation or regulations, however, they are subject to fisheries management regulations including maximum landing size, or total allowable catch.

10.4.4.6.1 **Crabs**

Brown crabs are found across a wide depth range from the lower shores of exposed and moderately exposed rocky shores, through the shallow sub-littoral fringes and in offshore water depths down to 100 m. They tend to inhabit rocky reefs, mixed coarse grounds and, for females in particular, offshore areas in soft sediments such as muddy sand (Neal & Wilson, 2008). Although non-migratory from a geographical perspective, females make substantial migrations inshore from deeper offshore waters to mate, before returning offshore to release larvae. In contrast, males are generally sedentary and stay in inshore waters (IFCA, 2022). They are fished off the entire rocky north coast of Sutherland and Caithness (Shelmerdine and Mouat, 2021).

Velvet crabs are typically found in intertidal areas down to approximately 80 m. However, they are most commonly found in depths of approximately 25 m in areas of hard substratum where rocky reef and boulders provide crevices for shelter (Jessop *et al.,* 2007). Although females are believed to move further offshore during winter months, long distance migrations have not been observed for this species.

Green crab, more commonly known as the common shoreline crab, is found on all types of shore in depths of up to 60 m, but predominantly they are found in shallow water depths. Egg-bearing females are typically only seen in spring in northern Scotland. Females will aggregate in ‘hotspots’ in areas where there is a defined reproductive season, where they will compete for males (Neal and Pizzolla, 2008).

10.4.4.6.2 **European lobster**

European lobster can be found in the intertidal zone in depths up to 200 m, however, they are most commonly found in waters of less than 30 m, on a hard bedrock or boulder substrate with holes, caves and overhangs which are used as safety retreats. The entire north coast of Sutherland and Caithness provides abundant suitable habitat. Lobsters typically do not undertake extensive migrations, only travelling a few miles along the shore (Pawson, 1995; Smith *et al*., 2001; Thomas, 1955; Keltz & Balley, 2010).

10.4.4.6.3 **European spiny lobster**

European spiny lobsters (*Palinurus elephas*) are a Scottish PMF species that are occasionally found off the north-east Scottish coast. They are mainly abundant off the western coast of Britain and Ireland, and northern waters towards Shetland (NatureScot, 2022). This species usually lives in water deeper than 15 m, and move offshore during their migration period (NatureScot, 2022).

10.4.4.6.4 **King scallops**

King scallops (*Pecten maximus*) are the main species of scallop found in Scottish waters (Howell *et al*., 2006). King scallops have a patchy distribution and are generally found in shallow depressions in the seabed on a mix of sediment types, including firm sand, fine or sandy gravel and occasionally on muddy sand (Marshall & Wilson, 2009).

Within Scottish waters, scallops spawn in either the spring or autumn and the eggs remain either on or near the seabed for a number of days before they then develop into larvae (Keltz & Bailey, 2010). The larvae will then migrate towards the sea surface and remain in the water column for approximately three weeks. Eventually, the larvae will descend back towards the seabed to further develop (Franklin *et al*., 1980). Scallops were observed within the MTT 2021 environmental survey to the south-east of the PFOWF Array Area (Offshore EIAR [Volume 3]: Technical Appendix 9.1).

10.4.4.6.5 **Periwinkle**

The common periwinkle is the largest British periwinkle and they are widely distributed on rocky coasts, typically found between the upper shore and in the sublittoral. They are also found in sheltered conditions, including sandy / muddy habitats (e.g. mud-flats). The species tend to aggregate and form clusters in areas of favourable habitat, for example rock pools. Periwinkles migrate down shore as temperatures fall in autumn, and then will retreat back up shore when temperatures rise in spring (Jackson, 2008).

10.4.5 Future Baseline

Section 10.4.4 describes the current Fish and Shellfish Ecology baseline for the Study Area. The composition of fish and shellfish communities is continuously evolving with natural variation, changes in predator-prey interactions, anthropogenic influences and climate change. The future baseline for commercial fishing activity is described in Chapter 13: Commercial Fisheries and the influence of climate change on fish and shellfish communities is described in Chapter 20: Climate Change and Carbon. These changes may alter the species presence and/or abundance of the species present within the Study Area. However, as a result of the complex interactions between anthropogenic impacts and natural variation it is not possible to make accurate predictions for the changes in the future Fish and Shellfish Ecology baseline over the life-cycle of the Offshore Development.

10.4.6 Summary of Baseline Environment

There are a number of PMF species anticipated to utilise the Offshore Site including:

- Atlantic Salmon;
- Sea trout;
- Blue whiting;
- Cod;
- Common Skate;
- European spiny lobster;
- European eel;
- Herring;
- Ling;
- Mackerel;
- Saithe (*Pollachius virens*);
- Sandeel;
- Spurdog; and
- Whiting.

Potential receptors and impacts scoped into the assessment and impacts scoped out are provided in Section 10.5 along with justification.

10.4.7 Data Gaps and Uncertainties

The baseline presented here is derived from an in-depth desk-based study. The spawning and nursery ground data from Coull *et al.* (1998) and Ellis *et al.* (2012) gives a general overview of the species expected to occur in the Study Area, rather than precise boundaries. This has been further supplemented by fish and shellfish stock data from MSS, confirmation of presence, absence and seasonality from fisheries statistics per ICES rectangle by the MMO and other key sources listed in Section 10.4.2.

10.5 Impact Assessment Methodology

10.5.1 Impacts Requiring Assessment

This assessment covers all potential impacts identified during scoping, as well as any further potential impacts that have been highlighted as the EIA has progressed. It should be noted that impacts are not necessarily relevant to all stages of the Offshore Development.

The list below indicates all of the direct and indirect impacts assessed with regards to Fish and Shellfish Ecology and indicates the Offshore Development phases to which they relate. Cumulative impacts are discussed in Section 10.7.

Table 10.6 Potential impact requiring assessment

Potential Impact	Description
Construction	
Disturbance or damage to sensitive species due to underwater noise generated from construction activities	Direct disturbance to fish populations caused by underwater noise generated during construction (e.g. hammered piles) including effects on migratory fish and fish spawning behaviour. This may depend on the number of piles required, and the duration and timing of installation activities. Other noise generating activities such as cable laying, suction dredging, trenching, rock remedial protection placement, UXO clearance and installation vessels are also considered.
Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and mooring lines on seabed	The Study Area occupies a very small proportion of potential habitat for a number of PMF, commercial or sensitive species. The extent of direct habitat loss from the placement of the Offshore Development subsea infrastructure will depend on the type of anchors selected and cable installation methods employed.
Effects of increased sedimentation / smothering on fish and shellfish during construction activities	Increased sedimentation caused from disturbance to sediment through placement of the Offshore Development subsea infrastructure may lead to direct smothering of slow moving or sessile species which may potentially result in injury or mortality to sensitive species.
Temporary burial of seabed from drilled cuttings	A cuttings pile of approximately 1,424 m^2 may arise from the drilling activities for the drilled anchor piles. This could result in temporary habitat loss or smothering of slow moving or sessile species, potentially resulting in injury or mortality.
Potential accidental release of pollutants	During construction, leakage of pollutants from vessels or equipment could potentially occur during the construction phase or at any stage of the development life-cycle, if no mitigations or management plans are in place. This could be damaging to fish and shellfish ecology, or habitats that are sensitive to toxins.
Operation and maintenance	
Habitat loss of spawning and nursery grounds due to presence of anchors and cables on the seabed	There is potential for spawning grounds to be affected as a result of changes to the seabed in the area of anchors, inter-array cables and Offshore Export Cable(s). The presence of anchors, scour protection and cables will remove some of the available habitat that is currently used as spawning and nursery grounds by numerous species.
Effects of EMFs from export and inter-array cables on sensitive species	EMFs occur naturally in the marine environment, however, there are several anthropogenic activities that can create altered and/or cause additional sources of EMF. Therefore, there is the potential that an introduction of dynamic inter-array cables and Offshore Export Cable(s) as part of the Offshore Development may have an impact on fish and shellfish species in the Study Area environment. EMF may affect sensitive species e.g. elasmobranchs and teleost fish (i.e. flatfish, salmonids and gadoids) by altering foraging or migratory behaviour.
Fish aggregation around the floating structure and associated infrastructure	The offshore infrastructure may act as a Fish Aggregation Device (FAD), providing refuge and/or habitat for some fish, shellfish and benthic species, whilst also potentially attracting larger predators. This could indirectly increase the risk of entanglement or collision for both fish and marine mammal species.
Ghost fishing due to lost fishing gear becoming entangled in installed infrastructure.	The potential impact of ghost fishing gear entanglement is assessed within Chapter 13 Commercial Fisheries.

Potential Impact	Description
Decommissioning	
Potential impacts arising during the decommissioning phase are expected to be similar to, but not exceeding, those arising during the construction phase.	

The assessment of impacts on Fish and Shellfish Ecology was a desk-based exercise making use of project specific data from site-specific surveys and published information on receptor sensitivities.

10.5.2 Impacts Scoped Out

The following impacts were scoped out of the assessment during EIA scoping:

10.5.2.1 Barrier effects on migratory fish from the presence of the floating platform and associated infrastructure

The small scale and offshore location of the Offshore Development enables passage either side, and therefore is unlikely to present a significant barrier to movement for migratory fish. Furthermore, the Offshore Site is located at least 13 km from the nearest SAC for migratory salmonids. Dodd and Briers (2021) concluded that there is no published information regarding the biological or behavioural responses of Atlantic salmon, or any fish species, to artificial light patterns of the characteristics associated with shadow flicker, and that shadow flicker is unlikely to result in a change at the population level to Atlantic salmon. Information from operational wind farms also notes the potential for wind farms to act as artificial reef systems whereby fish are attracted to the area, rather than deterred (as described in Section 10.6.2.3).

10.5.2.2 Effects of operational noise on sensitive species

Disturbance to migratory fish populations, particularly salmon and sea trout, caused by underwater noise produced from the operation of up to seven WTGs is anticipated to be minimal.

As discussed in Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling, the main source of underwater noise from operational WTGs will be mechanically generated vibration from the rotating machinery in the WTGs, which is transmitted into the sea through the structure of [fixed] WTG tower and foundations (Nedwell *et al*., 2003, Tougaard *et al*, 2020). Noise levels generated above the water surface are low enough that no significant airborne sound will pass from the air to the water. The continuous operational noise from the PFOWF WTGs is expected to be reduced when compared to fixed-foundation structures, due to the deployment of floating substructures for the Offshore Development. Due to a lack of available data, underwater noise from fixed-foundation structures was used as a worst case for underwater noise modelling.

There is limited data available on the underwater noise emissions of mooring line ‘pinging’, which is a phenomenon which occurs as a result of the sudden re-tension in a mooring line following a period of slackness, and the potential effects on fish and shellfish communities. As described in the Offshore EIAR (Volume 3): Appendix 11.1 Underwater Noise Impact Assessment, data is available for the Hywind demonstrator Project for a single WTG, where 23 pings were identified per day and of these, less than 10 pings exceeded SPL_{peak} of 160 dB re 1 µPa. Subsequent analysis undertaken for the Hywind Scotland Pilot Park by Xodus Group Ltd (2015) predicted a potential cumulative Sound Exposure Level (SEL) of up to 157 dB re 1 $µPa^2s$ over 24 hours at 150 m resulting from cable pinging from six WTG. Modelling based on ten WTGs estimated an equivalent SEL of approximately 160 dB re 1 $µPa^2s$ (Midforth *et al.,* 2022); the SEL for seven WTGs (as proposed for the Offshore Development) would be < 160 dB re 1 $µPa^2s$. The threshold is below the onset criteria for injury to fish and shellfish, and therefore, there is considered to be no risk of injury (Popper *et al.,* 2014). The Hywind Environmental Statement used a radius of 100 m from the mooring line pinging event at which a behavioural response could occur. Although it should be noted that the mooring arrangement and equipment used will differ for the Offshore Development, resulting in further uncertainty as to whether mooring line pinging noise will occur, the impacts are expected to be localised and are not anticipated to have any widespread effects at a population level.

Therefore, as the Offshore Development is a floating design and sufficiently small, the underwater noise which is generated during operation and maintenance is not expected to create a barrier effect to migration pathways of fish species through the Pentland Firth.

Within Offshore EIAR (Volume 3): Appendix 10.1 Underwater Noise Modelling, continuous operational noise from the WTGs was assessed based on 20 MW [fixed] WTGs. Results indicate there will be negligible risk of injury with both recoverable injury and Temporary Threshold Shift (TTS) occurring at < 50 m from the source. Behavioural responses from cable pinging are also expected to be localised, and it should be noted that the pinging sound is highly unlikely to occur for all WTG at the same time. Based on these results, and supported by comments from MSS (as set out in Table 10.2), the effects of operational noise on sensitive fish and shellfish species have not been considered further within this Chapter.

10.5.3 Assessment Methodology

The EIA process and methodology are described in detail in Chapter 6: EIA Methodology.

Project specific criteria has been developed for the sensitivity and vulnerability of the receptor, and the likelihood and magnitude of impact as detailed below.

10.5.3.1 Defining impact magnitude

Defining impact magnitude requires consideration of how the following factors will impact on the baseline conditions:

> Spatial Extent: The area over which the impact will occur;
> Duration: The period of time over which the impact will occur;
> Frequency: The number of times the impact will occur over the project lifespan;
> Intensity: The severity of the impact;
> Likelihood: The probability that the impact will occur and also the probability that the receptor will be present; and
> Reversibility: The ability for the receiving environment / exposed receptor to return to baseline conditions.

Based on these parameters, and expert judgement, a summarised description on the assignment of magnitude criteria is provided in Table 10.7.

Table 10.7 Impact magnitude criteria

Magnitude	Criteria
High	The impact occurs over a large spatial extent resulting in widespread, long-term, or permanent changes in baseline conditions or affects a large proportion of a receptor population. The impact is very likely to occur and/or will occur at a high frequency or intensity.
Moderate	The impact occurs over a local to medium extent with a short- to medium-term change to baseline conditions or affects a moderate proportion of a receptor population. The impact is likely to occur and/or will occur at a moderate frequency or intensity.
Low	The impact is localised and temporary or short-term, leading to a detectable change in baseline conditions or a noticeable effect on a small proportion of a receptor population. The impact is unlikely to occur or may occur but at low frequency or intensity.
Negligible	The impact is highly localised and short-term, with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or a receptor population. The impact is very unlikely to occur; if it does, it will occur at a very low frequency or intensity.
No Change	No change from baseline conditions.
Note: The magnitude of an impact is based on a variety of parameters. The definitions provided above are for guidance only and may not be appropriate for all impacts. For example, an impact may occur in a very localised area but at a very high frequency / intensity for a long period of time. In such cases, expert judgement is used to determine the most appropriate magnitude ranking as explained through the narrative of the assessment.	

10.5.3.2 Receptor sensitivity

As part of the assessment of significance of effects it is necessary to determine the receptor sensitivity. The sensitivity of a receptor is defined as 'the degree to which a receptor is affected by an impact'.

The overall receptor sensitivity is determined by considering a combination of value, adaptability, tolerance and recoverability. This is achieved through applying known research and information on the status and sensitivity of the feature under consideration coupled with professional judgement and past experience.

The ability of a receptor to adapt to change, tolerate, and/or recover and the timing for recovery from potential impacts is key in assessing its vulnerability to the impact under consideration. Table 10.8 details the criteria used to define sensitivity in terms of adaptability and recoverability.

Table 10.8 Sensitivity of receptor (in the context of ability to recover and adaptability)

Receptor sensitivity	Definition
Very high	The receptor has no capacity to accommodate a particular effect and no ability to recover or adapt.
High	The receptor has a very low capacity to accommodate a particular effect with a low ability to recover or adapt.
Moderate	The receptor has a low capacity to accommodate a particular effect with a low ability to recover or adapt.
Low	The receptor has some tolerance to accommodate a particular effect or will be able to recover or adapt.
Negligible	The receptor is generally tolerant and can accommodate a particular effect without the need to recover or adapt.

Receptor value considers whether, for example, the receptor is rare, has protected or threatened status, importance at local, regional, national or international scale and in the case of biological receptors, whether the receptor has a key role in the ecosystem function. Based on this, receptor value has been defined for Fish and Shellfish Ecology receptors in Table 10.9 below to aid the overall assessment of receptor sensitivity.

Table 10.9 Criteria for value of fish and shellfish ecology receptor

Value of receptor	Definition
Very high	Receptor of very high importance or rarity, e.g. species that are globally threatened e.g. those listed on the OSPAR list of Threatened and Declining Species, International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species ('Red List'), including those listed as endangered or critically endangered and/or a significant proportion of the international population (> 1%) is found within the Offshore Development.
High	Receptor of high importance or rarity, such as species listed on the OSPAR list of Threatened and Declining Species, species listed as near-threatened or vulnerable on the IUCN Red List. Species listed on Annex IV of the EU Habitats Directive as a European Protected Species (EPS), and / or is a qualifying interest of a SAC or NCMPA and a significant proportion of the national population (> 1%) is found within the Offshore Development.
Moderate	Receptor of least concern on the IUCN Red List, listed on the Wildlife and Countryside Act 1981, form a cited interest of a Site of Special Scientific Interest (SSSI), salmonids protected by the Salmon and Freshwater (Consolidation) Scotland Act 2003 or are listed in the UK BAP, PMF, SBL and a significant proportion of the regional population (> 1%) is found within the Offshore Development.
Low	Any other species of conservation or commercial interest.
Negligible	Receptor of very low importance, such as those which are generally abundant around the UK with no specific value or conservation or commercial concern.

The overall sensitivity for Fish and Shellfish Ecology receptors is thus defined based on professional judgement in line with the above criteria.

10.5.3.1 Evaluation to determine significance of effect

Significance of an effect is determined by correlating the magnitude of the impact and the sensitivity of receptor in conjunction with professional judgement, using industry best practice guidance, science and accepted approaches.

In order to ensure a transparent and consistent approach throughout the EIAR, a matrix approach has been adopted to guide the assessment of significance of effects (see Table 10.10). There is however latitude for professional assessment where deemed appropriate in the application of this matrix.

Table 10.10 Significance of effects matrix

Significance of Effects Matrix					
Sensitivity of Receptor	Magnitude of Impact				
	No Change	Negligible	Low	Moderate	High
Negligible	Negligible	Negligible	Negligible	Negligible	Minor
Low	Negligible	Negligible	Minor	Minor	Moderate
Moderate	Negligible	Minor	Minor	Moderate	Major
High	Negligible	Minor	Moderate	Major	Major
Very High	Negligible	Minor	Major	Major	Major

Definitions of significance of effect are described in Table 10.11. For the purposes of this EIAR, any effect with a significance of moderate or greater is generally considered 'significant' in EIA terms and additional mitigations may be required. Whilst effects identified as minor or negligible are generally considered to be 'not significant' in EIA terms.

Table 10.11 Assessment of consequence

Assessment consequence	Description (consideration of receptor sensitivity and value and impact magnitude)	Significance of Effect
Major Effects	Effects (beneficial or adverse) are likely to be highly noticeable and long term, or permanently alter the character of the baseline and are likely to disrupt the function and/or status / value of the receptor. They may have broader systemic consequences. These effects are a priority for mitigation in order to avoid or reduce the anticipated significance of the effect.	Significant
Moderate Effects	Effects (beneficial or adverse) are likely to be noticeable and result in lasting changes to the character of the baseline and may cause hardship to, or degradation of, the receptor, although the overall function and value of the baseline / receptor is not disrupted. Such effects are a priority for mitigation in order to avoid or reduce the anticipated significance of the effects.	Significant
Minor Effects	Effects (beneficial or adverse) are expected to comprise noticeable changes to baseline conditions, beyond natural variation, but are not expected to cause long term degradation, hardship, or impair the function and value of the receptor. Such effects are not typically contentious and will not generally require additional mitigation, but may be of interest to stakeholders.	Not Significant
Negligible	Effects are expected to be either indistinguishable from the baseline or within the natural level of variation. These effects do not require mitigation and are not anticipated to be a stakeholder concern and/or a potentially contentious issue in the decision-making process.	Not Significant

10.5.4 Design Envelope Parameters

As detailed in Chapter 5: Project Description, this assessment considers the Offshore Development parameters which are predicted to result in the greatest environmental impact, known as the 'realistic worst case scenario'. The realistic worst case scenario represents, for any given receptor and potential impact on that receptor, various options in the Design Envelope that would result in the greatest potential for change to the receptor in question.

Given that the realistic worst case scenario is based on the design option (or combination of options) that represents the greatest potential for change, confidence can be held that development of any alternative options within the design parameters will give rise to no effects greater or worse than those assessed in this impact assessment. Table 10.12 presents the realistic worst case scenario for potential impacts on Fish and Shellfish Ecology during construction, operation and maintenance and decommissioning phases of the Offshore Development.

In terms of Fish and Shellfish Ecology, the realistic worst case scenario has been derived by ensuring that the maximum parameters of components for the Offshore Development with potential to interact with Fish and Shellfish Ecology receptors are considered to enable, for example, that the maximum habitat disturbance area from the placement of subsea infrastructure, to be assessed.

Where there are a number of options for the various Offshore Development components e.g. both tension-leg platforms (TLP) and semi-submersible platforms currently being explored for the floating substructures, the option which has the largest potential impact on Fish and Shellfish Ecology receptors has been assessed and the maximum parameters identified. In this case the semi-submersible (square structure) parameters have been assessed for fish aggregation impacts as they are the largest structure and therefore have the maximum potential for fish aggregation of a floating structure.

For habitat loss from seabed disturbance impact, a number of anchoring options are being explored, however, gravity anchors have the largest footprint and therefore represent the worst case anchor solution in terms of seabed disturbance and potential effects on Fish and Shellfish Ecology receptors. Similarly, catenary mooring lines, although not the only mooring line option, have also been identified as the worst case in terms of seabed disturbance and therefore the associated maximum parameters have been assessed.

Hammer piles have been considered as the worst case for disturbance or damage to Fish and Shellfish Ecology receptors from underwater noise during installation of the piles. The 'cautious worst case' scenario assumes that three piles are installed per day and that the piling activities could last up to 63 days. This is considered to represent a precautionary approach.

The Offshore Development components which have been identified as resulting in the worst case scenarios for each potential impact on Fish and Shellfish Ecology receptors are detailed below.

Table 10.12 Design parameters specific to fish and shellfish ecology receptor impact assessment

Potential Impact	Design Envelope Scenario Assessed
Construction Phase	
Disturbance or damage to sensitive species due to underwater noise generated from construction activities	**Anchors: Hammer piles** > Up to 9 hammer driven piles per WTG (63 piles total), each pile being up to a maximum of 5 m in diameter. The following scenario is considered as the worst case for the impact assessment: ○ 5 m diameter tubular pile, 20 m length. Installed using a hammer with maximum blow energy of 2500 kJ. 14,912 blows over a total period of 8 hours with three piles installed in a 24-hour period (resulting in 44,736 blows over 24 hours). ○ Minimum no. of piles installed in 24 hours = 1 ○ Maximum of 63 days of piling.

<table>
<tr><th>Potential Impact</th><th>Design Envelope Scenario Assessed</th></tr>
<tr><td></td><td>

Soft-start procedures assume 5% of maximum hammer energy for first 5 mins, doubled every 5 mins for up to 20 mins before full hammer energy is employed.
Note that drilled piles still remain an option that will be considered within the EIA. However, drilling operations do not represent the worst case in terms of noise propagation.

UXO Clearance

UXO clearance is not planned nor anticipated to be required for the Offshore Development, based on the Risk Assessment carried out by Ordtek (2021). Any UXO clearance activities which are identified as being required during the UXO and geophysical survey campaign will be considered in consultation with the relevant stakeholders and will be covered under a separate licence application. Should clearance be required during the pre-construction phase, it would generate temporary underwater noise emissions with the potential to injure or disturb marine megafauna.
High-order detonation charge size: 525 kg (plus donor charge)

</td></tr>
<tr><td>Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and moorings on seabed</td><td>
Offshore Export Cable(s)

A maximum of two offshore export cables which will run from the PFOWF Array Area to landfall;
Maximum total combined length of cable is approximately 25 km;
Maximum trench width 3 m;
Maximum width of cable corridor 15 m (seabed disturbance, not trench width). Seabed prep including boulder removal, seabed levelling etc. will take place within this corridor;
Maximum % of seabed requiring preparation = 100%;
Maximum seabed preparation footprint = 375,000 m^2;
Maximum cable remedial protection footprint = 87,500 m^2;
Up to 50% of the Offshore Export Cable(s) may not reach the target burial depth of 0.6 m so will require remedial protection, therefore maximum length of remedial cable protection will be 6.25 km per cable, so 12.5 km in total. Maximum cable protection height and width of 1 m and 7 m respectively. Total area of 87,500 m^2 / 0.0875 km^2; and
Total duration of offshore operations = approximately 4 months, planned for spring/ summer of Stage 1 or Stage 2, during which cable installation is anticipated to take a nominal two-weeks within this period, weather permitting

Horizontal Directional Drilling (HDD) Protection methods

Two successful drilled holes (this may require up to five bore attempts);
The HDD exit point is expected to be approximately 600 m offshore from MHWS. The water depth range in this region is between 15 m to 40 m;
Maximum offshore HDD length 700 m;
Maximum bore diameter 750 mm; and
Total duration of offshore operations = approximately 7 months, planned to take place in the year before stage 1 of the construction phase (i.e. anticipated to take place in 2024).

</td></tr>
</table>

Potential Impact	Design Envelope Scenario Assessed
	Inter-array Cables > Maximum of 7 inter-array cables; > Maximum combined length of the cable is 25 km (all cables combined); > Maximum length of cable on the seabed is 20 km (all cables combined); > Maximum % of cable requiring seabed preparation (levelling, boulder removal) = 100%; > Maximum seabed preparation footprint (all cables) = 300,000 m^2; > Maximum of 14 gravity anchors (2 per cable, 20 m^2 per anchor) = 280 m^2; > Total cable protection footprint for all inter-array cables = 70,000 m^2; > It is assumed that up to 5,000 m of cable will be in the water column. These cables will be 300 mm diameter = (9,425 m^2 lateral surface area in the water column); and > Total duration of offshore operations = approximately 3 months, planned for summer of Stage 2. **Trench and burial methods for the Offshore Export Cable(s) and inter-array cables:** A combination of the following methods may be used, depending on the ground conditions: > Pre-lay trenching using a displacement plough to create a pre-lay trench which the cable is then installed into. A separate backfill plough may then be used to push the spoil heaps created by trenching over the cable, thus creating the required cable cover. > Post-lay trenching using a variety of tools including: o Jet trenchers (either self-propelled or mounted as skids onto Remotely Operated Vehicles [ROVs]) which inject water at high pressure into the sediment surrounding the cable. The seabed is temporarily fluidised and the cable is lowered to the required depth. Displaced material is suspended in the water and then resettles over the cable. This process is controlled, to ensure that sediment is not displaced too far from the cable; o Mechanical trenchers which bury the cable by lifting the laid cable whilst excavating a trench below, and then replacing the cable at the base of the trench and allowing the soil to naturally backfill behind the trencher; o Non-displacement ploughs which simultaneously lift a share of seabed whilst depressing the cable into the bottom of the trench. As the plough progresses the share of seabed is replaced on top of the cable; and > Simultaneous cable lay and burial, using a jet trencher or non-displacement plough. **Moorings: catenary** > Maximum number of moorings is 9 per substructure / WTG; > Maximum length of mooring that may come into contact with the seabed = 1,485 m per line (90% of total length); > Maximum lateral movement of 0.035 km^2 (assuming for full length of mooring line on seabed i.e., 1,485 m per mooring line); > Maximum mooring line seabed footprint = 93,555 m^2; > Maximum temporary footprint from lateral movement = 2,205,000 m^2; and

Potential Impact	Design Envelope Scenario Assessed
	> Total duration of offshore operations = approximately 4 months during summer Stage 1 (for the single WTG) and 6 months during spring/summer of Stage 2 of the construction phase. **Anchors: gravity** > Up to 9 anchors per WTG; > Maximum seabed footprint of 625 m^2 per anchor; > Maximum seabed footprint of scour protection per anchor of 260 m^2; > Maximum temporary area of seabed preparation (levelling) of 900 m^2 per anchor (total = 56,700 m^2); > Maximum permanent total anchor and scour protection footprint = 55,755 m^2; and > Total duration of offshore operations = approximately 6 months during spring/summer of Stage 1 of the construction phase.
Effects of increased sedimentation / smothering on fish and shellfish during construction activities	Same parameters as above.
Temporary burial of seabed from drilled cuttings	As discussed in Chapter 7: Marine Physical Processes, radius of the cuttings mound if drilled piles were selected as the optimum anchoring solution would be approximately 21 m and cover an area of approximately 1,424 m^2.
Potential accidental release of pollutants	Maximum of 30 vessels used during the construction campaign.
Operational Phase	
Habitat loss of spawning and nursery grounds due to presence of anchors and cables on the seabed	**Offshore Export Cable(s)** > A maximum of two offshore export cable which will run from the PFOWF Array Area to landfall; and > Maximum cable remedial protection footprint = 87,500 m^2. **Inter-array Cables** > Maximum of 7 inter-array cables; > Maximum combined length of the cable is 25 km (all cables combined); > Maximum length of cable on the seabed is 20 km (all cables combined); and > Maximum of 14 gravity anchors (2 per cable) each anchor will be 20 m^2 = 280 m^2; and > Total cable protection footprint for all inter-array cables = 70,000 m^2. **Moorings: catenary** > Maximum number of moorings is 9 per substructure / WTG; > Maximum length of mooring that may come into contact with the seabed = 1,485 m per line (90% of total length); > Maximum lateral movement of 0.035 km^2 (assuming for full length of mooring line on seabed i.e., 1,485 m per mooring line);

Potential Impact	Design Envelope Scenario Assessed
	> Seabed footprint of 1,485 m^2 per mooring line; and > Maximum mooring line seabed footprint = 93,555 m^2. **Anchors: gravity** > Up to 9 anchors per WTG; > Maximum seabed footprint of 625 m^2 per anchor; > Maximum seabed footprint of scour protection per anchor of 260 m^2; and > Maximum permanent total anchor and scour protection footprint = 55,755 m^2.
Effects of EMFs from the export cables and inter-array cables on sensitive species	**Offshore Export Cable(s)** > A maximum of two (High Voltage Alternating Current [HVAC]) offshore export cables which will run from the Offshore Development to landfall; > Maximum voltage of 110 kV. However, for the purpose of EMF impacts 66 kV is the worst case and is the basis for the assessment, as explained in Chapter 5: Project Description; Section 5.5.3; > Maximum cable length on seabed (per Offshore Export Cable) is 12.5 km (25 km in total for 2 cables); and > Maximum length of the dynamic/floating portion of the Offshore Export Cable(s) to touchdown point on seabed is 500 m. **Inter-array Cables** > Maximum of 7 inter-array with a maximum voltage of 110 kV. However, for the purpose of EMF impacts 66 kV is the worst case and is the basis for the assessment, as explained in Chapter 5: Project Description; Section 5.5.3; > Maximum proportion of cable on the seabed is 20 km; and > It is assumed that up to 5,000 m of cable will be in the water column.
Fish aggregation around the floating structure and associated infrastructure	**Floating Substructure: Semi-Submersible (square option)** > Overall surface area below water (per substructure) = 25,625 m^3; and > Maximum for 7 floating foundations = 179,375 m^3 of available surface below water. **Offshore Export Cable(s)** > A maximum of two offshore export cables which will run from the Offshore Development to landfall; > Maximum total combined length of cable is approximately 25 km; and > Maximum volume of cable protection of 43,750 m^3. **Inter-array Cables** > Maximum of 7 inter-array cables; > Maximum combined length of the cable is 25 km (all inter-array cables combined); > Maximum length of cable on the seabed is 20 km (all inter-array cables combined); > Maximum of 14 gravity anchors (2 per cable 20 m^2 per anchor = 280 m^2); > Total cable protection footprint for all inter-array cables = 70,000 m^2; and

Potential Impact	Design Envelope Scenario Assessed
	> Total cable protection volume for all inter-array cables = 35,000 m^3. **Anchors: gravity** > Up to 9 anchors per WTG; and > Maximum seabed footprint of 625 m^2 per anchor. > Maximum seabed footprint of scour protection per anchor of 260 m^2; and > Maximum permanent total anchor and scour protection footprint = 55,755 m^2.
Decommissioning	
Same as installation	In the absence of detailed information regarding decommissioning works, the implications for fish and shellfish ecology are considered analogous with or likely less than those of the construction phase. Therefore, the worst case parameters defined for the construction phase also apply to decommissioning. The decommissioning approach is set out in Chapter 5: Project Description; Section 5.11. It is expected that all offshore components will be completely removed to shore for re-use, recycling and disposal during decommissioning, unless there is compelling evidence to leave certain components, e.g. the buried sections, *in situ*. The only exception to this would be scour protection and piled foundations, which may be cut off 1 m below the seabed which may not be practical to recover. It may be preferable to leave the scour protection *in situ* to preserve the marine habitat that may have developed over the life of the Offshore Development; this is particularly the case for remedial protection placement / boulders as these are generally quite small in grade size and thousands in quantity so not practical to recover. A Decommissioning Programme will be developed pre-construction to address the principal decommissioning measures for the Offshore Development, this will be written in accordance with applicable guidance and detail the management, environmental management and schedule for decommissioning. The Decommissioning Programme will be reviewed and updated throughout the life-cycle of the Offshore Development to account for changing best practice. Relevant stakeholders and regulators will be consulted to establish the approach. The seabed will be restored, as far as reasonably practicable, to the condition it was prior to the construction of the Offshore Development.

10.5.5 Embedded Mitigation and Management Plans

As part of the Offshore Development design process, a number of designed-in measures and management plans have been proposed to reduce the potential for impacts on Fish and Shellfish Ecology receptors (Table 10.13). As there is a commitment to implement these measures, they are considered inherently part of the design of the Offshore Development and have therefore been considered in the assessment presented below (i.e. the determination of magnitude of impact and therefore significance of effects assumes implementation of these measures). These measures are considered standard industry practice for this type of development.

Activities involving clearance or detonation of UXO are not planned and therefore not subject to mitigation protocols. Should they be required in future, activities which relate to UXO clearance or detonation will be carried out under a separate marine licence application which would include mitigation protocols which will align with the relevant guidance at that time.

Table 10.13 Embedded Mitigation Measures and Management Plans specific to Fish and Shellfish Ecology for the Offshore Development

Embedded Mitigation Measures and Management Plans	Justification
Management Plans	
Construction Environmental Management Plan (CEMP)	The CEMP will set out procedures to ensure all activities with potential to affect the environment are appropriately managed and will include: a description of works and construction processes, roles and responsibilities, description of vessel routes and safety procedures, pollution control and spillage response plans, incident reporting, chemical usage requirements, waste management plans, plant service procedures, communication and reporting structures and timeline of work. It will detail the final design selected and take into account Marine Licence Conditions and commitments.
Offshore Construction Method Statement (CMS)	A CMS will be developed in accordance with the CEMP detailing how the Offshore Development activities and plans identified within the CEMP will be carried out, and also highlighting any possible dangers/risks associated with particular Offshore Development activities.
Operational Environmental Management Plan (OEMP)	The Developer will collate an OEMP to guide on-going operations and maintenance activities during the life-cycle of the Offshore Development. The OEMP will also set out the procedures for managing and delivering the specific environmental commitments including a Marine Pollution Contingency Plan and INNS Management Plan. Adopting these protocols will reduce risk in relation to spread of INNS across all phases of the Offshore Development.
Cable Plan	The Cable Plan will be provided post- consent and detail the location/ route and cable laying techniques of the inter-array and Offshore Export Cable(s)and detail the methods for cable surveys during the operational life of the cables for the Offshore Development. This will be supported by survey results from the geotechnical, geophysical and benthic surveys. The cable plan will also detail electromagnetic fields of the cables deployed. A Cable Burial Risk Assessment (CBRA) will also be undertaken and included within the Cable Plan which will detail cable specifications, cable installation, cable protection, target burial depths / depth of lowering and any hazards the cable will present during the lifespan of the cable.
Piling Strategy	A Piling Strategy will be written for the Offshore Development if impact piling is selected as the optimal installation mechanism for the turbine foundations. The strategy will provide full details of the piling activities and parameters, including expected noise levels, duration of activities and any required mitigations associated with this installation techniques.
Marine Pollution Contingency Plan	Consent conditions will require a Marine Pollution Contingency Plan to outline procedures in the event of an accidental pollution event arising from activities associated with the Offshore Development. The Plan provides guidance to personnel and contractors on the action and reporting requirements.
Embedded mitigation	
Adherence with the International Convention for the Prevention of Pollution from Ships (MARPOL)	All vessels will operate in adherence with Marine Pollution (MARPOL) requirements. Accordance with this will help to ensure that the potential for release of pollutants is minimised during operation and maintenance.

Embedded Mitigation Measures and Management Plans	Justification
Micrositing of WTGs and associated offshore infrastructure including cable routes	The final Project layout will be presented within the Cable Plan and Design Specification and Layout Plan, conditions of the Section 36 and/or Marine License consent As part of the pre-construction survey (which will be agreed with Marine Scotland) data will be analysed to ascertain the presences of any rare or important habitats. If pre-construction surveys were to identify any areas that are considered to be rare or important habitats, consultation with Marine Scotland will be required to ensure that planned installation would not have a significant adverse effect. Where possible, the Offshore Export Cable route(s) should aim to avoid more sensitive habitats and where this is not possible, the route should take the shortest distance possible through the sensitive areas.
Target depth of lowering	Static cables will be trenched and buried to a target depth of 0.6 m. Where this cannot be achieved, remedial cable protection will be applied. This will provide some separation between the cables and fish and shellfish ecology receptors, therefore reducing the effect of EMF. The cable burial target depth will be informed by a CBRA and implemented through the CaP produced post-consent.
Reducing localised habitat loss	Localised habitat loss during the installation phase is an unavoidable consequence of the Offshore Development. Best practice will be followed to ensure that potential habitat loss is minimised throughout the proposed works e.g., micrositing and minimising benthic footprint of the Offshore Development. The amount of remedial protection used to protect the Offshore Export Cable(s), anchors and mooring lines will be kept to a minimum where possible.
Nacelle, Tower and Rotor Design	The nacelle, tower and rotor are designed and constructed in order to contain leaks thereby reducing the risk of spillage into the marine environment.
Removal of debris from floating lines and cables	Mooring lines and floating inter-array cables will be inspected with a risk-based frequency during the operational life-cycle of the Offshore Development, starting at a higher frequency and likely declining after a number of years, based on evidence gathered during inspections. Any inspected or detected debris on the floating lines and cables will be recovered based on a risk assessment which considers impact on environment, risk to asset integrity and cost of intervention.
Removal of marine growth	The substructures will be designed to accommodate marine growth; however, in order to manage weight/ drag induced fatigue, growth levels will be inspected on a regular basis, and subsequent removal of this growth will be undertaken using water jetting tools if substantial accumulation is in evidence.

10.5.6 Data Gaps and Uncertainties

A number of data gaps for Fish and Shellfish Ecology have been outlined in the two ScotMER evidence maps: fish and fisheries and diadromous fish (Scottish Government, 2020). This includes:

- Underwater noise and vibration:
  - There is a lack of research specifically looking at the effects on cod, herring and other species and further research is required;

- EMF:
  - There is a lack of research specifically addressing EMF emissions from free-hanging or surface-laid cables;
  - There are no policies or regulations related to EMF;
  - Significant gaps remain in understanding how pelagic species (e.g. sharks, fish) may react specifically to dynamic cables suspended in the water column (Copping *et al.,* 2020); and
  - Sensitivity ranges for magnetic and electric field detection in general is better understood for some taxa (e.g., elasmobranchs) compared to others where information is lacking (e.g., teleost fish [the most diverse group of fishes], crustaceans) (Hutchison *et al*., 2020).
- Mapping of fish habitat:
  - There is a lack of mapping of essential fish habitat, particularly for spawning and nursery grounds.

The uncertainties around these impact mechanisms have been considered within the impact assessment when defining sensitivity of receptor and magnitude of impact.

10.6 Assessment of Environmental Effects

10.6.1 Effects during Construction

10.6.1.1 Disturbance or damage to sensitive species due to underwater noise generated from construction activities

Anthropogenic noise is now recognised as a pollutant of international concern. This includes noise generated by offshore construction activities such as impact piling. An increase in noise can affect acoustic communication in fish (Radford, Kerridge and Simpson, 2014) and reproductive success (De Jong *et al*., 2020) as well as foraging, predator avoidance and navigation (Hawkins and Myrberg, 1983). In addition to these behavioural effects, underwater noise can also cause physical injury and, in extreme cases, mortality to fish and shellfish species.

This section focuses on the underwater noise impacts from impact piling activities on sensitive fish and shellfish species as, if utilised, it will be the greatest noise source during construction. Other installation activities such as cable laying, dredging, trenching, rock placement and vessels also result in underwater noise and were included in the underwater noise modelling. This underwater noise modelling, undertaken by Subacoustech, predicted the potential effects of underwater noise produced from these sources (excluding piling) will be **negligible** and **not significant**, as presented in Offshore EIAR (Volume 3): Technical Appendix 10.1. The noise emissions from these sources fall below the appropriate injury or disturbance criteria for fish and shellfish species within 50 m of the source of the noise. Therefore they will not be discussed further in this assessment.

The potential underwater noise propagation from UXO clearance has also been modelled and assessed within Offshore EIAR (Volume 3): Technical Appendix 10.1, based on Popper *et al.* (2014) unweighted SPLpeak impact criteria for explosions. The assessment is highly precautionary and estimated that mortality and potential mortal injury to all fish species may range between < 50 to 810 m from the source, depending upon the charge weight of the UXO encountered. This assessment did not assume any embedded mitigations.

It is worth noting that the desk-based UXO risk assessment undertaken by Ordtek (2021) has indicated that it will be possible to avoid any UXO encountered during the UXO survey and, should further mitigation be required (i.e., clearance or detonation), this would be subject to separate assessment and applications. However, to provide a comprehensive assessment of potential worst case impacts associated with the Offshore Development activities, an initial assessment of noise-related impacts from UXO clearance has been undertaken for the Construction Phase of the Offshore Development.

Due to the challenging ground conditions of the Pentland Firth, both drilled and impact piles are included as an anchor option within the project Design Envelope (see Chapter 5: Project Description, for further information). An assessment of drilled and impact piles is presented below.

10.6.1.1.1 **Impact piling**

Impact piling is commonly used for the construction of fixed (i.e. not floating) wind farm foundations and involves multiple strikes from a pile hammer over an extended period of time. The impulsive sounds generated are characterised by a relatively rapid rise time to a maximal pressure value, followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures (Popper *et al.,* 2014). The peak sound levels resulting from impact piling activity vary substantially and depend on factors such as pile type, pile diameter, material, hammer size, water depth and seabed substrata.

The most relevant criteria for considering potential impacts on fish and shellfish from impact piling activities are considered to be those provided in the Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al.,* 2014). The guidelines set out criteria for injury and other impacts for impact piling. The criteria for the different types of sources include a range of indices; SEL, rms and peak sound pressure levels. Where insufficient data exist to determine a quantitative guideline value, the risk is categorised in relative terms as "high", "moderate" or "low" at three distances from the source: "near" (i.e. in the tens of metres), "intermediate" (i.e. in the hundreds of metres) or "far" (i.e. in the thousands of metres). It should be noted that these qualitative criteria cannot differentiate between exposures to different levels of sound and therefore all sources of sound, independent of source level, would theoretically elicit the same assessment result.

In relation to the potential for physical injury or behavioural effects, fish species are grouped into categories defined by a number of factors such as their hearing anatomy, particle motion detection, the use of sound during navigation or mating and the presence or absence of a swim bladder. Fish without swim bladders can only detect sound through particle displacement and therefore are only likely to be affected by extreme sound pressures. Fish with swim bladders have more sensitive hearing, as the gas within the swim bladder changes as a result of changing sound pressure. If the swim bladder is near the ear or connected to the hearing system, this further increases hearing sensitivity (Popper *et al.,* 2014).

Subacoustech undertook noise modelling to determine the extent of underwater noise propagation from impact piling operations. This model was used to determine the impact radius ranges of noise for key fish and shellfish species (Offshore EIAR [Volume 3]: Technical Appendix 10.1 Underwater Noise Modelling Report).

Both fleeing animal and stationary animal models have been used to assess the SELcum criteria for fish. SELcum is a metric of the cumulative sound energy an animal is exposed to over a standard time period (Popper *et al.,* 2014). For the underwater noise modelling presented in Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling Report, SELcum is calculated over a 24-hour period. There is limited evidence for fish fleeing from high level noise sources in the wild. The majority of species are likely to move away from sounds that is loud enough to potentially cause harm (Dahl *et al.,* 2015; Popper *et al.,* 2014). Those that may not move aware from loud sounds are likely to be benthic dependant species or species without swim bladders, which are less sensitive to sound compared to those with swim bladders (Goertner *et al.*, 1994; Stephenson *et al.*, 2010; Halvorsen *et al*., 2012; Popper *et al.,* 2014).

The worst case scenario piles were modelled in the noise assessment (Offshore EIAR [Volume 3]: Technical Appendix 10.1 Underwater Noise Modelling Report). A maximum of 9 piles per WTG (63 in total for the Offshore Development). Impact pilling was considered as the worst case scenario and will last for a maximum duration of 63 days. This will not be continuous. From this, the following scenario was derived:

> 5 m diameter tubular pile, 20 m length. Installed using a hammer with maximum blow energy of 2,500 kJ 14,912 blows over a total period of 8 hours with three piles installed in a 24-hour period (resulting in 44,736 blows over 24 hours).

The worst case is precautionary (i.e. due to hammer capacity, pile fatigue, the likelihood of three piles all being installed within 24 hours with the worst case parameters, or other on-site practicalities) (see Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling Report for further detail). However, this is considered to represent a 'cautious worst case' scenario for the impact assessment.

Popper *et al.*, 2014 criteria for the potential impact on fish from impact piling activities and the modelling results from the worst case scenario are summarised in Table 10.14.

Table 10.14 Popper *et al.* (2014) thresholds and results (Offshore EIAR (Volume 3): Technical Appendix 10.1 Underwater Noise Modelling Report)

Type of Animal	Parameter	Mortality and potential mortal injury		Impairment				Masking	Behaviour
				Recoverable Injury		TTS			
		Threshold	Mean range	Threshold	Mean range	Threshold	Mean range		
Fish: no swim bladder (particle motion detection) e.g. dab and other flatfish	SELcum dB re 1 µPa 2 ·s	>219	Fleeing <100 m Stationary 1.8 km	>216	Fleeing <100 m Stationary 2.8 km	>>186	Fleeing 19 km Stationary 34 km	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	SPLpeak dB re 1 µPa	>213	100 m	>213	100 m	-	-		
Fish: swim bladder is not involved in hearing (particle motion detection) e.g. Atlantic salmon	SELcum dB re 1 µPa 2 ·s	210	Fleeing <100 m Stationary 6.6 km	203	Fleeing <100 m Stationary 14 km	>186	Fleeing 19 km Stationary 34 km	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
	SPLpeak dB re 1 µPa	>207	250 m	>207	250 m	-	-		
Fish: swim bladder involved in hearing (primarily pressure detection) e.g. Atlantic cod,	SELcum dB re 1 µPa 2 ·s	207	Fleeing <100 m Stationary 9.5 km	203	Fleeing <100 m Stationary 14 km	186	Fleeing 19 km Stationary 34 km	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
	SPLpeak dB re 1 µPa	>207	250 m	>207	250 m	-	-		

Type of Animal	Parameter	Mortality and potential mortal injury		Impairment				Masking	Behaviour
				Recoverable Injury		TTS			
		Threshold	Mean range	Threshold	Mean range	Threshold	Mean range		
herring and relatives.									
Eggs and larvae	SELcum dB re 1 μPa 2 ·s	>210	Fleeing <100 m Stationary 6.6 km	(N) Moderate (I) Low (F) Low					
	SPLpeak dB re 1 μPa	>207	250 m						

Adult fish which are not in the immediate vicinity of the sound generating activity are generally able to vacate the area and avoid the likelihood of physical injury. However, eggs and larvae are less mobile, smaller in size and generally more vulnerable than adult fish, and are therefore more likely to incur injuries from the sound energy, including damage to their hearing, kidneys, hearts and swim bladders (Popper *et al.*, 2014).

In terms of disturbance from underwater noise which can result in a behavioural response, the impacts from the impact piling operations are presented in qualitative terms rather than quantitatively. Based on these qualitative criteria, there is a high-level of risk of disturbance up to tens of metres from the moving device, moderate at distances of hundreds of metres (except for fish with swim bladders were the risk remains high) and low beyond this (i.e. 'far'). For eggs and larvae, the risk is moderate close to the centre of the activity (tens of metres) and low beyond this point.

Fish species can be split into four groups when it comes to sound sensitivity (Hawkins and Popper, 2017):

- Group 1: Flatfish, shark skates and rays lack swim bladders that are sensitive to particle motion and therefore only show sensitivity to a narrow band of frequencies;
- Group 2: Salmonids and some tuna are fish with swim bladders; however, swim bladders do not appear to play a role in hearing. Therefore, they are only sensitive to particle motion and only show sensitivity to a narrow band of frequencies;
- Group 3: Eels and codfish are fish with swim bladders that are connected to the ear but not intimately connected. These species are sensitive to both particle motion and sound pressure extending up to around 500 Hertz (Hz); and
- Group 4: Herring species have structures mechanically linking the swim bladder to their ear. Therefore, they are sensitive primarily to sound pressure, but they can also detect particle motion. Their frequency range is much wider, extending to several kHz and they generally show higher sensitivity to sound pressure than the other groups.

10.6.1.1.1.1 Mortality, potential mortal injury and recoverable injury

For the purpose of this assessment, there are three classes of potential injury to individual fish: mortality, potential mortal injury and recoverable injury. Mortal injuries are severe injuries resulting from a noise source that result in death to an individual. The threshold for mortality and for potential mortal injury will differ between species. A recoverable injury is a survivable injury where the fish or shellfish receptor will fully recover after the exposure to noise has ended. However, the effect may result in a temporary decrease in fitness and increase the individual's susceptibility to predation.

Sandeels (Group 1)

Sandeels are demersal spawners and are known to burrow into the sediment. Therefore, they are considered to be stationary receptors. They are, however, a Group 1 species and are the least sensitive to sound pressure. Due to this, sandeels have been assessed separately to other fish and shellfish species.

The noise modelling results suggest mortality and potential mortal injury for spawning sandeels (>219 SELcum dB re 1 μPa 2 ·s) may occur up to 1.8 km away. For recoverable injury, the results suggest injury may occur up 2.8 km (Table 10.14).

The assumptions for the noise modelling are considered to represent a 'cautious worst case' scenario, however, is it considered to be extremely conservative for the reason detailed in Section 10.6.1.1.1.1.

Sandeels were identified in one of the grab samples within the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1). Ellis *et al.,* (2012) data also suggests the Offshore Site overlaps with low intensity sandeel spawning and low density nursery grounds. However, sandeel preferred habitats and spawning grounds are widely distributed across Scottish and English waters.

Sandeels are a protected species and are therefore considered to be **high** value receptors. Sandeels are considered to have **low** sensitivity to underwater noise generated from construction activities at the Offshore Site, as according to Popper *et al*., (2014) criteria, the hearing sensitivity of Group 1 fish is low. There is a limited impact radius range when considering the worst case scenario and the Offshore Site is not located in key sandeel spawning or nursery grounds. Based on localised spatial and temporal change and low frequency of construction/installation events, the impact is defined as being of **low** magnitude. In addition, based on the short-term duration of a maximum of 63 days of not continuous pilling noise (i.e. there would be periods of quiet between piling events), any impacts are unlikely to affect long term functioning of the sandeel populations. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**

Herring (Group 4)

Herring are also demersal spawners and are the most sensitive species to underwater noise. For these reasons Herring are also assessed separately to other fish and shellfish.

Herring are considered as stationary receptors regarding larvae and mobile receptors regarding adults. Herring were not identified in the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1) and the IHLS estimates of herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2015). Ellis *et al.,* (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds but overlaps with low intensity nursery ground. Due to this, herring have been assessed as a mobile (fleeing) receptor as larvae and eggs are not expected to be in the vicinity of the Offshore Site in high numbers.

The noise modelling results suggest mortality and potential mortal injury for herring (>207 SPLpeak dB re 1 μPa) may occur up to 250 m away. For recoverable injury, the results suggest injury may occur 250 m away from the source (Table 10.14).

Herring are highly protected and are therefore considered to be **high** value receptors. Herring are highly sensitive to underwater noise, however, considering herring are mobile species that are likely to flee the area, and the as the Offshore Site is not located within a key spawning or nursery ground for this species, herring have been assessed to have **moderate** sensitivity to underwater noise generated from construction activities at the Offshore Site. Based on the highly localised spatial and temporal change and low frequency of construction/installation events being intermittent and short term (63 days, not continuous), impacts are unlikely to affect long term functioning of the herring populations, as the Offshore Site does not overlap with areas of high intensity spawning or nursery grounds. Therefore, for herring the impact is defined as being of **low** magnitude and the overall effect to herring receptors is considered to be **minor** and **not significant.**

As it is anticipated that the overall effect of underwater noise generated from construction activities on herring will be a **minor** and **not significant**, it is not expected that this impact will propagate up the food chain to predator species such as sea trout, marine mammal and bird species. Therefore, there will not be a significant impact upon predator species.

All other fish species

The remaining fish receptors (excluding herring and sandeel) are listed in Table 10.15, which also denotes the group that these receptors belong according to the criteria set by Popper *et al.,* (2014). The majority of other fish receptors identified as relevant to the Offshore Development are Group 1 receptors, that have a lower sensitivity to underwater noise. The exception to this is salmonids, including Atlantic salmon and sea trout (group 2), gadoids (e.g. cod) and European eel (Group 3) and sprat (Group 4). These species are all considered to be mobile and can therefore flee an area to avoid underwater noise impacts. Eggs and larvae are also potentially vulnerable to underwater noise and vibration due to their smaller size and limited mobility (Popper *et al.,* 2014).

Table 10.15 Fish receptors relevant to the Offshore Development

Group	Fish receptors relevant to the Offshore Development
Group 1	Flatfish, such as plaice, sole and lemon sole, elasmobranchs, such as common skate, thornback ray, spurdog and tope shark, and mackerel and horse mackerel.
Group 2	Salmonids such as Atlantic salmon and sea trout.
Group 3	Gadoids such as cod, ling, saithe, whiting, blue whiting, haddock and hake, and European eel.
Group 4	Sprat.

Group	Fish receptors relevant to the Offshore Development
Eggs and larvae	All fish species potentially spawning in the area (see Section 10.4.4.3).

The impact radius ranges for mortality or potential mortality is 100 m from the noise source for Group 1 fish, to 250 m for Group 3 and 4 fish, and eggs and larvae (SPL_{peak}). This radius range increases to 1.8 km for Group 1 fish, 6.6 km for Group 2 fish and eggs and larvae and 9.5 km for Group 3 and 4 fish, based on SEL_{cum} and when a stationary animal is assumed.

For recoverable injury, the range increases further to 2.8 km for Group 1 fish and 14 km for Group 2, Group 3 and 4 fish (SEL_{cum}; Table 10.14). A threshold for recoverable injury is not available for eggs and larvae. However, Popper *et al*., (2014) assesses the relative risk for eggs and larvae as moderate at distances near to the source (tens of metres), and low at distances intermediate (hundreds of metres) or far (thousands of metres) from the source.

When a fleeing animal is assumed, the range for mortality, potential mortality injury or recoverable injury decreases to < 100 m for all groups of fish based on SEL_{cum}. A fish's behavioural reaction to noise will be to move away from the noise source, and therefore, the fish is not likely to be exposed to higher levels of noise for a notable period of time (Maes *et al.* 2004). As a result of the behavioural reaction to high-levels of noise, sensitivity is considered to be **low** for all species.

Many of the fish species predicted to utilise the Offshore Site are highly protected and therefore considered to be **high** value receptors. However, the Offshore Site is not located with any peak or high concentration spawning grounds for any species. It does overlap with high intensity nursery grounds for monkfish, blue whiting and spurdog. Blue whiting are gadoids and are therefore classed a Group 3 species and are potentially sensitive to noise. The Offshore Site also overlaps with low density spawning and/or nursery grounds for several gadoid species (haddock, cod, sprat, whiting, ling and saithe) (Group 3) and sprat (Group 4) but is not considered to be a key spawning and / or nursery ground for these species. Nonetheless, for the reasons identified above, including fish being able to move out of the injury impact zone, all other fish species are considered have **low** sensitivity to underwater noise generated from construction activities at the Offshore Site. Based on localised spatial and temporal change and low frequency of construction/installation events, and on the basis that all of the species considered here are pelagic spawners, the impact is defined as being of **low** magnitude. The assessment has been based on a cautious worst case, and therefore, the injury ranges are expected to be less than predicted in reality. In addition, the effect will be short term (63 days, not continuous) therefore migratory routes for species such as Atlantic salmon and sea trout are not anticipated to be affected.

Since effects are unlikely to affect the long term functioning of the fish species populations, the overall effect to fish receptors is considered to be **minor** and **not significant.**

Shellfish

Unlike fish, there are no set impact criteria for the assessment of potential underwater noise impacts on shellfish. However, as shellfish do not possess a swim bladder, it is assumed that they are only able to detect particle motion, similar to Group 1 fish species assessed in the section above. Shellfish are, however, not as mobile as fish, and are therefore, less able to avoid underwater noise impacts.

Crustaceans have been recorded as being able to detect particle motion, such as hermit crab (*Pagurus bernhardus*) and American lobster (*Homarus americanus*) (Roberts *et al.,* 2016; Miller *et al*., 2016). Therefore, it is assumed that the shellfish present in the Study Area, including crabs, European lobster, European Spiny lobster and scallops could potentially detect particle motion.

Shellfish are considered to be of **low** sensitivity to underwater noise, on the basis that shellfish do not possess a swim bladder, and therefore, have reduced hearing sensitivity. Shellfish are judged to be of **moderate** value, as they are not protected but are of commercial importance in the Study Area. The impact from construction noise will be localised and temporary, lasting 63 days, not continuous. Considering this, as well as the widespread presence of the shellfish species present in the Study Area throughout UK waters, the impact is defined as being of **low** magnitude. Therefore, the overall effect is **minor** and **not significant.**

10.6.1.1.1.2 TTS, masking and behavioural disturbance

TTS is a temporary reduction in hearing sensitivity that is caused when a receptor is exposed to intense sound. Normally hearing ability returns shortly after the emitted noise ends. Whilst the receptor is experiencing TTS there may be a temporary decrease in fitness and ability to detect prey.

Fish and shellfish species will have varying reactions and sensitivities to piling noise. This is dependent on how these species perceive sound in the environment. There is potential for these responses to lead to significant effects at an individual level (e.g. reduced fitness, susceptibility to predation) or potentially at a population level (e.g. avoidance or delayed migration to key spawning grounds), depending on the duration and strength of the impact.

As the spatial extent of the Offshore Development is small, and there is a large surrounding area of similar habitat, it is reasonable to assume that if vocalisations were masked, fish would move out of the zone of effect to an area that is less affected.

Sandeels (Group 1)

As detailed above, sandeels are considered a stationary species for this assessment. The potential for TTS of stationary sandeels (>>186 SELcum dB re 1 μPa 2 ·s) may occur up to 34 km from the noise source.

The assumptions for the noise modelling are considered to represent a 'cautious worst case' scenario, however, is it considered to be extremely conservative for the reason detailed in Section 10.6.1.1.1.1. The potential for behavioural effects on this species from noise are lower due to their lack of swim bladder.

The Offshore Site overlaps with low intensity spawning grounds and low density nursery grounds for sandeels, however, these grounds extend over a large area. Pilling activity taking place will be in a small proportion of this wider available habitat. Therefore, according to the qualitive data provide by Popper *et al.,* (2014), auditory masking in sandeel from piling activity are expected to be Low, except near to the source (i.e. tens of metres) from the piling locations and behavioural effects are Low to Moderate, except near to the source, resulting in a localised effect.

Sandeels are highly protected and therefore considered to be **high** value receptors. In addition, the Offshore Site is not located in key sandeel spawning or nursery grounds. Considering this and the fact that sandeel have a low hearing sensitivity, according to Popper *et al.,* (2014) sandeels are assessed as having a **low** sensitivity to underwater noise generated from construction activities at the Offshore Site. Based on the local to medium spatial extent of the impact range, temporal change and low frequency of construction/installation events, the impact is defined as being of **moderate** magnitude. In addition, based on the short-term duration (63 days, not continuous) of impact piling activity, any effects are unlikely to affect long term functioning of the sandeel populations.

Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**

Herring (Group 4)

As detailed above, herring are considered to be mobile species as herring larvae and eggs are not expected to be in the vicinity of the Offshore Site in high numbers. The potential for TTS of herring (186 SELcum dB re 1 μPa 2 s) may occur up to 19 km from the noise source.

The assumptions for the noise modelling are considered to represent a 'cautious worst case' scenario, however, is it considered to be extremely conservative for the reason detailed in Section 10.6.1.1.1.1. Herring are more sensitive to sound pressure as they have swim bladders and are therefore at a greater risk of potential behavioural effects and masking over larger distances. The Offshore Site is not located within key herring spawning or nursery grounds. As such, it is more likely if herring are present within the vicinity of the Offshore Site, they are likely to be adult herring that will flee from the noise, reducing the likelihood of behavioural effects or masking. Therefore, according to the qualitive data provide by Popper *et al*., (2014) criteria, behavioural effects or auditory masking in herring from impact piling, are expected to be Moderate in the far field, and High within the intermediate field.

Herring are highly protected and therefore considered to be **high** value receptors. The Offshore Site is not located in key herring spawning or nursery grounds and the impact will be short term (63 days, not continuous). Therefore, although behavioural effects or auditory masking in herring from piling are expected to be Moderate in the far field, and High within the intermediate field, herring are considered to have low vulnerability to piling noise. Herring are highly sensitive to underwater noise, however, herring are a mobile species that are likely to flee the area, and therefore herring have been assessed to have **moderate** sensitivity to underwater noise generated from impact piling activities at the Offshore Site. Based on the localised spatial and temporal change, low frequency of construction/installation events, and as the Offshore Site and 19 km impact radius does not overlap with key herring spawning ground, the impact is defined as being of **low** magnitude. The Offshore Site does not overlap with areas of high intensity spawning or nursery grounds for herring and therefore, any effects are unlikely to affect long term functioning of the herring populations.

Therefore, the overall effect to herring receptors is considered to be **minor** and **not significant.**

As it is predicted that there will be a **minor** and **not significant** impact on herring from underwater noise generated from construction activities, it is not expected that this impact will propagate up the food chain to predator species such as sea trout, marine mammals and birds species. Therefore, there will not be a significant impact upon predator species.

All other fish species

For all other fish species, these are considered to be mobile receptors as discussed previously in Table 10.15 and Section 10.6.1.1.1.1. The potential of TTS for all fish species (186 SELcum dB re 1 μPa^{2}s) may occur up to 19 km from the noise source for Group 1 – 4 species, when fleeing animals are assumed. For stationary species, the potential for TTS may occur up to 34 km. For eggs and larvae, Popper *et al*., (2014) assesses the relative risk to individuals as moderate at distances near to the source (tens of metres), and low at distances intermediate (hundreds of metres) or far (thousands of metres) from the source.

The assumptions for the noise modelling are considered to represent a 'cautious worst case' scenario, however, is it considered to be extremely conservative for the reason detailed in Section 10.6.1.1.1.1. Regarding masking and behavioural effects, as all other fish species are considered to be mobile receptors, they would be expected to flee the area in which the impact could occur with the onset of pilling activity. Considering the Popper *et al.,* (2014) criteria, behavioural effects or auditory masking in fish and shellfish species from impact piling are expected to be moderate in the far field (i.e. thousands of metres), and high within the intermediate field (i.e. hundreds of metres) for Group 3 and 4 species. For Group 1 and 2 species, the behavioural effects range from high at distances near to the source, moderate at distances intermediate to the source and low at distances far from the source. Masking effects range from moderate near the source to low at intermediate and far distances from the source for Group 1 and 2 species (Popper *et al.,* 2014).

Many of the fish predicted to utilise the Offshore Site are highly protected and therefore considered to be **high** value receptors. Fish and shellfish species have **low** sensitivity to underwater noise generated from construction activities at the Offshore Site, as described in Section 10.6.1.1.1.1. Based on localised spatial and temporal change (63 days, not continuous) and low frequency of construction/installation events, and all other fish species considered here are pelagic spawners, the impact is defined as being of **low** magnitude.

Since any effects are unlikely to affect long term functioning of the fish species populations the overall effect to fish receptors is considered to be **minor** and **not significant.**

Shellfish

As described in Section 10.6.1.1.1.1, there are no noise thresholds to undertake a quantitative assessment of the potential effects of underwater noise on shellfish. However, as described previously, shellfish do not have swim bladders and are therefore only able to detect particle motion.

Shellfish are considered to be of **low** sensitivity to underwater noise, on the basis that shellfish do not possess a swim bladder, and therefore, have a reduced hearing sensitivity. Shellfish are judged to be of **moderate** value, as they are not protected but are of commercial importance in the Study Area. The impact from construction noise will be localised and temporary, lasting 63 days, not continuous. Considering this, as well as the widespread presence of the shellfish species present in the Study Area throughout UK waters, the impact is defined as being of **low** magnitude. Therefore, the overall effect is **minor** and **not significant.**

10.6.1.1.2 **Drilled piles and construction vessel noise**

In the case of drilled piles, noise will be transmitted into the water from rotating equipment such as generators, pumps and the drill string. This noise will be at the interface between the bedrock and drill bit directly, via ground borne noise and also directly from the drill bit into the water. As there is no impulsive sound (e.g. impact piling) associated with the drilled piles, noise emitted will be continuous resulting in considerably lower noise emissions than impact piling operations, owing to the pile being installed through rotary penetration and so giving rise to only low levels of noise and vibrations.

The most common and best-studied continuous sounds in the oceans are those produced by ships as well as smaller vessels. However, continuous sounds are also produced by other sources, such as vibratory pile drivers and vessels dredging for aggregates (Robinson *et al.*, 2011). Popper *et al*. (2014) states that there is no direct evidence of mortality or potential mortal injury to fish from ship noise. However, continuous noise of any level that is detectable by fish can mask signal detection, and thus may have a pervasive effect on fish behaviour. Nonetheless, the consequences of this masking and any attendant behavioural changes for the survival of fish are unknown. Popper *et al.,* (2014) concludes that lack of quantification of exposure sound levels that elicit responses to ships makes it impossible to provide numerical guidelines for behavioural responses of fish to sounds from ships.

In order to determine the likely impacts on fish associated with the proposed drilled pile installation methods, a review of a number of studies has been undertaken to determine noise levels associated specifically with offshore drilling operations. These published studies identify the measurements of sound levels for drilling activity which vary between 100 to 195 dB re 1 µPa (rms) at ranges of between 1 m and 405 m from the drilling operation. In general, from the studies, sound from drilling has been found to be predominantly low frequency (<1 kHz) with relatively low source levels. Overall, all drilling studies reviewed concluded that drilling activities are considered unlikely to produce noise levels that could result in Permanent Threshold Shift (PTS) or TTS to sensitive fish receptors (i.e., those which use swim bladders for hearing, and any behavioural effects would only occur within tens of metres of the source (Xodus, 2015; Green, 1987; Nedwell and Howell, 2004; Bach *et al*, 2013; Nedwell and Brooker, 2008).

The underwater noise levels associated with typical drilling operations from the studies reviewed are provided in Table 10.16.

Table 10.16 Underwater noise levels assessed for typical drilling operations

Study	Drilling Source	Noise measurement	Frequency (khz)
Nedwell and Howell (2004)	Drill Ship- drilling	195 dB (rms) re 1 µPa @ 1 m	0.001-139
Green (1987)	Drill Ship - logging	125 dB (rms) re 1 µPa @ 170 m	0.02-1
	Drill Ship – drilling	134 dB (rms) re 1 µPa @ 200 m	0.02-1
Bach *et al*, (2013)	Fixed Platform - drilling	148 dB (rms) re 1 µPa @ 1 m	n/a
Hannay *et al,* (2004)	Fixed Platform- drilling/ production/ water injection	162 dB (rms) re 1 µPa @ 1 m	0.01-10
Nedwell and Brooker (2008)	Jack-up Platform – pile drilling tidal device	139 dB re 1 µPa (rms) at 28 m	7 - 80
Broudic *et al*, (2014)	Jack-up Platform – drilling of foundation	100 dB re 1 µPa (rms)	n/a

Study	Drilling Source	Noise measurement	Frequency (khz)
Xodus (2015)	Large Diameter Drill Rig - Installation of Oyster 800 Array wave energy devices	153.8 ± 12.1 dB re 1 Pa at 1m	n/a
McCauley (1998)	Semi-submersible – drilling	115 dB (rms) re 1 μPa @ 405 m	0.01-10
	Semi-submersible – active no drilling	117 dB (rms) re 1 μPa @ 125 m	0.01-10

Additionally, it is important to note, based on Automatic Identification System (AIS) data within the Pentland Firth and the Offshore Site, that there are multiple commercial shipping routes that traverse the Offshore Site and the surrounding area (Chapter 14 Shipping and Navigation). As such, the baseline noise within the region from vessel activity is likely to be high and subsequently any additional continuous noise emitted from drilling is likely to be largely indistinguishable from background vessel noise.

For the reasons outlined above, the impact on fish ecology from drilled piles is defined as being of **negligible** magnitude**.** Therefore, drilled piles will not be considered further within this impact assessment for underwater noise.

10.6.1.1.3 UXO Clearance

UXO clearance has been identified as a possible noise source with the potential to impact Fish and Shellfish Ecology through the generation of underwater noise. The detonation of UXOs would be a short term (seconds) increase in underwater noise (i.e. sound pressure levels and particle motion). Underwater noise levels will be temporarily elevated, and this may result in injury or behavioural effects on fish and shellfish species.

An initial desk-based UXO assessment undertaken by Ordtek (2021) has indicated a low likelihood of UXO being encountered in the Offshore Site and it is anticipated that it will be possible to avoid any UXO encountered during the survey. Should further mitigation be required, such as clearance or detonation, this would be subject to separate assessment and Marine Licence applications. Nonetheless, for the purpose of providing a comprehensive assessment of potential worst case impacts associated with Offshore Development activities, an initial assessment of noise-related impacts from UXO clearance has been undertaken at this stage. If UXO clearance is identified as being required in order to proceed with the Offshore Development, it will be located within either the PFOWF Array Area or the OECC.

In order to assess the potential impacts of UXO clearance, two scenarios of potential UXO clearance have been modelled within the Subacoustech Environmental Report (Offshore EIAR [Volume 3]: Technical Appendix 10.1), in line with Popper *et al.* (2014) criteria for explosions. The two scenarios are detailed below:

1) The worst case high-order detonation of a large 525 kg UXO plus donor charge, whereby the detonation of the donor charge causes a complete detonation of all explosive material in the 525 kg UXO; and

2) The low-order detonation of any size of UXO using a small specialist donor charge (up to 500 g) to vaporise the explosive material in the UXO in the absence of an explosion (deflagration) and therefore noise levels are proportional to the donor charge only.

It is expected that if any UXO clearance is required, that it would be undertaken using low-order clearance, however, the potential impact radii associated with a high-order detonation have been taken forward into the following assessment to provide a cautious worst case. The impact radii modelled for the high-order detonation scenario within the Subacoustech Environmental Report (Offshore EIAR [Volume 3]: Technical Appendix 10.1) are shown in Table 10.17.

For all groups of fish species within Popper *et al.* (2014) criteria for explosions mortality and potential mortal injury is expected to occur between 229 – 234 dB. This is due to methodologies and data on fish species in relation to explosions being highly varied, and as such, the guidelines provided by Popper *et al.* (2014) for explosions use the lowest amplitude in the literature available that have caused consistent mortality. Due to this, for all groups there is the potential that UXO clearance could result in mortality and potential mortal injury impacts at a radius of between 490 to 810 m from the source. Therefore, as a cautious worst case for this impact assessment, although highly conservative, the 810 m radius has been assumed for all fish species.

No particle motion modelling for mortality and potential mortal injury has been modelled for eggs and larvae at this stage. Popper *et al.* (2014) states that risk of mortality and potential mortality could occur at a peak particle motion velocity greater than 13 mm/s $^{-1}$ in a spawning bed during the period of egg incubation.

Table 10.17 Summary of the impact ranges for UXO detonation using the unweighted SPLpeak explosion noise criteria from Popper *et al.* (2014) for species of fish

Popper *et al.* (2014) Unweighted SPLpeak	525 kg + donor
234 dB (Mortality and potential mortal injury)	490 m
229 dB (Mortality and potential mortal injury)	810 m

Full details of the underwater noise modelling and ranges for both scenarios are provided in the Underwater Noise Modelling Subacoustech Environmental Report (Offshore EIAR [Volume 3]: Technical Appendix 10.1).

All fish species

As discussed above, for all fish species (Groups 1 to 4), the maximum mortality and potential mortality impact radius for UXO clearance (based on a 525 kg UXO plus donor charge) is 810 m from the source. This impact will be an isolated explosion, instantaneous and occur over a matter of seconds. No particle motion modelling has been undertaken at this stage, but it is conservatively assumed that the impact radius for mortality and potential mortal injury for eggs and larvae would be similar to those presented for all other fish species.

For recoverable injury and TTS, only qualitative risk levels are available from Popper *et al.* (2014) due to lack of data available on these effects from explosions. For fish Groups 2-4 (e.g. those with a swim bladder), the risk of recoverable injury and TTS impacts are expected to be High in the near field (tens of metres) and intermediate field (hundreds of metres) and Low in the far field (thousands of metres). For Group 1 fish species (i.e. those with no swim bladder), the recoverable injury impacts are expected to be High in the near field and Low in the intermediate and far field. TTS impacts for Group 1 species are expected to be High in the near field, Moderate in the intermediate field and Low in the far field. For eggs and larvae a qualitative risk-based approach is also presented in Popper *et al.* (2014). The risk of impacts for recoverable injury for eggs and larvae are High in the near field and Low in the intermediate and far field. It is acknowledged that UXO clearance may lead to disturbance, but it will be an isolated explosion (i.e. not continuous) and impacts are anticipated to be very short lived (e.g. a matter of seconds).

For all fish species considered, sensitivity to mortal injury and potential injury impacts from UXO clearance is based on the value of the receptor, rather than sensitivity to noise as used for other noise related construction activities assessed. In terms of the fish species identified as potentially present within the Offshore Site, many of the fish species identified are **high** value receptors (e.g. Atlantic salmon, sandeels, herring etc., as detailed in Section 10.4.4.4) based on their conservation status and presence of spawning or nursery grounds. As such, conservatively, a **high** value receptor and therefore **high** sensitivity is assumed for all fish species.

The underwater noise impact ranges for mortality and potential mortality for explosion are the same across all the fish Groups assessed with a maximum impact radius of 810 m. For TTS and recoverable injury, all impacts will be localised within the near and intermediate fields. The impact will be a single explosion, highly localised and extremely short lived (a matter of seconds) and will not affect long term functioning of fish populations. As such, the magnitude of impact from UXO clearance (if required) for all fish species, including eggs and larvae, are assessed at this stage as being of **negligible** magnitude. All fish species are conservatively assessed as having **high** sensitivity to UXO clearance, based on value, and therefore, the overall effects from UXO clearance are assessed as being **minor** and **not significant**.

Shellfish

Unlike fish, there are no set impact criteria for the assessment of potential underwater noise impacts on shellfish, including explosions. As such, no modelling has been undertaken for shellfish to inform impact ranges for mortality or potential mortal injury. However, crustaceans have been recorded as being able to detect particle motion, such as hermit crab and American lobster (Roberts *et al.,* 2016; Miller *et al*., 2016). Therefore, it is assumed that the shellfish present in the Study Area, including crabs, European lobster, European Spiny lobster and scallops could potentially detect particle motion, similar to Group 1 fish species assessed in the section above.

As above, in terms of sensitivity to mortality and potential mortal injury impacts, from UXO clearance, this is based on the value of the receptor rather than sensitivity to noise as used for other noise related construction activities assessed. In terms of the shellfish species identified as potentially present within the Offshore Site, many of the species identified are **moderate** value receptors based on their commercial importance (as shown in Table 10.5). As such, conservatively, a **moderate** value receptor and therefore **moderate** sensitivity is assumed for all shellfish species.

Based on modelling undertaken for all fish species (including Group 1 fish species), the impact from UXO clearance (if required) will be localised, temporary (lasting seconds) and not continuous. Considering this, as well as the widespread presence of the commercially important shellfish species present in the Study Area and throughout UK waters, the impact is defined as being of **negligible** magnitude. All shellfish species are conservatively assessed as having **moderate** sensitivity to UXO clearance, based on value, and therefore, the overall effects from UXO clearance are assessed as being **minor** and **not significant**.

As detailed above, it is worth noting that the desk-based UXO risk assessment undertaken by Ordtek (2021) has indicated that it will be possible to avoid any UXO encountered during the UXO survey and, should further mitigation be required (i.e., clearance or detonation), this would be subject to separate assessment once further details of any UXO were established and separate licence applications. However, this assessment for fish and shellfish has been provided to give an indicative assessment of potential worst case impacts associated with project construction activities.

10.6.1.2 Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and mooring lines on seabed

Disturbance of the seabed could result in loss of deposited eggs or larvae and spawning habitat. This disturbance will occur from the placement of anchors, scour protection, installation of the Offshore Export Cable(s) and inter-array cables.

The installation of the inter-array cables, anchors, mooring lines and scour protection on the seabed within the PFOWF Array Area will result in some habitat loss of spawning and nursery grounds. As per Table 10.12, the combined permanent footprint of the infrastructure associated with the PFOWF Array Area is 219,590 m^2 and the temporary disturbance, resulting from trenching and seabed levelling activities is 356,700 m^2.

As per Table 10.12, the permanent footprint of the Offshore Export Cable(s) and associated infrastructure within the OECC is 87,500 m^2 with a temporary footprint of 375,000 m^2. Additionally, a maximum of two HDD exit points will be located in the subtidal zone, within the OECC, with a maximum borehole diameter of 750 mm. The cable duct will be pushed through the hole from the landward side and then capped and temporarily protected using a highly localised spread of remedial placement until cable installation commences. Temporary habitat loss resulting from these activities has been considered within the Offshore Export Cable(s) footprint. The HDD will extend from above MHWS, below the intertidal, and breaches the seabed in the subtidal. As such, no impacts to intertidal fish and shellfish receptors are expected.

The seabed conditions in the Offshore Site has a relatively smooth profile with no large bedforms (e.g. sandwaves) and occasional sand ripples. Wave exposed sediments are present at near-shore open ground as described in Chapter 7: Marine Physical Processes. The presence of sand ripples across the Offshore Site suggests existing seasonal sediment movements, likely to be associated with an interaction of wave action and tidal currents. Sediments are predominantly sandy gravel but with varying proportions of fine sand, gravel, pebbles and cobbles patchily distributed; there is only a very small proportion of mud (see Chapter 9: Benthic Ecology).

The Offshore Site may provide spawning areas for herring, sprat, sandeel and lemon sole (Table 10.4), and may provide nursery grounds for herring, mackerel, sandeel, haddock, cod, lemon sole, blue whiting, saithe, hake, ling, common skate, Spurdog, thornback ray, spotted ray, tope shark, and whiting. Specifically, herring are seabed dependent during spawning and egg maturation, and are an important commercially exploited species.

The effect on spawning grounds is considered to be greater than nursery grounds, as larvae and eggs are only mobile via currents, whereas juvenile fish are able to flee from disturbance. There is a particular focus on herring and sandeels as they are demersal spawners and for these reasons these species are considered separately below.

Herring

Herring are demersal spawners and it has been reported that herring eggs are sensitive to substratum loss (Faber *et al.,* 2007). Herring were not identified in the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1) and the IHLS estimates herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2015). Ellis *et al*., (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds and overlaps with only low intensity nursery ground. Due to this, herring larvae and eggs are not expected to be in the vicinity of the Offshore Site in high numbers.

Herring are highly protected and therefore considered to be **high** value receptors. Herring have **moderate** sensitivity to substratum loss, although the Offshore Site is not located in key herring spawning or nursery grounds. Based on potential localised spatial and temporal change and low frequency of construction/installation events, the impact is defined as being of **low** magnitude.

Any impacts are unlikely to affect the long term functioning of the herring populations, as the Offshore Site does not overlap with areas of high intensity spawning or nursery grounds for herring. Therefore, the overall effect to herring receptors is considered to be **minor** and **not significant.**

Sandeels

Sandeels are also demersal spawners and are known to burrow into the sediment. Sandeels were identified in one of the grab samples within the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1). Ellis *et al.,* (2012) data also suggests the Offshore Site overlaps with low intensity sandeel spawning and low intensity nursery grounds. However, sandeel preferred habitats and spawning grounds are widely distributed across Scottish and English waters and therefore potential impacts from construction activities associated with the Offshore Development will affect only a small proportion of available habitat. It is likely that sandeel and their eggs are vulnerable to the impact of substratum loss (Faber *et al*., 2007). However, sandeel spawn in winter and therefore sandeel spawning is unlikely to be affected by construction activities (Table 10.4).

Sandeels are a protected species and are therefore considered to be **high** value receptors. Sandeels have **moderate** sensitivity to substratum loss as a result of construction activities at the Offshore Site, although the Offshore Site is not located in a key sandeel spawning or nursery ground. Based on the localised spatial and temporal change and low frequency of construction/installation events (not occurring within the spawning season) the impact is defined as being of **low** magnitude. In addition, based on the short term duration of installation activities, impacts are unlikely to affect long term functioning of the sandeel populations.

Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**

All other fish species

All other fish species, with the exception of sandeel and herring, are pelagic spawners, with a wider availability of spawning grounds that are not dependent on the seabed. These species are less vulnerable to habitat loss or disturbance to spawning grounds.

The indicative installation period is within Spring/ Summer of Stage 1 or Stage 2 (April – September), and the HDD installation works may occur in the year before this. There is the potential for construction works to overlap with lemon sole spawning which occurs between April and September and sprat spawning which occurs between May and August. However, as these species are not demersal spawners construction and installation activities are unlikely to affect the spawning of these species.

Many other fish predicted to utilise the Study Area (as shown in Table 10.4) are highly protected and therefore considered to be **high** value receptors. Any impacts are unlikely to affect long term functioning of the fish and shellfish populations (including sprat and lemon sole), as these species spawn into the pelagic environment and will be able to avoid temporary habitat loss or disturbance impacts. Therefore, fish species, with the exception of sandeel and herring, are considered to have a **low** sensitivity to direct habitat loss due to disturbance of spawning and nursery grounds during construction activities at the Offshore Site. Any effects on feeding habitat and prey items are expected to affect only a small proportion of the available habitat in the area (as described in Chapter 9: Benthic Ecology), and therefore, are not anticipated to have a widespread impact on feeding opportunities. Based on the localised spatial and temporal change and low frequency of construction/installation events, the impact is defined as being of **low** magnitude.

Therefore, the overall effect to other fish receptors is considered to be **minor** and **not significant.**

It is anticipated that there will be a **minor** and **not significant** impact on fish ecology from direct habitat loss due to disturbance of spawning and nursery grounds during the installation of Offshore Export Cable(s) and placement of anchors on seabed, it is not expected that this impact will propagate up the food chain to predator species such as sea trout, marine mammals and bird species. Therefore, there will not be a significant impact to predator species.

Shellfish

There are no defined boundaries for shellfish in the data from Coull *et al*., (1998) and Ellis *et al*., (2012), with the exception of *Nephrops norvegicus* (which do not overlap with the Offshore Site). However, shellfish are potentially vulnerable to habitat loss and disturbance during the construction of the Offshore Development, as these species have a more limited mobility when compared with fish.

During the breeding season, 'berried' female crabs and lobsters carry their eggs under their abdomen, are often found buried under sediment and are considered to have limited mobility during this time (Neal & Wilson, 2008). Scallops and periwinkle are also of limited mobility to avoid habitat loss or disturbance. These species are judged to be of a **moderate** value, as they are not protected but are of commercial importance in the region, and of **moderate** sensitivity, due to their immobility during the breeding season. Any habitat loss or disturbance during the construction phase will be short-term and localised in nature, representing a small proportion of the available habitat in the area. It would also be expected that individuals could recolonise the area as the seabed recovers. As such, the impact is defined as being of **low** magnitude. Therefore, the overall effect is **minor** and **not significant**.

10.6.1.3 Effects of increased sedimentation / smothering on fish and shellfish during construction activities

The installation of subsea infrastructure such as the Offshore Export Cable(s), inter-array cables, anchors, mooring lines and scour protection, is likely to result in a temporary increase in suspended sediments resulting in the potential smothering of species located within the installation zones. The composition of the seabed is mainly gravels and sands, along with an occasional small percentage of silts. The average ratio of gravel:sand:silt is 13:84:3. The maximum amount of silts in any sample is 5%.

As described above, the installation of the inter-array cables, anchors, mooring lines and scour protection on the seabed within the PFOWF Array Area will result in a temporary disturbance during installation that may result in an increase in sedimentation and potential smothering of fish and shellfish species. As per Table 10.12, the combined permanent footprint of the infrastructure associated with the PFOWF Array Area is

219,590 m^2 and the temporary disturbance, resulting from trenching and seabed levelling activities is 356,700 m^2. As described in Chapter 7: Marine Physical Processes, the worst case increase to suspended sediment concentrations results from seabed levelling of the gravity anchors. Suspended sediments will increase to above representative background concentrations immediate vicinity of the works but these quickly reduce within 500 m of release. Silt sediments may remain suspended for around 1 to 9 hours and may be transported via near-bed flows (at a distance within 3 m of the seabed) (a process called advection) and resettle on the seabed. This has been modelled to occur over a maximum lateral extent of 3.7 km to the east and around 2.6 km to the south-west (Chapter 7: Marine Physical Processes).

As per Table 10.12, the Offshore Export Cable(s) and associated infrastructure within the OECC will have a temporary footprint of 375,000 m^2. Additionally, a maximum of two HDD exit points will be located in the subtidal zone, within the OECC, each with a borehole diameter of 750 mm. The cable duct will be pushed through the hole from the landward side (or pulled through from the offshore side) and then capped and temporarily protected using a highly localised spread of remedial placement until cable installation commences. Temporary habitat loss resulting from these activities has been considered within the Offshore Export Cable(s) footprint. The HDD will extend from above MHWS, below the intertidal, and breaches the seabed in the subtidal. As such, no impacts upon intertidal receptors are expected.

As has been stated previously, the Offshore Site lies within a spawning area for herring, sprat, sandeel and lemon sole. It is a nursery site for nineteen species. As has been described in Section 10.4.4, these species' spawning and nursery areas extend widely beyond the Offshore Site, covering large portions of Scottish and English waters and therefore any disturbance from construction activities associated with the Offshore Development will affect only a small proportion of available habitat (Coull *et al*., 1998, Ellis *et al.,* 2012).

The indicative installation period is within the spring/summer months of Stage 1 or Stage 2 (April – September) and HDD may occur in the year before this. Therefore, there is the potential for construction works to overlap with lemon sole spawning which occurs between April and September and sprat spawning which occurs between May and August. Sandeel spawn in winter therefore sandeel spawning is unlikely to be affected by construction activities (Table 10.4).

The effect on spawning grounds is considered to be greater than nursery grounds as larvae and eggs are only mobile via currents, whereas juvenile fish are able to flee away from disturbance. There is a particular focus on herring and sandeels as they are demersal spawners and for these reasons these species are considered separately below.

Herring

Herring are demersal spawners and it has been reported that herring eggs are sensitive to suspended sediment and smothering with effects likely to be detrimental if the material is not moved by current (Faber *et al.,* 2007). Herring were not identified in the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1) and the IHLS estimates herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2015). Ellis *et al*., (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds and overlaps with low intensity nursery ground. Due to this, herring larvae and eggs are not expected to be in the vicinity of the Offshore Site in high numbers. As adult herring are mobile, they may show avoidance behaviour to the impact.

Herring are highly protected and are therefore considered to be **high** value receptors. Herring have **moderate** sensitivity to increases in suspended sediments and smothering. Based on the localised spatial and temporal change and the low frequency of construction/installation events, which will only affect a small proportion of the population, the impact is defined as being of **low** magnitude. Any impacts are unlikely to affect long term functioning of the herring populations as the Offshore Site does not overlap with area of high intensity spawning or nursery grounds for herring. Therefore, the overall effect upon herring receptors is considered to be **minor** and **not significant.**

Sandeels

Sandeels are also demersal spawners and are known to burrow into the sediment. Sandeels were identified in one of the grab samples within the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1). Ellis *et al.,* (2012) data also suggests the Offshore Site overlaps with low intensity spawning and low density nursery grounds. However, sandeel preferred habitats and spawning grounds are widely distributed across

Scottish and English waters and therefore potential impacts from construction activities associated with the Offshore Development will affect only a small proportion of available habitat. It is likely that sandeel and their eggs are vulnerable to the impact of smothering (Faber *et al*., 2007), however, sandeel spawn in winter and therefore sandeel spawning is unlikely to be affected by construction activities associated with the Offshore Development (Table 10.4).

Sandeels are a protected species and are therefore considered to be **high** value receptors. Sandeels have **moderate** sensitivity to increases in suspended sediments and smothering as a result of construction activities at the Offshore Site, however, sandeel and sandeel eggs tend to live within high energy environments where sediment resuspension and deposition are frequent. Based on the localised spatial and temporal change and the low frequency of construction/installation events, the impact is defined as being of **low** magnitude. In addition, based on the short term duration of the installation activities, impacts are unlikely to affect long term functioning of the sandeel populations. Therefore, the overall effect upon sandeel receptors is considered to be **minor** and **not significant.**

All other fish species

All other fish species, with the exception of herring and sandeel, are less vulnerable to increases in suspended sediments. Adult fish are mobile and able to avoid areas with high sediment loads (Robertson *et al.,* 2006). These species are also pelagic spawners with buoyant eggs and are therefore less vulnerable to smothering. In extreme cases, pelagic eggs may sink if sediment adheres to the surface, resulting in reduced oxygen diffusion rates, and larvae be impacted by increased suspended sediment concentrations which could damage gill tissue (Robertson *et al.,* 2006; Wenger *et al.,* 2017). However, this would only effect eggs or larvae in close proximity to the construction works. Sediments are also expected to be rapidly dispersed by the strong tidal currents present in the Pentland Firth and fish are expected to tolerant to temporary increases in suspended sediment concentrations as a result of the strong currents in the region.

Many of the fish predicted to utilise the Study Area (as outlined in Table 10.4) are highly protected and are therefore considered to be **high** value receptors. As fish species other than sandeel and herring are able to avoid areas of high sediment load with eggs that are not highly vulnerable to increased suspended sediment concentrations, they are considered to have a **low** sensitivity to increased sedimentation and smothering at the Offshore Development. Based on the localised spatial and temporal change and low frequency of increased sedimentation, the impact is defined as being of **low** magnitude. Therefore, the overall impact upon fish receptors is considered to be **minor** and **not significant.**

Shellfish

Generally, mobile crustaceans can move away from areas of increased suspended sediment concentrations (although to a lesser extent in comparison to most fish) and mortality as a result of increased suspended sediment concentrations is considered unlikely (Neal & Wilson, 2008). However, less mobile shellfish species, such as berried crabs and lobsters, scallops and periwinkles are more vulnerable to increases in suspended sediment concentrations.

Berried crabs and lobsters have a lower mobility, as described in Section 10.6.1.1.3, and therefore, less able to migrate away from areas of increased suspended sediment concentrations. They are potentially vulnerable to sediment deposition as their eggs need regular aeration (Neal and Wilson, 2008).

Increased suspended sediment concentrations may also adversely impair the feeding capabilities of scallops, although individuals are capable of moving away from areas with higher sediment loads. Smothering impacts may be avoided by scallops as individuals can lift themselves clear of the newly deposited sediment layer (Marshall & Wilson, 2008). Periwinkles are potentially vulnerable to smothering but can move back up through sediment if smothered in a thin layer of sediment that is well oxygenated and fluid (Jackson, 2008).

Shellfish are judged to be of a **moderate** value, as they are not protected but are of commercial importance in the Study Area. They have been assessed as being of **moderate** sensitivity to increased sedimentation / smothering, due to their relative immobility, either throughout the life cycle or during the breeding season. Any increases in suspended sediment concentrations and associated smothering during the construction phase will be short-term and localised in nature, representing a small proportion of the available habitat in the area. As such, the impact is defined as being of **low** magnitude. Therefore, the overall effect is **minor** and **not significant**.

10.6.1.4 Temporary burial of seabed from drilled cuttings

As described in Chapter 7: Marine Physical Processes, the drilling activities for the anchor piles may result in drill cuttings piles within the PFOWF Array Area, each with a volume of 350 m^2. The worst case scenario in terms of seabed footprint, assumes the cuttings piles are formed of coarse sediments and are 1 m high, each covering 1,424 m^2 (89,712 m^2 in total). Conversely, if the drill cuttings piles are formed of silt sediments, then this material will be dispersed and expected to settle in approximately 3 hours.

Sedentary organisms and demersal spawners (i.e. herring and sandeel) are most likely to be affected by any potential habitat loss or smothering resulting from the drill cuttings piles at the PFOWF Array Area. More mobile species may be able to avoid unfavourable conditions, and to work their way back through the cuttings to the surface.

Herring

As outlined in Section 10.6.1.1.3 and 10.6.1.3, herring are demersal spawners, and therefore, their spawning grounds and eggs and larvae are vulnerable to any habitat loss or smothering impacts potentially resulting from the drills cuttings piles. However, the PFOWF Array Area is not expected to be an important herring spawning ground, and therefore, herring larvae and eggs are not expected to be in the PFOWF Array Area in high numbers.

Herring are highly protected and therefore considered to be **high** value receptors. As herring are demersal spawners that require specific habitats for spawning, they are considered to have a **moderate** sensitivity to any habitat loss or smothering resulting from the drill cuttings piles. Based on potential localised change which is highly unlikely to affect a large proportion of the available spawning grounds for this species, considering the fact that the PFOWF Area is not a key spawning ground for this species, the impact is defined as being of **low** magnitude. Therefore, the overall effect to upon sandeel receptors is considered to be **minor** and **not significant.**

Sandeels

As outlined in Section 10.6.1.1.3 and 10.6.1.3, due to the fact that sandeel are seabed dependent as demersal spawners that live in burrows for the majority of their life cycle, they are potentially vulnerable to any habitat loss and smothering that could result from the presence of the cuttings piles. However, the area covered by the drill cuttings piles represents a small proportion of the available spawning and nursery grounds for this species, that are widely distributed across Scottish and English waters. There are also expected to be fewer sandeel burrows within the PFOWF Array Area, where the drill cuttings piles will be located, when compared to the OECC (Langton *et al.,* (2021).

Sandeels are a protected species and are therefore considered to be **high** value receptors. Sandeels have **moderate** sensitivity to any habitat loss or smothering as a result of construction activities at the Offshore Development, however, sandeel and sandeel eggs tend to live within high energy environments where sediment resuspension and deposition are frequent. Based on the localised extent on the impact, which will affect a small proportion of the available spawning and nursery grounds for this species, the impact is defined as being of **low** magnitude. Therefore, the overall effect to upon sandeel receptors is considered to be **minor** and **not significant.**

All other fish species

All other fish species other than herring and sandeel are less vulnerable to habitat loss and smothering caused by the drill cuttings piles, as these species are pelagic spawners without any specific seabed habitat requirements for spawning.

Many other fish predicted to utilise the Study Area are highly protected and therefore considered to be **high** value receptors. As other fish species, with the exception of sandeel and herring, are pelagic spawners, they are considered to have a **low** sensitivity to any potential direct habitat loss or smothering due caused by the drills cuttings piles. Based on the localised change that is not expected to affect a large proportion of any fish species population, the impact is defined as being of **low** magnitude. Therefore, the overall effect to other fish receptors is considered to be **minor** and **not significant.**

Shellfish

As discussed in Section 10.6.1.1.3 and 10.6.1.3, shellfish with reduced mobility (e.g. berried crab and lobster, scallops and periwinkle) are vulnerable to any potential habitat loss or smothering caused by the drill cuttings piles.

Shellfish are judged to be of a **moderate** value, as they are not protected but are of commercial importance in the region, and of **moderate** sensitivity, due to their reduced mobility. Any habitat loss or smothering from the drill cuttings piles will be localised in nature, representing a small proportion of the available habitat in the area. It would also be expected that individuals could recolonise the area as the seabed recovers. As such, the impact is defined as being of **low** magnitude. Therefore, the overall effect is **minor** and **not significant**.

10.6.1.5 Potential accidental release of pollutants

Vessels involved with the installation and construction activities will discharge liquid effluents into the sea during operations (i.e. bilge water). Procedures will be in place to ensure all discharges are compliant with appropriate anti-pollution regulations (e.g. MARPOL). All routine discharges will be rapidly dispersed by water currents and will have no significant reduction in the sediment or water quality in the Offshore Site and surroundings.

Leakage of pollutants from vessels or equipment could occur during the construction phase, or at any stage of the Offshore Development's operational life. This could be damaging to fish and shellfish ecology or habitats on which they rely. An accidental event such as a vessel collision has the potential to result in the release or spillage of fuel or other contaminants from vessels. The initial result of such a spill or leakage would likely include physical disturbance at the discharge location. As the area is a high energy environment (see Chapter 7: Marine Physical Processes), it is likely that there would be a reasonably high dispersal rate of any material.

Plankton in the immediate area of the release can be affected with greater effects occurring during a period of plankton bloom and during fish spawning periods. Contamination of marine prey including plankton and small fish species may then lead to aromatic hydrocarbons accumulating in the food chain. These could have long-term chronic effects such as breeding failure and reduced fecundity in fish, bird and cetacean populations. In extreme cases, this may affect fish stocks of commercially fished species. Juvenile fish and eggs are potentially the most sensitive life-stage to accidental release or spillage of fuel. As outlined above, a number of commercially important pelagic and demersal fish species are found within the Offshore Site.

The Offshore Development construction works are planned across a two year construction phase with two seven month construction phases during the spring and summer months. The maximum number of Offshore Development vessels expected onsite simultaneously during the construction phase is ten. As set out in Chapter 14: Shipping and Navigation, vessel displacement may also lead to increased vessel densities in certain areas, as vessels displaced from the PFOWF Array Area use the remaining available sea room. However, there is ample sea room available north of the PFOWF Array Area and therefore, collision risk is not expected to significantly increase during the construction phase of the Offshore Development.

The majority of the fish and shellfish predicted to utilise the Offshore Site are highly protected and therefore considered to be **high** value receptors. Fish and shellfish species have **moderate** sensitivity to localised accidental pollution events, since any impacts are unlikely to affect long term functioning of the fish and shellfish populations. Based on the unlikely event that a pollution event will take place combined with the area being a high energy environment, any spills or leakages are likely to disperse rapidly, and the impact will be highly localised. In addition, embedded mitigation implemented during construction (e.g. implementation of a pollution prevention plan agreed with the Regulator), will avoid the risk of accidental releases of pollution and as a result fish and shellfish are extremely unlikely to be adversely affected by such an incident. Therefore, the impact is defined as being of **negligible** magnitude, and the overall effect to fish and shellfish receptors is considered to be **minor** and **not significant.**

10.6.1.6 Summary of effects during construction

A summary of the assessment of effects during construction is provided in Table 10.18.

Table 10.18 Summary of significance of effects from construction impacts

Summary of Effect	Receptor	Sensitivity	Magnitude of impact	Rationale	Consequence	Significance of Effect	Additional Mitigation Requirements	Significance of Residual Effect
Disturbance or damage to sensitive species, due to underwater noise generated from construction activities	Herring	Moderate	Low	**Mortality, potential mortal injury and recoverable injury (Impact Piling)** Herring have a **moderate** sensitivity to underwater noise generated from construction activities at the Offshore Development and a **high** value receptor. The impact is of **low** magnitude. The overall effect to herring receptors is considered to be **minor** and **not significant.**	Minor effect	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant
		Moderate	Low	**TTS, masking and behavioural disturbance (Impact Piling)** Herring have a **moderate** sensitivity to underwater noise generated from construction activities at the Offshore Site and are a **high** value receptor. The impact is defined as being of **low** magnitude. The overall effect to herring receptors is considered to be **minor** and **not significant.**	Minor effect	Not Significant		Not Significant
	Sandeels	Low	Low	**Mortality, potential mortal injury and recoverable injury (Impact Piling)** Sandeels have **low** sensitivity to underwater noise generated from construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **low** magnitude. The overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor effect	Not Significant		Not Significant
		Low	Moderate	**TTS, masking and behavioural disturbance (Impact Piling)** Sandeels have **low** sensitivity to underwater noise generated from construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **moderate** magnitude. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor effect	Not Significant		Not Significant
	All other fish species	Low	Moderate	**Mortality, potential mortal injury and recoverable injury (Impact Piling)** Fish and shellfish species have **low** sensitivity to underwater noise generated from construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **moderate** magnitude. The overall effect to fish and shellfish receptors is considered to be **minor** and **not significant.**	Minor effect	Not Significant		Not Significant
		Low	Moderate	**TTS, masking and behavioural disturbance (Impact Piling)** Fish species, other than sandeel and herring have **low** sensitivity to underwater noise generated from construction activities at the Offshore Development. The impact is defined as being of **moderate** magnitude. The majority of the fish predicted to utilise the Offshore Site are highly protected and therefore considered to be **high** value receptors. The overall effect to fish receptors is considered to be **minor and not significant.**	Minor effect	Not Significant		Not Significant
		High	Negligible	**Mortality, potential mortal injury and recoverable injury (UXO Clearance)** Fish species are conservatively assessed as **high** value receptors and have **high** sensitivity to UXO clearance. Impact radius ranges are localised, not continuous and extremely short lived (seconds). As such there is a **negligible** magnitude of impact and the overall effect is considered to be **minor** and **not significant**.	Minor effects	Not Significant		Not Significant
	Shellfish	Low	Moderate	**Mortality, potential mortal injury and recoverable injury (Impact Piling)** Shellfish species have **low** sensitivity to underwater noise generated from construction activities at the Offshore Development and are a moderate value receptor. The impact is defined as being of **moderate** magnitude. The overall effect to shellfish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant

Summary of Effect	Receptor	Sensitivity	Magnitude of impact	Rationale	Consequence	Significance of Effect	Additional Mitigation Requirements	Significance of Residual Effect
		Low	Moderate	**TTS, masking and behavioral disturbance** Shellfish species have **low** sensitivity to underwater noise generated from construction activities at the Offshore Development and are a **moderate** value receptor. The impact is defined as being of **moderate** magnitude. The overall effect to shellfish receptors is considered to be **minor** and **not significant.**	Minor Effects	Not Significant		Not Significant
		Moderate	Negligible	**Mortality, potential mortal injury and recoverable injury (UXO Clearance)** Shellfish species are conservatively assessed as **moderate** value receptors and have **moderate** sensitivity to UXO clearance. Impact radius ranges are localised, not continuous and extremely short lived (seconds). As such there is a **negligible** magnitude of impact and the overall effect is considered to be **minor** and **not significant**.	Minor Effects	Not Significant		Not Significant
Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of Offshore Export Cable(s) and placement of anchors on seabed	Herring	Moderate	Low	Herring have **moderate** sensitivity to substratum loss as a result of the construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to herring receptors is considered to be **minor** and **not significant.**	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant
	Sandeels	Moderate	Low	Sandeels have **moderate** sensitivity to substratum loss as a result of construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	All other fish species	Low	Low	Fish species have **low** sensitivity to substratum as a result of construction activities at the Offshore Development and are a high value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to fish and shellfish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	Shellfish	Moderate	Low	Shellfish species have **moderate** sensitivity to substratum as a result of construction activities at the Offshore Development and are a **moderate** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to shellfish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
Effects of increased sedimentation / smothering on fish and shellfish during construction activities	Herring	Moderate	Low	Herring have **moderate** sensitivity to increases in suspended sediments and smothering as a result of construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to herring receptors is considered to be **minor** and **not significant.**	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant
	Sandeels	Moderate	low	Sandeels have **moderate** sensitivity to increases in suspended sediments and smothering as a result of construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	All other fish species	Low	Low	Fish species have **low** sensitivity to increased sedimentation and smothering as a result of the construction activities at the Offshore Development and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to fish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	Shellfish	Moderate	Low	Shellfish species have **moderate** sensitivity to increased sedimentation and smothering as a result of the construction activities at the Offshore Development and are a moderate value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to shellfish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant

Summary of Effect	Receptor	Sensitivity	Magnitude of impact	Rationale	Consequence	Significance of Effect	Additional Mitigation Requirements	Significance of Residual Effect
Temporary burial of sediment from drill cuttings piles	Herring	Moderate	Low	Herring have **moderate** sensitivity to habitat loss or smothering as a result of drill cuttings piles at the PFOWF Array Area and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant
	Sandeels	Moderate	Low	Sandeels have **moderate** sensitivity to habitat loss or smothering as a result of drills cuttings piles at the PFOWF Array Area and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	All other fish species	Low	Low	Fish species have **low** sensitivity to habitat loss and smothering as a result of drills cuttings piles within the PFOWF Array Area and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to fish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	Shellfish	Moderate	Low	Shellfish species have **moderate** sensitivity to habitat loss and smothering as a result of drills cuttings piles within the PFOWF Array Area and are a **moderate** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to shellfish receptors is considered to be **minor** and **not significant**	Minor	Not Significant		Not Significant
Potential accidental release of pollutants	All fish and shellfish species	Moderate	Negligible	Fish and shellfish species have **moderate** sensitivity to accidental pollution events and are a **high** value receptor. The impact is defined as being of **low** magnitude**.** Therefore, the overall effect to fish and shellfish receptors is considered to be **minor** and **not significant.**	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant

10.6.2 Effects during Operation and Maintenance

10.6.2.1 Habitat loss of spawning and nursery grounds, due to presence of anchors, cables and mooring lines on the seabed

There is potential for spawning and nursery grounds to be affected as a result of changes to the seabed in the area of anchors, inter-array cables and Offshore Export Cable(s). The presence of anchors, scour protection, cables and associated remedial protection will remove some of the available habitat that is currently used as spawning and nursery grounds by numerous species (Table 10.4).

For the PFOWF Array Area the total maximum seabed footprint consists of gravity anchors, scour protection inter-array cables and remedial protection. As per Table 10.12, the total permanent footprint is 219,590 m^2. Inter-array cables within the PFOWF Array Area will be buried to a minimum depth of 0.6 m where possible. If burial is not achieved, remedial protection will be required. This will prevent lateral movement and thus remove the potential for scour during operation.

In addition, within the PFOWF Array Area there will be a maximum lateral movement of 0.035 km^2 per mooring line resulting in an overall temporary disturbance area of 2,205,000 m^2. This movement is considered to be highly conservative as there will be a maximum of 40 clump weights per mooring line which will reduce the movement of the mooring lines and thus reduce the potential for scour.

As per Table 10.12, the total permanent remedial protection within the OECC for the Offshore Export Cable(s) is 87,500 m^2.

As stated above, the Offshore Site is sited within known spawning grounds for herring, sprat, lemon sole and sandeel. The Offshore Site is also within a known nursery area for nineteen species (Table 10.4). Out of these species, only herring and sandeels are demersal spawners and for this reason these species are considered separately below

As these spawning and nursery grounds extend widely beyond the Offshore Site, the proportion of spawning and nursery ground that may be affected by the Offshore Development is very small in relation to the available spawning and nursery grounds.

Herring

Herring were not identified in the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1) and the IHLS estimates herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2015). Ellis *et al.,* (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds and overlaps with low intensity nursery ground. Due to this, herring larvae and eggs are not expected to be in the vicinity of the Offshore Site in high numbers.

Herring are highly protected and are therefore considered to be **high** value receptors. Herring have **moderate** sensitivity to substratum loss, as the Offshore Site is not located in a key herring spawning and nursery grounds, whilst recognising the highly selective nature of this species spawning grounds. Based on localised spatial and temporal change and low frequency of construction/installation events, the impact is defined as being of **low** magnitude. Any impacts are unlikely to affect long term functioning of the herring populations as the Offshore Site does not overlap with areas of high intensity spawning or nursery grounds for herring. Therefore, the overall effect to herring receptors is considered to be **minor** and **not significant.**

Sandeel

Sandeels are also demersal spawners and are known to burrow into the sediment. Sandeels were identified in one of the grab samples within the MMT 2021 surveys (Offshore EIAR [Volume 3]: Technical Appendix 9.1). Ellis *et al.,* (2012) data also suggests the Offshore Site overlaps with low intensity sandeel spawning and low density nursery grounds. However, sandeel preferred habitats and spawning grounds are widely distributed across Scottish and English waters and therefore any disturbance from construction activities associated with the Offshore Development will affect only a small proportion of available habitat. It is likely that sandeel and their eggs are vulnerable to the impact of substratum loss (Faber *et al*., 2007).

Sandeels are a protected species and are therefore considered to be **high** value receptors. Sandeels have **moderate** sensitivity to substratum loss at the Offshore Site, as this species has a limited availability of suitable habitat due to its habitat requirements. Based on localised spatial and temporal change, the impact is defined as being of **low** magnitude. In addition, impacts are unlikely to affect the long term functioning of the sandeel populations. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**

All other fish species

Many other fish species predicted to utilise the Study Area are highly protected and are therefore considered to be **high** value receptors. However, fish, other than herring and sandeel, are considered to have **low** sensitivity to habitat loss of spawning and nursery grounds, due to the presence of anchors, inter-array cables, Offshore Export Cable(s) and remedial protection on the seabed at the Offshore Site, as these species are pelagic spawners. Based on localised spatial change, which will occur over a small proportion of the spawning and nursery grounds available, the impact is defined as being of **low** magnitude. Therefore, the overall effect to fish and shellfish receptors is considered to be **negligible** and **not significant**.

As it is anticipated that there will be a **minor** and **not significant** impact on Fish and Shellfish Ecology from habitat loss of spawning and nursery grounds due to the presence of anchors, cables and remedial protection on the seabed during the operational phase, it is not expected that this impact will propagate up the food chain. This is due to there not being a significant increase in habitat complexity or change to trophic levels. Therefore, there will not be a significant impact to predator species.

Shellfish

Some shellfish receptors are potentially vulnerable to long-term habitat loss and disturbance, including berried crab and lobster, scallops and periwinkle. The Offshore Development may result in a reduced habitat availability for these species that utilise burrowed habitats.

Shellfish are judged to be of a **moderate** value, as they are not protected but are of commercial importance in the region, and of **moderate** sensitivity, due to their use of burrowed habitats which could be altered by the presence of infrastructure for the Offshore Development. However, any habitat loss during the operation and maintenance phase will be short-term and localised, representing a small proportion of the available habitat in the area. It would also be expected that shellfish could recolonise adjacent areas. Therefore, the impact is defined as being of **low** magnitude. Therefore, the overall effect is **minor** and **not significant**.

10.6.2.2 Effects of EMFs from export and inter-array cables on sensitive species

EMFs have the potential to alter the behaviour of marine organisms that are able to detect electric (E field) or magnetic (B field) components of the fields. Both B field and E fields dissipate rapidly from the source.

A number of fish and shellfish species are able to detect EMFs and use them for various different reasons, and particular focus has been placed on assessing the response of crustaceans, elasmobranchs and salmonids to EMF (Hutchison *et al.,* 2020; Copping *et al.,* 2020; Copping *et al*., 2021). The Offshore Export Cable(s) carrying electricity away from the WTGs will emit low frequency EMFs. The introduction of anthropogenic EMF into the marine environment has the potential to alter the behaviour of some fish and shellfish species and the migratory behaviours of salmonids (e.g. Atlantic salmon and sea trout) and eels, potentially resulting in increased energy expenditure.

Generally, electrosensitive species are mainly responsive to both Direct Currents (DC) and Alternating Currents (AC), low intensity electric fields between 0.02 microvolts (μV) cm^{-1} and 100 μV cm^{-1} and frequencies of 0–15 Hertz (Hz) (Tricas and Sisneros, 2004; Stoddard, 2010; Hutchison *et al.,* 2020).

Up to two 110 kV Offshore Export Cable(s) (HVAC) will be installed as part of the Offshore Development, each with a maximum length of 12.5 km. Although a maximum voltage of 110 kV is proposed, the worst case in terms of EMF is the lower 66 kV option (as set out in Chapter 5: Project Description, Section 5.3.3). A maximum of 500 m of the Offshore Export Cable(s) will be dynamic at the point of connection to the first WTG and buried for the remainder of its length. Where seabed conditions allow, the Offshore Export Cable(s) will be buried to a depth of a minimum of 0.6 m, with the aim of burying up to 100% of the cable to this minimum target depth. Remedial protection will be used where burial is not achieved to a height of 1 m, and it is expected that remedial protection will account for up to 50% of the cable length as a worst case scenario.

Up to seven 110 kV inter-array cables will be installed as part of the Offshore Development. Although a maximum voltage of 110 kV is proposed the worst case in terms of EMF is the lower 66 kV option (as set out in Offshore EIAR (Volume 3): Chapter 5: Project Description, Section 5.3.3). The inter-array cables will be dynamic. These sections will be suspended in the water column, therefore they will only be buried from the point of touch down on the seabed. A maximum of 5 km of inter-array dynamic cable will be present in the water column across the PFOWF Array Area, and a maximum of 20 km will be situated on the seabed and either buried, wherever possible, to a minimum depth of 0.6 m or covered by remedial rock placement to a height of 1 m.

Although the burial of cables and other protective measures such as rock protection are not considered to be effective ways to mitigate the extent of magnetic fields in the marine environment, it does separate the most sensitive species from the source of the emissions, therefore reducing the maximum field strength likely to be encountered (e.g. at the seabed) (Copping *et al*., 2020). In addition, design parameters and installation methods are expected to conform to industry standard specifications which includes shielding technology to reduce the direct emission of EMFs.

HWL has commissioned an initial modelling exercise of the predicted EMF from both the inter-array and Offshore Export Cable(s) to determine the realistic worst case EMF potential based on the worst case EMF potential, i.e. the 66 kV option. The modelling demonstrates that EMF effects will be below the natural variation of the earth's magnetic field for both seabed laid and in-water dynamic cables. Should two Offshore Export Cable(s) be installed, the anticipated separation distance between cables (20 m) means there will be no potential interaction between EMF effects (Prysmian, 2022).

10.6.2.2.1 *Buried / protected cable sections*

It recognised that the burial of cables and other protective measures, such as placement of remedial protection, are not considered to be effective ways to mitigate magnetic emissions into the marine environment entirely. However, burial separates the most sensitive species from the source of the emissions (Copping *et al*., 2020). In addition, design parameters and installation methods are expected to conform to industry standard specifications which includes shielding technology to reduce the direct emission of EMFs.

The results of the Prysmian (2022) study are shown in Table 10.19 for the various protection heights or burial depths assessed. From the modelling undertaken, an EMF strength of approximately 17.7 μT would be produced by the buried Offshore Export Cable(s) at the seabed, assuming 0.6 m burial is achieved (Prysmian, 2022). This rapidly dissipates when assuming 1 m burial or protection and no EMFs are experienced at a distance of 5 m from the source.

The earth's magnetic field intensity is known to vary between 25 -to 65 μT (National Oceanic and Atmospheric Administration (NOAA), 2021a). For context, a reference magnitude of the earth's magnetic field at a particular location can be estimated from models publicly available (NOAA, 2021b), and for the Offshore Site, from sea level to maximum water depth, the geomagnetic total field is estimated as 50.7±0.14μT. As such, the magnetic field produced by 66 kV cables would be less than the value associated with the earth's magnetic field at the Offshore Site. As such fish and shellfish receptors are unlikely to detect any notable change from EMFs produced by 66 kV cable(s), particularly if burial of 0.6 m achieved, or remedial cable protection measures are applied for the inter-array cables and the Offshore Export Cable(s).

Table 10.19 EMF levels at various distance from buried Offshore Export Cable(s)

Component	5 m	1 m	Seabed (cable buried by a minimum of 0.6 m)
Offshore Export Cable(s)	≈ 0 μT	0.73 μT	17.1 μT

10.6.2.2.2 *Dynamic inter-array and Offshore Export Cable(s) sections*

Up to 5 km of the 110 kV dynamic inter-array cables will be present within the water column and up to 500 m of the Offshore Export Cable(s) will be dynamic at the point of connection to the first WTG. Migratory fish are more likely to encounter EMFs produced by these cables, as there will not be buried / have a physical barrier between the fish and the EMF source.

As detailed above, modelling has been conducted on the worst case of a 66 kV inter-array cable given the increased EMF potential, as set out in Chapter 5: Project Description. The results of the Prysmian (2022) study are shown in Table 10.20 for the various distances from the source assessed. From the modelling undertaken, an EMF strength of approximately 3.21 μT would be produced by the dynamic portions of the cables at 1 m from the source (Prysmian, 2022). This rapidly attenuates, as shown by no EMFs experienced at 5 m from the source.

Table 10.20 EMF levels at various distances from the dynamic cables in the water column

Component	10 m	5 m	1 m
Inter-array / Offshore Export Cable(s)	≈0 μT	≈0 μT	3.21 μT

10.6.2.2.3 *Elasmobranchs and diadromous species*

There are a number of studies which consider the impacts of EMF from cables on sensitive fish species, with several noting behavioural responses to EMF (Hutchison *et al,* 2020; Hutchison *et al*, 2018, Anderson *et al*, 2017, Woodruff *et al,* 2012). However, studies which exhibit a response in fish have largely been in conditions which are not directly comparable to the use of the proposed 66 kV cable, such as where cables used are High Voltage Direct Current (HVDC) cables at significantly higher voltage than that proposed for the Offshore Development. Additionally, these studies are predominantly undertaken in laboratory conditions and largely use magnetic fields which are greater than earth's magnetic field (25 - 65 μT (NOAA, 2021a), in order to test behavioural response.

10.6.2.2.3.1 Elasmobranchs

Elasmobranchs are recorded in the Pentland Firth and have been found to detect magnetic fields directly, rather than via induction of E-fields (Anderson *et al.* 2017) and are more responsive to magnetic fields in comparison to other species (Hutchison *et al*., 2020; Porsmoguer *et al*., 2015). Some species of skate and ray are species of conservation concern, with the common skate being listed as Critically Endangered on the IUCN Red List. Skates and rays are likely to be found on sandy substrates in and around the Offshore Site.

Research on elasmobranch response to EMFs in the environment has considered that when an individual approaches an EMF, it experiences an E- field, which stimulates its electroreceptive sensory apparatus. Other recent studies suggest that elasmobranchs can detect magnetic fields directly rather than via induction of E-fields (Anderson *et al.* 2017).

A number of elasmobranch species have been identified in the area that are IUCN Red List species, including common skate, thornback ray, and tope sharks. Therefore, the receptors are considered to be **high** value. Elasmobranch species are sensitive to increases in EMF, as such have been given a **moderate** sensitivity rating**.** EMF will be emitted throughout the life-cycle of the Offshore Development, however, based on the localised spatial change as discussed, the EMF emitted by the cables is considered to be low, therefore, the impact is defined as being of **low** magnitude**.**

EMF emissions from both the Offshore Export Cable(s) and the inter-array cables will be reduced through cable burial and/or cable protection measures, delivered through management plans, including the Cable Plan, as shown through the Prysmian (2022) study. Cables will also be insulated, sheathed and armoured to reduce EMF emissions in the water column, where the inter-array cables are more exposed. Considering this, the overall effect to elasmobranch species receptors is considered to be **minor** and **not significant.**

10.6.2.2.3.2 Diadromous species

Unlike elasmobranch species, diadromous species do not possess specialist magnetic receptor cells. Instead within their skeletal structure they contain magnetically sensitive material and use EMFs as a navigational tool for migration. Therefore, if a diadromous species migratory route crosses the Offshore Development cable routes, there is a potential for cable EMFs to affect the behaviour of the individuals, especially in shallow waters of 20 m or less (Gill, *et al*. 2012). Such an effect could result in avoidance behaviour, delaying the migration of salmonids and eels. However, studies have shown widely variable results, and therefore the extent of the effect of EMFs on migratory fish is currently unclear (Gill & Bartlett, 2010). In particular, electro-magnetic-sensitive species may be receptive to anthropogenic EMFs that fall within the range of natural EMFs. The global geomagnetic field ranges from approximately 25 µT to 65 µT (Hutchison *et al,* 2020).

Most migratory salmonids swim within the top 5 m of the water (Godfrey *et al.,* 2014); therefore, they would not be affected by EMF emitted from the Offshore Export Cable(s) and inter-array cables on the seabed, and are more likely to encounter the dynamic cables in the water column. Eels migrate at various depths throughout the water column and therefore are more likely to encounter the EMF from the dynamic cables. Sea trout are also sensitive to magnetic fields and commonly found in water depths between 0 -190 m (MarLIN, 2022d). The proportion of the water column affected by the EMF is a relatively small area (in comparison to the wider Study Area) that the Offshore Export Cable(s) cover. Additionally, the location of the inter-array cables suggests that only a small number of eels would encounter the EMF. A study carried out by Marine Scotland (Armstrong *et al*., 2015) indicated that there was no evidence of a difference in the movement of eels as a result of EMF and there were no observations of changes in behaviour of the eels.

Armstrong *et al.* (2015) concluded that there was no identifiable behavioural response of Atlantic salmon to magnetic fields at intensities of 95 µT and below. Furthermore, Hutchinson *et al.* (2018), conducted field surveys on a single HVAC cable. The measured magnetic field levels were extracted and scaled to full power. The scaled magnetic fields were in the range 0.005 to 3.1 µT. This study concluded that the results did not find high enough EMFs of concern to affect shark, rays, and skate species. It should be noted that the EMF emissions for the Offshore Development will be in the range between 3.21 and 17 µT.

The diadromous fish species identified to potentially utilise the Offshore Development are considered to be **medium** value receptors. High levels of EMF may have the potential to impact the migration of diadromous fish, however, they are considered to have **low** sensitivity to the levels being emitted. EMF will be emitted throughout the life-cycle of the Offshore Development, however, based on the localised spatial change, the impact is defined as being of **low** magnitude as the levels of EMF emitted will be low**.**

Low levels of EMF are anticipated from both the Offshore Export Cable(s) and the dynamic inter-array cables, as shown through the Prysmian (2022) study. This will be secured through cable burial and/or cable protection measures, delivered through management plans, including the Cable Plan. As such, the overall effect to diadromous fish species receptors is considered to be **minor** and **not significant.**

10.6.2.2.4 Shellfish

A specific study on lobsters demonstrated statistically significant responses to EMF, however, there was no indication that the parameters were associated with zones of high or low EMF, but was an overall response (Hutchison *et al.,* 2020). As mentioned above, it is also important to note that whilst this study does show a response to EMF on lobster, the study considered HVDC cables at 300 kV and 500 kV, where the magnetic fields exhibited were much greater than that of earth's magnetic field, and as such these results are not comparable to the proposed 66 kV Offshore Export Cable(s) or inter-array cables. A recent study on lobsters and edible crabs found EMF did not alter embryonic development time, larval release time, or vertical swimming speed for either species. However, when exposed throughout embryonic development, an increase in larval deformities was observed and reduced swimming test success rate amongst lobster larvae (Harsanyi *et al.,* 2022). Again this study looked at exposure to 2.8 Millitesla (mT) of EMF, which is significantly higher and thus not comparable to the proposed 66 kV Offshore Export Cable(s) or inter-array cables.

Similarly, a recent laboratory study on brown crab (Scott *et al.*, 2021), found that there were no adverse physiological or behavioural impacts at magnetic fields of 250 µT. Adverse physiological impacts, however, were observed at 500 µT and above. Although responses are observed at these elevated levels, the proposed cables would not emit magnetic fields within these magnitudes, as discussed above.

Overall, research since 2016 concerning invertebrates generally supports previous studies that demonstrated no or minor effects of encounters with EMFs (Albert *et al.*, 2020).

The shellfish species identified to potentially utilise the Offshore Site are considered to be **moderate** value receptors. Shellfish species are considered to have **low** sensitivity to EMF levels associated with the low levels of EMF produced by the cables. With consideration of these studies, associated magnetic field strengths will be indistinguishable from the earth's own magnetic field intensity at the Offshore Site, and as the Offshore Export Cable(s) and seabed-laid portions of the inter-array cables will be sufficiently buried or protected to reduce EMFs experienced at the seabed, the impact is defined as being of **low** magnitude.

Given the low levels of EMF that are anticipated to be emitted, as shown by the Prysmian (2022) study, due to cable burial and/or application of cable protection measures, secured through the Cable Plan, the overall effect upon shellfish receptors is considered to be **minor** and **not significant**.

10.6.2.3 Fish aggregation around the floating structure and associated infrastructure

Subsea infrastructure from offshore wind farms can provide new habitats for fish and shellfish species as they can act as artificial reefs. The introduction of hard infrastructure alters previously soft sediment habitat areas, which can attract new species to the area increasing habitat complexity and biodiversity of the area (Degraer *et al*., 2020).

Floating structures and associated moorings have the potential to act as artificial reefs and FADs, attracting fish from the surrounding area and concentrating them into a smaller area. The surface of any hard structure placed in the marine environment will become fouled by marine organisms, creating new habitats and exhibiting an artificial reef effect. If these artificial reefs attract fish, the structure becomes known as a FAD. It is thought that FADs concentrate fish stock in a particular area, rather than increasing productivity (Inger *et al.* 2009). There is evidence, however, to suggest that hard structures acting as artificial reefs provide food and refuge, and therefore may increase the productivity of an area (Langhamer & Wilhelmsson, 2009; Wilhelmsson *et al*. 2006; Linley *et al.* 2007).

If no antifouling treatments are applied to the floating substructures, mooring lines, anchors or inter-array cables, biofouling will occur upon all of these surfaces. Additionally, if it is not possible to bury the cables along the entire cable route, there will also be remedial protection applied on top of the cables which could also be colonised.

The installation of the inter-array cables, anchors, mooring lines, clump weights and remedial protection on the seabed within the PFOWF Array Area will provide surfaces that have the potential to be colonised. As per Table 10.12, the combined permanent seabed footprint of the infrastructure associated with the PFOWF Array Area is 219,590 m^2. The inter-array cables will be buried where possible to reduce the footprint of additional remedial protection. In addition, the submerged exterior surface of the floating foundations within the PFOWF Array Area will provide additional colonisable surface. The total surface area coverage of the floating foundations below sea level is 179,375 m^2. Although these surfaces are not on the seabed, they may provide new habitat for some benthic species. The potential impact regarding benthic species colonising the installed structures has been assessed in Chapter 9: Benthic Ecology (for further information on the impact this will have on prey species see Section 9.6.2.3 within this chapter).

As per Table 10.12, the permanent footprint of the Offshore Export Cable(s) due to remedial protection within the OECC is 87,500 m^2. To reduce the surface volume of the remedial protection, the Offshore Export Cable(s) will be buried where possible and remedial protection will only be required where a target burial depth of 0.6 m is not achieved.

The surfaces provided by the floating substructures, anchors and mooring lines will provide minimal surface area for colonisation, when compared with the larger area over which substructures will be deployed. Hence, the artificial reef effect of the PFOWF Array Area is likely to be small and is unlikely to significantly increase the productivity of the area. As a result, fish production in the area is unlikely to increase significantly. It is expected that the floating substructures will be painted in a low-toxicity anti-fouling paint and the floating substructures, mooring lines and anchors will be fitted with cathodic (anode) protection to reduce the risk of corrosion of the steel structures. Substructures, anchors and mooring lines will be regularly inspected, and subsequent removal of marine growth will be undertaken using water jetting tools if substantial accumulation is in evidence. The exact protection measures to be employed will be developed during detailed design and will be provided to MS-LOT post-consent as required.

Many of the fish predicted to utilise the Study Area (as shown in Table 10.4) are highly protected and therefore considered to be **high** value receptors. The total area of potential new habitat is small but this still represents a minor shift away from baseline conditions. The sensitivity of the fish and shellfish receptors is considered to be moderate. Based on the localised spatial extent of the area available for colonisation and the embedded mitigation measures outlined above, the impact is defined as being of **low** magnitude. Any impacts are unlikely to affect long term functioning of the baseline fish and shellfish receptors.

Therefore, the overall effect to fish and shellfish receptors is considered to be **minor** and **not significant**.

10.6.2.4 Summary of effects during Operation and Maintenance

A summary of the assessment of effects during Operation and Maintenance is provided in Table 10.21.

Table 10.21 Summary of significance of effects from Operation and Maintenance Impacts

Summary of Effect	Receptor	Sensitivity	Magnitude of impact	Rationale	Consequence	Significance of Effect	Additional Mitigation Requirements	Significance of Residual Effect
Habitat loss of spawning and nursery grounds due to presence of anchors and Offshore Export Cable(s) on the seabed	Herring	Moderate	Low	Herring have **moderate** sensitivity to substratum loss and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to herring receptors is considered to be **minor and not significant.**	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant
	Sandeels	Moderate	Low	Sandeels have **moderate** sensitivity to substratum loss and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**	Minor	Not Significant		Not Significant
	All other fish species	Low	Low	Fish species have **low** sensitivity to substratum loss and are a **high** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to fish receptors is considered to be **minor** and **not significant**.	Minor	Not Significant		Not Significant
	Shellfish	Moderate	Low	Shellfish species have **moderate** sensitivity to substratum loss and are a **moderate** value receptor. The impact is defined as being of **low** magnitude. Therefore, the overall effect to fish and shellfish receptors is considered to be **minor** and **not significant**.	Minor	Not Significant		Not Significant
Effects of EMFs from subsea and dynamic cables on sensitive species	Elasmobranch fish	Moderate	Low	Elasmobranch species are sensitive to increases in EMF, however, as discussed, the EMF emitted by the cables is considered to be minimal, therefore it has been given a **moderate** sensitivity rating**.** Elasmobranchs are a **high** value receptor and the impact is defined as being of **low** magnitude**.** The overall effect to elasmobranch species receptors is considered to be **minor** and **not significant.**	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant
	Diadromous fish	Low	Low	Diadromous fish are considered to have **low** sensitivity to EMF levels being emitted and are a **moderate** value receptor. The impact is defined as being of **low** magnitude**.** The overall effect to diadromous fish is considered to be **minor** and **not significant**	Minor	Not Significant		Not Significant
	Shellfish	Low	Low	Shellfish species are considered to have **low** sensitivity to EMF and are a moderate value receptor. The impact is defined as being of **low** magnitude. The overall effect to shellfish communities is **minor** and **not significant**.	Minor	Not Significant		Not Significant
Fish aggregation around the floating structure and associated infrastructure	All fish and shellfish species	Moderate	Low	The sensitivity of the fish and shellfish receptors is considered to be **moderate**. Fish and shellfish receptors have been assigned a **high** value. The impact is defined as being of **low** magnitude. Therefore, the overall effect to fish and shellfish receptors is considered to be **minor** and **not significant**.	Minor	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded project mitigation listed in Section 10.5.5 as it was concluded that the effect was not significant	Not Significant

10.6.3 Effects during Decommissioning

Decommissioning will involve the dismantling and removal of the seven WTGs and associated floating substructures, anchoring systems and the removal of the dynamic and seabed laid cables (unless there is compelling evidence to leave the buried sections *in situ*). Scour protection may also be left *in situ* as it may not be practical to remove and anchor piles may be cut to a depth of 1 m below the seabed with the remainder left *in situ*. Detail on the decommissioning of the Offshore Development infrastructure is limited at this time as this will occur after the 30 year operational life of the Offshore Development. A Decommissioning Programme will be developed to address the principal decommissioning measures for the Offshore Development, this will be written in accordance with applicable guidance and will detail the management, environmental management and schedule for decommissioning. The decommissioning programme will be reviewed and updated throughout the life-cycle of the Offshore Development to account for changing best practice.

Given the nature of the decommissioning activities, which will largely be a reversal of the installation process, the impacts during decommissioning are expected to be similar to, or less than those assessed for the construction phase. Therefore, the magnitudes of impact assigned to Fish and Shellfish Ecology receptors during the construction stage are also applicable to the decommissioning stage. It is also assumed that the receptor sensitivities will not materially change over the life-cycle of the Offshore Development. Therefore, the decommissioning effects are not expected to exceed those assessed for construction.

10.7 Assessment of Cumulative Effects

10.7.1 Introduction

The consideration of projects which could result in potential cumulative effects is based on the results of the Fish and Shellfish Ecology specific impact assessment, together with the expert judgement of the specialist consultant.

Projects within 50 km of the Offshore Site are considered to have the potential to result in cumulative impacts for Fish and Shellfish Ecology. Impacts relating to habitat disturbance are expected to be localised to the Offshore Development with a similar Zone of Influence (ZoI) to Marine Physical Processes (20 km) (see Chapter 7: Physical Processes). A similar ZoI has been used for EMF effects, however, this is considered to be conservative due to the extremely localised extent of EMF emissions. However, it is recognised that underwater noise impacts may extend to a further distance and that a greater ZoI needs to be considered for potential impacts on migratory species (e.g. EMF impacts on migratory routes of salmon etc.). Therefore, a 50 km ZoI has been assumed based on the results of the underwater noise modelling for impact piling which highlights the maximum mean disturbance range to Atlantic Salmon (and other migratory species) may extend to 34 km (see Table 10.14). The projects that have been considered for the cumulative impact assessment are listed in Table 10.22 and shown on Figure 10.10.

The approach to the assessment of projects includes:

- Quantitative assessment of projects submitted to Scoping up to six months prior to PFOWF application submission;
- Qualitative assessment of projects submitted to Scoping up to five months prior to PFOWF application submission; and
- Acknowledgement of projects submitted to Scoping between five and two months prior to PFOWF application submission.

There are limited project details for offshore wind farms sites awarded Option Agreements within the ScotWind leasing round. As noted above, the cut-off date for a qualitative assessment of projects in the Scoping stage was February 2022, therefore, the ScotWind Projects are acknowledged but no assessment has been conducted. The sites with the greatest potential to act cumulatively with the Offshore Development include the West of Orkney Windfarm (within the N1 PO) as well as other sites along the north, north-east and east coasts of Scotland (i.e. those sites within the N2, N3, NE2, NE3 and NE4 POs). These projects will undertake more detailed cumulative assessments with the Offshore Development to support their applications for development consent.

This approach was shared with MS-LOT and agreement was confirmed via email on 6 December 2021.

The MeyGen tidal project is 39 km from the Offshore Site and is therefore beyond the area of search for cumulative impacts other than underwater noise. However, due to lack of publicly available information on MeyGen's construction timelines it has not been considered within the cumulative impact assessment[1].

Table 10.22 List of projects considered for the Fish and Shellfish Ecology Cumulative Impact Assessment

Development Type	Project Name	Status	Phase	Distance from Offshore Site (km)	Data Confidence	Relevant Receptors
Cable	SHE Transmission Orkney – Caithness project	Consented	Consented (construction timelines unknown)	0	Medium	All
Cable	Scottish Hydro Electric Power Distribution (SHEPD) Orkney to Hoy North Cable	Operational (awaiting replacement)	Cable replacement expected 2021/2022	42	High	All
Cable	SHE Transmission Shetland HVDC Link	Under construction	Construction period: 2021 to 2023	50	High	All
Cable	BT R100 telecommunications cables across Orkney	Pre-consent (application stage)	2022	43	Medium	All
Dredge disposal site	Scrabster Extension dredge disposal site	Open	Active	18	High	All
Dredge disposal site	Scapa dredge disposal site	Open	Active	46	High	All
Dredge disposal site	Stromness B dredge disposal site	Open	Active	41	High	All
Dredge disposal site	Stromness C dredge disposal site	Open	Active	45	High	All

[1]The MeyGen tidal project has currently four 1.5 MW turbines deployed, as well as a subsea hub for the existing turbines which was installed in 2020. In 2017, MeyGen Limited were granted permission to deploy a further four turbines (Phase 1b) however no construction activity for this phase has taken place to date, and there is very limited publicly available information on their construction timelines for this phase. The project has restrictions on the consent for phased development (under the deploy and monitor approach) and cannot proceed to subsequent phases without application and further consultation. On 7th July 2022, MeyGen Limited was successful in the Contracts for Difference (Cfd) Allocation Round 4, for Phase 1c (28 MW). Whilst the results announced by Department for Business, Energy and Industrial Strategy indicates that MeyGen aim to install this phase in 2026/27, a new separate application will need to be made to Marine Scotland for this phase under their phased consent.

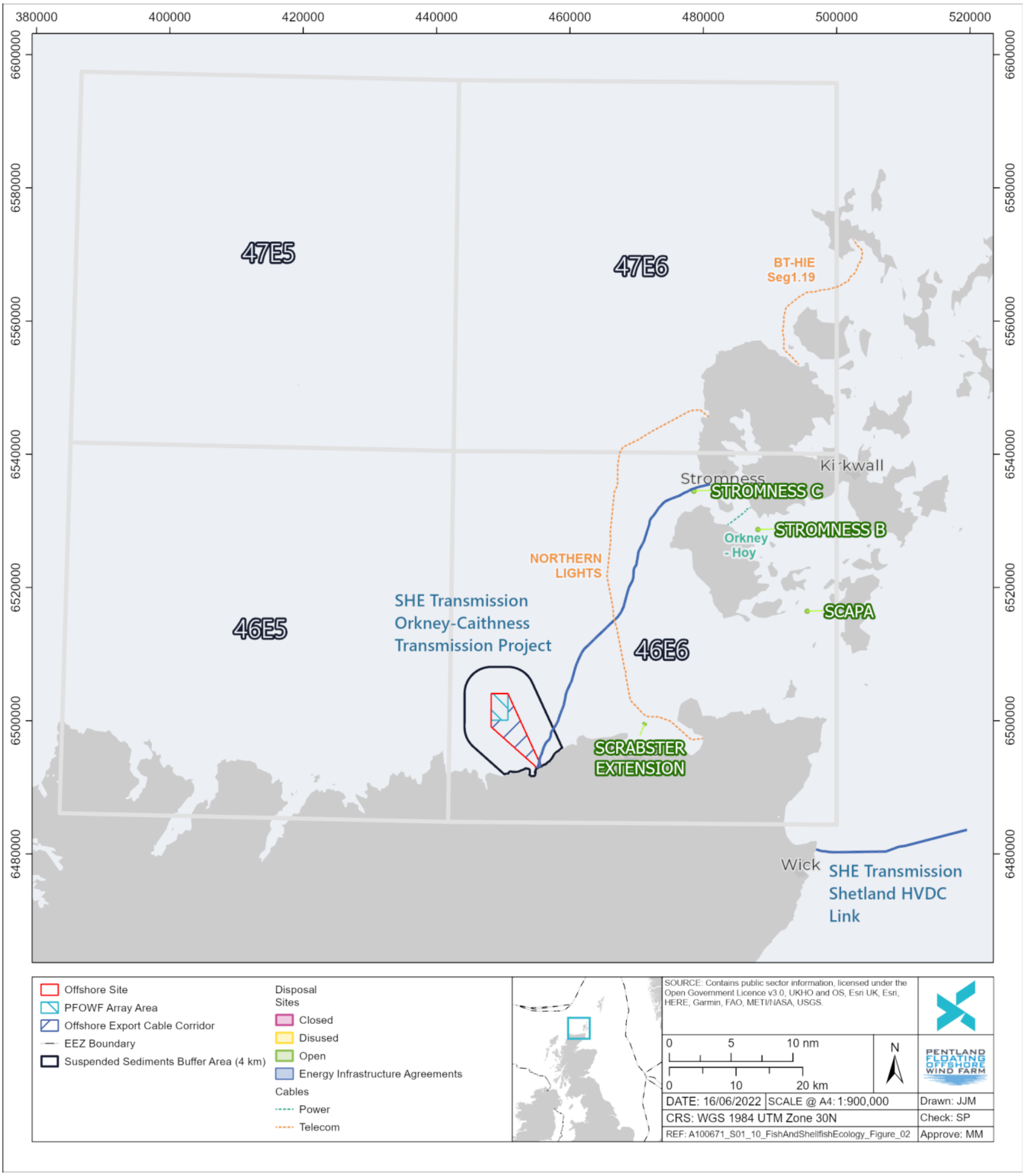

Figure 10.10 Cumulative Projects identified for Fish and Shellfish Ecology within 50 km of the Offshore Development

The following sections summarise the nature of the potential cumulative impacts for each stage of the Offshore Development.

The following impacts have been taken forward for the cumulative assessment:

- Construction/Decommissioning;
  - Disturbance or damage to sensitive species due to underwater noise generated from construction activities;
  - Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of the Offshore Export Cable(s) and placement of anchors on seabed;
  - Effects of increased sedimentation / smothering on fish and shellfish during construction activities;
  - Temporary burial of seabed from drill cuttings piles; and
  - Potential accidental release of pollutants.
- Operation and Maintenance;
  - Habitat loss of spawning and nursery grounds due to presence of anchors and cables on the seabed; and
  - Effects of EMFs from export and inter-array cables on sensitive species.

10.7.2 Cumulative Construction Effects

10.7.2.1 Disturbance or damage to sensitive species due to underwater noise generated from construction activities

As described above for the Offshore Development alone, the most sensitive fish and shellfish receptor to underwater noise are herring which have been identified as a **moderately** sensitive receptor.

The underwater noise impact assessment focused on piling activities. Other anthropogenic underwater noise generating activities such as cable laying, suction dredging, trenching, remedial protection and installation vessels do not have the potential to cause injury. The projects considered within the cumulative impact assessment are cable and dredging projects where piling activity will not occur. Therefore, the magnitude of impact is considered to be **negligible**, making the overall effect **negligible** and **not significant**.

10.7.2.2 Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and mooring lines on seabed

As described above for the Offshore Development alone, the most sensitive fish and shellfish receptors to habitat loss are sandeels, herring and shellfish which have been identified as **moderately** sensitive receptors.

The type of developments considered within the cumulative impact assessment consist of cable projects and dredging projects. Dredging sites receive their permits of the basis that they will not have an adverse impact upon spawning and nursery areas and associated habitats. They may also have seasonal restrictions to prevent interference with migration and spawning (OSPAR, 1998). Therefore, no cumulative impact on spawning grounds is expected to occur with the dredging developments listed in Table 10.22.

There will be temporary seabed disturbance during installation of the cable projects, however, it is expected that the SHE Transmission Orkney – Caithness Project and the R100 telecommunication cables will be buried where possible and remedial protection will be used where target burial is not achievable (Xodus Group Ltd, 2018; Intertek, 2021). The Orkney to Hoy North replacement cables are expected to be surface laid for a length of 5 and 5.5 km, representing a small area of habitat loss (Xodus Group, 2021). In addition, the SHE Transmission Orkney – Caithness Project is the only project that overlaps geographically with the Offshore Development (within the OECC). However, the construction timelines for this project are uncertain and therefore it is not possible to ascertain if there will be a cumulative impact with the installation of the Offshore Export Cable(s) for the Offshore Development, which are anticipated to take place within the spring and summer months of Stage 1 or Stage 2.

Nonetheless, as the SHE Transmission Orkney – Caithness Project only covers a small proportion of the grounds available for spawning and nursery grounds of these sensitive species, the impact of both these projects is still defined as being of **low** magnitude**.**

Therefore, the overall effect is considered to be **minor** and **not significant**.

10.7.2.3 Effects of increased sedimentation / smothering on fish and shellfish during construction activities

As described above for the Offshore Development alone, the most sensitive fish and shellfish receptors are sandeels, herring and shellfish which have been identified as **moderately** sensitive receptors.

The type of developments considered within the cumulative impact assessment consist of cable projects and dredging projects. Dredging sites receive their permits on the basis that they will not have an adverse impact upon spawning and nursery areas and associated habitats. They also may have seasonal restrictions to prevent interference with migration and spawning (OSPAR, 1998). Therefore, no cumulative impact on spawning grounds is expected to occur with the dredging developments listed in Table 10.22.

There will be a temporary increase in sedimentation and potential smothering disturbance during installation of the cable projects. The SHE Transmission Orkney – Caithness Project is the only project that overlaps with the Offshore Development. However, the construction timelines for this project are uncertain and therefore it is not possible to ascertain if there will be a cumulative impact with the installation of the Offshore Export Cable(s) for the Offshore Development, which are anticipated to take place within the spring and summer months of Stage 1 or Stage 2. If the construction of these projects did occur simultaneously it is anticipated that with consideration of the dynamic nature of the wave and tidal regime within the Pentland Firth, any fine sediments within the OECC released into the water column will become diluted to very low concentrations (indistinguishable from natural background levels and variability) within short timescales (as discussed in Chapter 7: Marine Physical Processes). As such, based on localised spatial and temporal change, the impact of both these projects is still considered to be of **low** magnitude**.**

Therefore, the overall effect is still considered to be **minor** and **not significant**.

10.7.2.4 Temporary burial of seabed from drill cuttings piles

As described above for the Offshore Development alone, the most sensitive fish and shellfish receptors are sandeels, herring and shellfish which have been identified as **moderately** sensitive receptors.

There is the potential for cumulative habitat loss and smothering disturbance with cables and dredging projects, as described in Section 10.7.2.2 and 10.7.2.3. For the cable projects listed in Table 10.18, planning applications for the cables projects state a commitment for cable burial where possible and remedial protection will be used where target burial is not achievable as a contingency, with the exception of the Orkney to Hoy North cable replacement, which will limit habitat loss or disturbance. Furthermore, these projects cover a small proportion of the available habitat in the region for fish and shellfish receptors. Therefore, based on the localised change, the impact of the Offshore Development with other project and plans is still considered to be of **low** magnitude.

Therefore, the overall effect is still considered to be **minor** and **not significant**.

10.7.2.5 Potential accidental release of pollutants

As described above for the Offshore Development alone, fish and shellfish receptors have been identified as having **moderate** sensitivity to the release of pollutants.

All vessels involved in the construction of the projects considered within the cumulative impact assessment will have the same legislation and industry standard guidance (e.g. MARPOL) in place to reduce the risk of collision and accidental discharge. This includes the implementation of a pollution prevention plan and adhering to the Project CEMP. In addition, as set out in Table 10.22, it is very unlikely that the other projects within the vicinity of the Offshore Development will have overlapping construction dates.

The SHE Transmission Orkney – Caithness Project is the only project that overlaps geographically with the Offshore Development. However, the construction timelines for this project are uncertain and therefore it is not possible to ascertain if there will be a cumulative impact with the installation of the Offshore Development, which are anticipated to take place within the spring and summer months of Stage 1 or Stage 2. Nonetheless, this project would also need to comply with industry standards and adhere to pollution prevention control measures. As such, as the impact is very unlikely to occur and if it did would only occur at very low frequency or intensity, the impact of both these projects is still considered to be of **negligible** magnitude**.**

Therefore, the overall effect is still considered to be **negligible** and **not significant.**

10.7.3 Cumulative Operation and Maintenance Effects

10.7.3.1 Habitat loss of spawning and nursery grounds due to presence of anchors and cables on the seabed

As described above for the Offshore Development alone, the most sensitive fish and shellfish receptors are sandeels and herring which have been identified as **moderately** sensitive receptors.

The type of developments considered within the cumulative impact assessment consist of cable projects and dredging projects. Dredging sites receive their permits of the basis that they will not have an adverse impact upon spawning and nursery areas and associated habitats. They may also have seasonal restrictions to prevent interference with migration and spawning (OSPAR, 1998). Therefore, no cumulative impact on spawning grounds is expected to occur with the dredging developments listed in Table 10.18.

For the cable projects listed in Table 10.18, the planning applications state a commitment for cable burial where possible where possible and remedial protection will be used where target burial is not achievable as a contingency, with the exception of the Orkney – Hoy North Cable Replacement. The only project which overlaps geographically with the Offshore Development is the SHE Transmission Orkney – Caithness Project which could also affect the spawning and nursery grounds identified which overlap with the Offshore Site. Nonetheless, Ellis *et al*., (2012) data suggests the Offshore Site does not overlap with herring spawning grounds and only overlaps with low intensity nursery ground. Ellis *et al.* (2012) data also suggests the Offshore Site overlaps with only low intensity sandeel spawning and low density nursery grounds. Given this, and the wider availability of nursery and spawning grounds for these sensitive species across Scottish and English Waters, the impacts of both projects if remedial protection of the SHE Transmission Orkney – Caithness Project and Offshore Development are considered to be localised in spatial extent and as such is still considered to be of **low** magnitude**.**

Therefore, the overall effect is still considered to be **minor** and **not significant**.

10.7.3.2 Effects of EMFs from export and inter-array cables on sensitive species

As described above for the Offshore Development alone, the most sensitive fish and shellfish receptors are elasmobranch species which have been identified as **moderately** sensitive receptors.

The range of EMF from subsea cables is very localised, therefore, only the SHE Transmission Orkney – Caithness Cable Project has been considered as having the potential to act cumulatively with the Offshore Development. The planning application for the SHE Transmission Orkney – Caithness Project states a commitment to bury the cables to a sufficient burial depth where possible or, where burial is not possible, remedial protection measures will be applied to reduce the effects of EMF (Xodus Group, 2018).

If the SHE Transmission Orkney – Caithness Project is already installed by the time the Offshore Development is constructed, the Offshore Export Cable(s) required for the Offshore Development may have to cross this asset. The crossing will be installed in line with industry best practice to reduce any potential damage and will be in accordance with a crossing agreement sought between SHE Transmission and HWL. Proximity agreements will also be developed, if required, and these will seek agreement on how close construction activities can occur to existing infrastructure. HWL has been in regular contact with SHE Transmission and this engagement will continue to occur throughout the construction, operation and maintenance and decommissioning phases of the Offshore Development. As proximity agreements will be in place, the cables will not be close enough to cause cumulative EMF effects, with the exception of the point of crossing. However, cables will need to be further protected at the crossing and therefore, given the EMF levels anticipated with the application of 1 m of cable protection (0.73 μT), even cumulatively, it is highly unlikely that these levels will surpass those of the Earth's own magnetic field at the Offshore Site (50.7±0.14μT [NOAA, 2021b]). Therefore, the magnitude of impact is still considered to be **low**, making the overall effect **minor** and **not significant**.

10.7.4 Cumulative Decommissioning Effects

The construction impacts discussed in Section 10.7.2 are anticipated to be similar during the decommissioning phase as explained in Section 10.6.3. Therefore, any cumulative effects are anticipated to be the same or less than those assessed for cumulative construction effects and, as such, would not result in significant effects on Fish or Shellfish receptors.

10.8 Assessment of Transboundary Effects

In terms of the impacts on Fish and Shellfish Ecology receptors, impacts will be localised to the extent of the Fish and Shellfish Ecology Study Area, within UK waters. Given the intervening distance to neighbouring European Economic Area (EEA) states, there is no potential for transboundary impacts and resultant effects to occur.

10.9 Assessment of Impacts Cumulatively with the Onshore Development

The Onshore Development components are summarised in Chapter 5: Project Description. These Project aspects have been considered in relation to the impacts assessed within this Chapter.

There are no river SACs designated for fish or shellfish species that overlap with the Onshore Development. In addition, there will not be any discharge of pollutants to the marine environment at this location and as such no effects from the onshore activities are anticipated on Fish and Shellfish Ecology receptors. There is the potential for surface run-off and increased sedimentation from onshore activities to reduce the water quality of rivers, however, this will be managed through management plans such as a Drainage Strategy, CEMP and PPP, and therefore, there will not be a cumulative impact.

The Onshore Development will undertake HDD operations above MHWS, with a HDD exit point occurring between 400 to 700 m offshore. The impacts from the HDD exit point on Fish and Shellfish Ecology receptors have been assessed in full in Section 10.6. It is not anticipated that there will be any additional impacts from the Onshore Development on Fish and Shellfish Ecology receptors as all other activities from the Onshore Development are fully terrestrial. As Fish and Shellfish Ecology receptors which may be impacted occur wholly offshore (as HDD operations will bypass the inter-tidal region), there are not anticipated to be any impacts from the Onshore Development on Fish and Shellfish Ecology receptors.

10.10 Mitigation and Monitoring Requirements

There is no requirement for additional mitigation over and above the embedded measures for the Offshore Development proposed in Section 10.5.5.

10.11 Inter-relationships

Interrelated effects describe the potential interaction of multiple project impacts upon one receptor which may interact to create a more significant impact on a receptor than when considered in isolation. Interrelated effects may have a temporal or spatial element and may be short term, temporary or longer term over the life-cycle of the Offshore Development.

In line with the Scoping Opinion and Scoping Opinion Addendum received, this chapter has assessed all impacts that are relevant to Fish and Shellfish Ecology receptors during construction, operation and maintenance and decommissioning phases of the Offshore Development. Therefore, it is considered that the assessment and conclusions presented in Section 10.6 provides a complete and robust assessment of all potential impacts relevant to Fish and Shellfish Ecology. The assessment has also considered the potential for inter-related effects in relation to Fish and Shellfish Ecology, and no additional inter-related effects beyond those presented in Section 10.12 have been identified.

Where the assessment contained in this chapter is considered within other assessment chapters, a summary of these interrelationships are presented below in Table 10.23.

Table 10.23 Inter-relationships identified with Fish and Shellfish Ecology and other receptors in this Offshore EIAR

Receptor	Impacts	Description
Marine Physical Processes	In-direct impacts on benthic habitats and fish and shellfish species from suspended sediments	Changes in marine physical processes could lead to suspension of sediments which may in-directly result in smothering of fish and shellfish habitats and fish and shellfish species which depend on these habitats. These impacts are discussed in Section 10.6.1.3 of this Chapter.
	In-direct impacts on benthic habitats and fish and shellfish species from changes to hydrodynamics	Changes in hydrodynamics could lead to increased scour and abrasion which may in-directly result in loss or disturbance of fish and shellfish habitats and fish and shellfish species. These impacts are discussed in Section 10.6.2.1 of this Chapter.
Water and Sediment Quality	In-direct impacts on fish and shellfish habitats and fish and shellfish species from changes in water and sediment quality	Changes in water and sediment quality can result in in-direct impacts to fish and shellfish species which are sensitive to contamination and toxins. These impacts are discussed in Section 10.6.1.5 of this Chapter.
Benthic Ecology	In-direct impacts to fish and shellfish ecology from changes to spawning and nursery ground habitats from loss/disturbance of benthic ecology habitats.	Changes in benthic habitats can lead to an in- direct impact on fish spawning and nursery grounds which relay on these habitats. Direct impacts to benthic habitats from the Offshore Development are assessed within Chapter 9: Benthic Ecology. Habitat loss of spawning and nursery grounds due to presence of the Offshore Development infrastructure are assessed within Section 10.6.1.1.3 of this Chapter.
	In-direct impacts to fish and shellfish fish aggregation from changes to colonisation of benthic habitats and species.	Colonisation of benthic habitats and species may occur as a result of the Offshore Development infrastructure and scour. These impacts are assessed within Chapter 9: Benthic Ecology. This can in-directly impact fish species through increase of reefs and food availability resulting in fish aggregations around these structures. These impacts are assessed within Section 10.6.2.3 of this Chapter.
Marine Mammals and other Megafauna	In-direct impacts to marine mammals and other megafauna through long term fish and shellfish habitat change, including the potential for changes to habitat quality.	Changes in fish and shellfish habitats can lead to an in-direct impact on marine mammals and other megafauna due to changes in prey availability of fish, which may be impacted due to loss/disturbance of the habitat on which they rely. Direct impacts to fish and shellfish habitat from the Offshore Development are assessed within Sections 10.6.1.1.3 and 10.6.2.1 of this Chapter. Impacts on marine mammals and other megafauna from long term habitat changes are assessed within Chapter 11: Marine Mammals and other Megafauna.
Marine Ornithology	In-direct impacts to Marine Ornithology from potential change in prey availability	Changes in fish and shellfish habitats can lead to an in-direct impact on marine ornithology due to changes in prey availability of fish, which may be impacted due to loss/disturbance of the fish and shellfish habitat on which they rely. Direct impacts to fish and shellfish habitats from the Offshore Development are assessed within Sections 10.6.1.1.3 and 10.6.2.1 of this Chapter. Impacts on marine ornithology from potential change in benthic habitat and prey availability are assessed within Chapter 12: Marine Ornithology.
Commercial Fisheries	Impacts on commercially important fish and shellfish species from loss of spawning/ nursery grounds.	Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and mooring lines on seabed may result in impacts to fishing for these commercially important species. These commercially important species and potential changes to their

Receptor	Impacts	Description
		spawning and nursery ground from habitat loss are assessed within Section 10.6.2.1 of this Chapter.
	Potential for fishing gear to become entangled with subsea structures, resulting in ghost fishing.	There is potential for lost gear to become entangled with Offshore Development infrastructure leading to ghost fishing, and consequently impacting fish and shellfish species. The potential for this to occur and the significance of the impact to fish and shellfish species is assessed within Chapter 13: Commercial Fisheries.
Climate Change and Carbon	In-direct impacts on fish and shellfish ecology from climate change in combination with the Offshore Development activities.	In-direct impacts from climate change and the Offshore Development combined, such as increased rainfall in combination with the Offshore Development activities, may result in increased concentrations of suspended solids in the water column leading to smothering of fish and shellfish ecology spawning and nursery ground habitats. Climate change impacts in combination with the Offshore Development activities such as changes in temperature, salinity, oxygen and pH also have the potential to effect fish and shellfish ecology receptors. These in-direct impacts on fish and shellfish ecology are assessed within Chapter 20: Climate Change and Carbon.

10.12 Summary and Residual Effects

The summary of the residual effects for Fish and Shellfish Ecology is provided in Table 10.24.

Table 10.24 Summary of residual effects for Fish and Shellfish Ecology

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation identified	Significance of Residual Effect
Construction					
Disturbance or damage to sensitive species due to underwater noise generated from construction activities	Herring	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Sandeel	Minor Effects	Not Significant		Not Significant
	All other fish species	Minor Effects	Not Significant		Not Significant
	Shellfish	Minor Effects	Not Significant		Not Significant
Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and mooring lines on seabed	Herring	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded	Not Significant
	Sandeel	Minor Effects	Not Significant		Not Significant
	All other fish species	Minor Effects	Not Significant		Not Significant
	Shellfish	Minor Effects	Not Significant		Not Significant

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation identified	Significance of Residual Effect
				that the effect was not significant.	
Effects of increased sedimentation / smothering on fish and shellfish during construction activities	Herring	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Sandeel	Minor Effects	Not Significant		Not Significant
	All other fish species	Minor Effects	Not Significant		Not Significant
	Shellfish	Minor Effects	Not Significant		Not Significant
Temporary burial of seabed from drill cuttings	Herring	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Sandeel	Minor Effects	Not Significant		Not Significant
	All other fish species	Minor Effects	Not Significant		Not Significant
	Shellfish	Minor Effects	Not Significant		Not Significant
Potential accidental release of pollutants	All fish and shellfish species	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
Operation and Maintenance					
Habitat loss of spawning and nursery grounds due to presence of anchors and cables on the seabed	Herring	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Sandeel	Minor Effects	Not Significant		Not Significant
	All other fish species	Minor Effects	Not Significant		Not Significant
	Shellfish	Minor Effects	Not Significant		Not Significant

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation identified	Significance of Residual Effect
Effects of EMFs from subsea and inter-array cables on sensitive species	Elasmobranch fish	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Diadromous fish	Minor Effects	Not Significant		Not Significant
	Shellfish	Minor Effects	Not Significant		Not Significant
Fish aggregation around the floating structure and associated infrastructure	All fish and shellfish species	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
Decommissioning					
Decommissioning effects are not expected to exceed those assessed for the construction phase.					
Cumulative - Construction					
Disturbance or damage to sensitive species due to underwater noise generated from construction activities	Herring	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Sandeel				
	All other fish species				
	Shellfish				
Direct habitat loss due to disturbance of spawning and nursery grounds during the installation of cables and placement of anchors and mooring lines on seabed during the construction phase	Herring	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
	Sandeel				
	All other fish species				
	Shellfish				

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation identified	Significance of Residual Effect
Effects of increased sedimentation / smothering on fish and shellfish during construction activities	Herring Sandeel All other fish species Shellfish	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
Temporary burial of seabed from drill cuttings during the construction phase	Herring Sandeel All other fish species Shellfish	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
Potential accidental release of pollutants during the construction phase	All fish and shellfish species	Negligible Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
Cumulative – Operation and Maintenance					
Habitat loss of spawning and nursery grounds due to presence of anchors and cables on the seabed during the operational phase	Herring Sandeel All other fish species Shellfish	Minor Effects	Not Significant	No additional mitigation measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	Not Significant
Effects of EMFs from subsea and inter-	Elasmobranch fish	Minor Effects	Not Significant	No additional mitigation	Not Significant

Predicted Effect	Receptor	Assessment Consequence	Significance	Mitigation identified	Significance of Residual Effect
array cables on sensitive species during the operational phase	Diadromous fish			measures have been identified for this effect above and beyond the embedded mitigation listed in Table 10.13 as it was concluded that the effect was not significant.	
	Shellfish				
Cumulative - Decommissioning					
Cumulative effects are anticipated to be the same or less than those assessed for cumulative construction effects.					

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