Fall of Warness EIA Report

Volume 1, Chapter 13: Fish and Shellfish Ecology

November 2025




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13 Fish and Shellfish Ecology

13.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) identifies the Fish and Shellfish Ecology receptors of relevance to the Project, including in the marine environment up to mean high water springs (MHWS) and considers the potential impacts from the installation, operation and maintenance and decommissioning of the Project. Where required, mitigation is proposed, and the residual impacts and their significance are assessed. Potential cumulative and transboundary impacts are also considered.

13.2 Legislation, Policy and Guidance

Volume 1, Chapter 2: Legislation and Policy sets out the general legislation, policy and guidance that underpins the impact assessment within this EIAR. Further relevant legislation, policy and guidance, specific to Fish and Shellfish Ecology, above what has been presented in Volume 1, Chapter 2: Legislation and Policy, has been detailed below.

13.2.1 Legislation

The relevant legislations that have informed this topic assessment are as follows:

- The Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention) 1992;
- The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention) 1979;
- The Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention);
- The UK Biodiversity Action (UKBAP);
- The Wildlife and Countryside Act 1981 (as amended);
- The Wildlife and Natural Environment (Scotland) Act 2011;
- The Nature Conservation (Scotland) Act 2004;
- The Conservation of Salmon (Scotland) Regulations 2016 (as amended); and
- The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) (‘Habitats Regulations) (as amended).

13.2.2 Policy

The relevant plans and policies that have informed this topic assessment are as follows:

- Scotland’s National Marine Plan (Marine Scotland, 2015);
- Scottish Biodiversity Strategy to 2045 (Scottish Government, 2024; NatureScot, 2022a); and
- The Orkney Islands Regional Marine Plan (Consultation Draft) (Orkney Islands Council, 2024).

13.2.3 Guidance

The relevant technical guidance that have informed this topic assessment are as follows:

- The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) guidance document for Environmental Impact Assessment for the licensing of offshore windfarms (CEFAS, 2004);

- CEFAS (2011), Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects;
- NatureScot, (2016), Description of Scottish Priority Marine Features, provides the list of 81 Priority Marine Features (PMFs) adopted by Scottish Ministers many of which are features characteristic of the Scottish marine environment; and
- IUCN (2022), 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 (IUCN, 2022).

13.3 Scoping Comments and Consultation

Scoping and consultation has been ongoing throughout the Environmental Impact Assessment (EIA) and has played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the Project and the requirements of the regulators and their advisers.

Relevant comments from the EIAR Scoping Opinion (MS-LOT, 2022) and other consultation specific to Fish and Shellfish Ecology provided by MS-LOT[1], Marine Science Scotland[2] and NatureScot are summarised in Table 13-1 below, which provides a high-level response from European Marine Energy Centre (EMEC) on how these comments have been addressed within the EIAR. Following the expiration of the Scoping Opinion, a reassessment of the Scoping Opinion comments was presented in the EMEC Scoping Report (EMEC, 2022). Following Project design changes, EMEC consulted with NatureScot on 13th March 2025 to present the Project changes and to discuss a range of topic-specific questions. An initial response was provided by NatureScot on 2nd May 2025 and a re-assessment of the relevance of the Scoping Opinion in light of the Project design changes was submitted to NatureScot provided on 2nd September 2025. Also included in Table 13-1 is the response received from the HRA Screening Opinion which agreed that consideration of diadromous fish be included within the EIA only (MD-LOT, 2024).

[1] Now known as Marine Directorate – Licensing Operations Team (MD-LOT)

[2] Now known as Marine Directorate – Science, Evidence, Data and Digital (MD-SEDD)

Table 13-1 Summary of consultation responses specific to Fish and Shellfish Ecology

CONSULTEE	COMMENT	EMEC RESPONSE
SCOPING OPINION (DECEMBER 2022)		
MD-LOT on behalf of Scottish Ministers	With regard to the baseline information, the Scottish Ministers highlight the additional data sources to be published by the ScotMER fish and fisheries group detailed in the NatureScot representation and advise that these should be considered to inform assessment of fish and shellfish.	Noted, thank you. Data sources published under the Scottish Marine Energy Research (ScotMER) programme (e.g. Franco *et al.,* 2023) have been reviewed and used to understand the distribution of fish and shellfish species within the Study Area in Section 13.4.3.
MD-LOT on behalf of Scottish Ministers	With regards to the Developers consideration of protected sites, the Scottish Ministers agree with the inclusion of the River Thurso and River Naver SACs in the forthcoming assessment. However, in addition to these sites, the Scottish Ministers advise that there may be potential connectivity with other SACs for Atlantic salmon. Due to the potential for connectivity, the Scottish Ministers advise that the Developer must consider Berriedale & Langwell SAC, Borgie SAC and Little Gruinard River SAC in the assessment. Additionally, the Scottish Ministers highlight the monitor and tracking projects referenced in representation from NatureScot and advise that the Developer must fully consider the findings in the assessment and use them to guide the HRA for the SACs found to have connectivity.	It is acknowledged that there is the potential for connectivity with the SACs listed, as described in Table 13-3. However it is important to note that the assessments presented on Atlantic salmon consider impacts at the Scottish population level, and not on SAC populations due to the uncertainty in apportioning impacts to specific rivers or SAC for this species. As set out in the Fall of Warness HRA Screening Report (EMEC, 2022) and in line with recent feedback from NatureScot, impacts to Atlantic salmon are considered within the EIAR only as it is not possible to apportion impacts to individual SACs.
MD-LOT on behalf of Scottish Ministers	PMFs are identified within the Scoping Report in Table 7.5 as an appraisal mechanism, however, there is no discussion of PMFs within the baseline overview or included within the key data sources. The Scottish Ministers highlight the NatureScot representation that in addition to being qualifying features of European sites, Atlantic salmon, European eel and sea trout are PMFs. European eel is listed as 'critically endangered' on the IUCN Red list and is therefore a conservation priority, and sea trout are a UK Biodiversity Action Plan priority species. The Scottish Ministers agree with representation from NatureScot and advise that all three of these species must be considered in the EIA Report with respect to their life history stages and potential impact routes. The Scottish Ministers also advise that the Developer must include the sources referenced in the NatureScot representation with regards to migration routes and behaviour and the effects of noise and EMF on both European eels and sea trout in the assessment.	Noted, thank you. Atlantic salmon, European eel and sea trout are identified as PMFs in Section 13.4.3.4, and assessed as such in Section 13.6. The relevant protections for diadromous fish are also noted and Atlantic salmon, European eel and sea trout have been taken forward to the assessment and recommended sources from NatureScot considered.
MD-LOT on behalf of Scottish Ministers	The Scottish Ministers are content that other fish species considered by NatureScot such as European river and sea lamprey, sparling, and allis and twaite shad, can be scoped out.	Noted, thank you. These species have been scoped out of further assessment.

CONSULTEE	COMMENT	EMEC RESPONSE
MD-LOT on behalf of Scottish Ministers	Potential effects on fish and shellfish pathways are described in Table 7-3 and Table 7-4 of the Scoping Report. The Scottish Ministers agree with the potential impacts which have been identified however, advise that the NatureScot representation and MSS advice on both marine and diadromous fish regarding barrier effects, noise and electromagnetic fields, sediment and collision with turbine blades must be fully considered and addressed in the EIA Report. The Scottish Ministers also highlight the MSS advice regarding the assumptions made regarding diadromous fish and advise that this should be duly considered.	Noted, thank you. Barrier effects, underwater noise, EMF, changes to sediment regime, and collision with turbine blades have been scoped in for marine and diadromous fish, as noted in Table 13-6.
MD-LOT on behalf of Scottish Ministers	The Scottish Ministers agree with representation from NatureScot and are content with the approach to the cumulative impact assessment outlined in Section 7.5 of the Scoping Report.	Noted, thank you. The cumulative effects assessment is provided in Section 13.7.
MD-LOT on behalf of Scottish Ministers	In regard to the approach to assessment, the Scottish Ministers advise that the information identified in the NatureScot representation must be fully considered by the Developer and highlight in particular the likely requirement for operational noise modelling to inform the EIA.	Underwater noise modelling has been conducted for the operational turbines for the Project (Volume 2, Appendix D: Underwater Water Noise Modelling Report). The most relevant threshold criteria for fish are presented in Popper *et al*. (2014). The operational noise of the turbines represents a continuous noise source, and for most fish groups, only qualitative threshold criteria are available, with the risk being 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). Only quantitative criteria are available for the "Fish with swim bladder involved in hearing" for recoverable injury (170 dB rms for 48 hours) and Temporary Threshold Shift (TTS) (158 dB rms for 12 hours) (Popper *et al.,* 2014). Therefore, quantitative noise modelling could only be conducted for this hearing group and for the recoverable injury and TTS impacts. This is considered to provide minimal additional value to the assessment given that it is unlikely that operational turbine noise from turbines would result in injury for fish (Lossent *et al.,* 2018). Therefore, the assessment of underwater noise is mostly qualitative and reference is made to underwater sound signatures from representative turbine models proposed for use at EMEC (e.g. Risch *et al*., 2020; 2023). The assessment has been informed by the best available scientific literature, including recent studies on individual turbine noise emissions, fish hearing sensitivity, and known avoidance behaviours. These sources provide a precautionary basis for evaluating potential impacts in the absence of site-specific cumulative noise data.

CONSULTEE	COMMENT	EMEC RESPONSE
		The qualitative assessment considers key factors such as sound propagation characteristics, device spacing, fish sensory capabilities, and the existing high-energy acoustic environment of the site. Together, these elements support the conclusion that while turbine noise may be detectable by fish, it is unlikely to result in significant adverse effects, particularly given the likelihood of avoidance behaviour and the rapid attenuation of sound with distance.
MD-SEDD	MSS have reviewed the EMEC Fall of Warness Scoping Report. The project description has not been clearly explained and it is confusing to work out what changes are proposed.	The Applicant apologises for this. The Volume 1, Chapter 4: Project Description includes the key details of the proposed changes.
MD-SEDD	MSS are largely content with all the effect pathways proposed to be scoped in and out of the EIA. However, MSS would query whether 'collision with turbine blades leading to injury or death' as an effect pathway is scoped in for marine fish? It is currently unclear as 'Collision with turbine blades leading to injury or death' is included in Table 7-4 as a 'potentially important' effect on marine fish but it is missing in the summary table 7-6 and appears to be scoped out. If it has been scoped out, there is no justification provided behind this decision.	Collision with turbines blades leading to injury or death is scoped in for diadromous fish and marine fish groups, and scoped out for marine shellfish, as detailed in Table 13-6.
MD-SEDD	With regards to electromagnetic field (EMF) effects on marine fish species, EMF effects are only mentioned in reference to shark, skates and rays as being sensitive to EMF. Whilst this is accurate, MSS also recommend consideration of other marine fish species such as demersal marine fish species e.g. cod and haddock and pelagic marine fish species e.g. herring which may also be sensitive to EMF. EMF effects on pelagic marine fish species will be of particular concern for any dynamic cabling in the water column from any floating platforms.	Effects from EMF have been assessed for diadromous fish, marine fish and marine shellfish, as noted in Table 13-6. The assessment for this impact pathway is provided in Section 13.6.3.4.
MD-SEDD	As the scoping report acknowledges, there is a lack of information on the occurrence of diadromous fish at the Falls of Warness site, but MSS agree that Atlantic salmon, sea trout and European eel are likely to be present. There is also a lack of information on what rivers any Atlantic salmon and sea trout that are present are likely to be associated with, but MSS agree that there is potential connectivity of salmon with the Thurso and Naver salmon SACs and indeed other salmon SACs, such as the Borgie SAC.	Atlantic salmon, sea trout and European eel are included as receptors following baseline compilation, as noted in Section 13.4.3.4. These SACs are considered are part of the assessment, Table 13-3, as having potential connectivity to the Offshore Site. As outlined within the Fall of Warness HRA Screening Report (EMEC, 2022), received HRA Screening Response (MD-LOT, 2024) and in line with recent advice from NatureScot and MD-LOT on other projects, impacts to Atlantic salmon are considered in the EIAR only and are screened out of the HRA.
MD-SEDD	MSS are content with the assessment in Table 7.3 and 7.4 of the importance of potential effect pathways for diadromous fish, although various assumptions in the tables are questionable;	These clarifications are welcome, thank you.

CONSULTEE	COMMENT	EMEC RESPONSE
	• that diadromous fish are always mobile in the marine environment, which is not the case – they may be foraging rather than actively migrating, for example, • that diadromous fish will move away from unfavourable conditions, • that diadromous fish will not aggregate around structures, and may not apply in all circumstances.	While it is noted that diadromous fish are not always actively migrating, they are highly mobile and are able to vacate an area with unfavourable conditions and reduce their susceptibility to injury effects even if they are foraging. With regards to impacts from aggregation, it is acknowledged that there is the potential for fish to aggregate around hard structures when foraging (Copping *et al*. 2021; Reubens *et al*., 2013a; 2013b). However, considering the relatively small footprint and scale of the turbines (in comparison to offshore wind turbines, for example, where there is evidence of predators targeting the structures which could lead to increased predation on post-smolts), and wide availability of alternative foraging habitat, it is unlikely that habitat creation and fish aggregation effects will be significant for mobile diadromous fish. Potential impacts from this impact on diadromous fish therefore remain scoped out.
MD-SEDD	MSS welcome the proposed collision risk modelling for salmon, which appears from the information which is given to be potentially very informative.	Noted. The impact of collision with turbine blades to Atlantic salmon is included in Section 13.6.3.6. Quantitative collision modelling has been conducted for Atlantic salmon and is presented in Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report.
MD-SEDD	MSS agree with all the main points made by NatureScot in their comprehensive response of 17th August, insofar as they apply to diadromous fish. However, both NatureScot and EMEC appear to have overlooked the Borgie SAC, which includes salmon as a species interest; and Foinaven SAC does not include salmon as a species interest, although some populations of freshwater pearl mussel, which is a species interest, may be dependent on them.	River Borgie has been included for assessment, as detailed in Table 13-3. It is acknowledged that there is the potential for connectivity for the additional SACs listed, as described in Table 13-3. However it is important to note that the assessments presented on Atlantic salmon consider impacts at the Scottish population level, and do not assess impacts on specific SAC populations due to the uncertainty. Impacts to Atlantic salmon are considered in the EIAR only and are screened out of the HRA, as outlined within the Fall of Warness HRA Screening Report (EMEC, 2022).
NatureScot	Additional data sources which should be included in table 7.1, pages 46-47, are the Essential Fish Habitats maps to be published (August 2022) by the ScotMER fish and fisheries group.	Noted, thank you. The habitat maps from the ScotMER programme have been reviewed and used to understand the distribution of fish and shellfish species within the Study Area in Section 13.4.3.
NatureScot	Protected sites – diadromous interests River Thurso and River Naver SACs are correctly cited within the scoping report in Section 7.2.3, page 48, for inclusion. There may also be potential connectivity with other SACs for Atlantic salmon, even though they are further away. For example, Berriedale & Langwell SAC, Foinaven SAC and Little Gruinard River SAC. There are monitoring and tracking projects which could provide relevant information on the routes some Atlantic salmon use to and from these SACs. Particularly from the Atlantic Salmon Trust (Moray Firth8	The listed SACs are included in the assessment, however, the assessments presented on Atlantic salmon consider impacts at the Scottish population level and do not assess impacts on specific SAC populations. Impacts to Atlantic salmon are considered in the EIAR only and are screened out of the HRA, as outlined within the Fall of Warness HRA Screening Report (EMEC, 2022).

CONSULTEE	COMMENT	EMEC RESPONSE
	and Laxford tracking projects). These findings should then be used to guide HRA for those SACs subsequently found to have connectivity.	
NatureScot	PMFs are identified within the scoping report as an appraisal mechanism in table 7.5, page 52. However, it is noted there is no discussion of PMFs within the baseline overview nor is it included within the Key Data Sources in Table 7.1. In addition to being qualifying features of European sites, Atlantic salmon are PMFs along with European eel and sea trout. All three of these species are present in Orkney's waters and should be considered in the assessment with respect to their life history stages and potential impact routes.	Noted, thank you. Atlantic salmon, European eel and sea trout are identified as PMFs in Section 13.4.3.4, and assessed as such in Section 13.6. The relevant protections for diadromous fish highlighted by NatureScot are also noted and Atlantic salmon, European eel and sea trout have been taken forward to the assessment.
NatureScot	European eel is a conservation priority due to a dramatic drop in its population over the last 20 years; it is listed as 'critically endangered' on the IUCN Red list. Very little is known about their migration pathways, either as juveniles or adults. A literature review from Marine Scotland Science (Malcolm *et al.*, 2010) reviews the data available in relation to European eel migration routes and behaviour. A 2010 SNH literature review considers the effects of noise and EMF on European eels.	Noted, thank you. This information is included within the baseline (Section 13.4.3.4.3) and considered within the assessment of impacts for European eel with regards to the receptor sensitivity.
NatureScot	Sea trout are a UK Biodiversity Action Plan priority species. Sea trout support a number of fisheries in Scotland and many of these fisheries have undergone declines in the last 25 years. The 2010 report from Marine Scotland Science also reviews the data available in relation to sea trout migration routes and behaviour. SNH's 2010 report considers the effects of noise and EMF on sea trout.	Noted, thank you. This information is included within the baseline (Section 13.4.3.4.2) and considered within the assessment of impacts for sea trout with regards to the receptor sensitivity.
NatureScot	We have considered other fish, such as European river and sea lamprey, sparling, and allis and twaite shad, and are content for these to be scoped out. Very little is known about the population sizes and migratory behaviour of these species, and, although there are anecdotal records of the presence of some of these species from the north coast of Scotland, it is thought that they do not occur in Orkney's waters.	Noted, thank you. These species have been scoped out for further assessment.
NatureScot	We welcome the acknowledgement of the potential barrier effect of the larger development on diadromous fish (particularly Atlantic salmon and sea trout) migratory routes in table 7.4, page 50. The proposed collision modelling will be required to evaluate and assess this impact.	Noted. Impacts from barrier effects are assessed for diadromous fish in Section 13.6.3.5.1 and marine fish in Section 13.6.3.5.2. The impact of collision with turbine blades to Atlantic salmon is included in Section 13.6.3.6 and this has been informed by collision risk modelling (Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report). Quantitative collision risk modelling has not been conducted for sea trout due to their being insufficient input parameters (see Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report).

CONSULTEE	COMMENT	EMEC RESPONSE
NatureScot	In general terms, we welcome that Section 7.3 of the scoping report acknowledges the importance of assessing underwater noise for marine and diadromous fish and electromagnetic fields (EMF) for marine and diadromous fish and shellfish.	Noted, thank you. The assessment of underwater noise is provided in Sections 13.6.2.1 and 13.6.3.2, and the assessment of EMF is provided in Section 13.6.3.4.
NatureScot	With regards to diadromous fish, European eel and sea trout need to be given greater consideration as PMFs.	Both European eel and sea trout are noted as PMFs, as included within the baseline (Section 13.4.3.4.3) and their conservation value is considered within the assessment of impacts, with regards to the receptor sensitivity.
NatureScot	In contrast to Atlantic salmon, sea trout do not migrate rapidly out to sea and may linger in coastal areas longer (Malcolm *et al.,* 2010) therefore increasing the likelihood of prolonged exposure to noise. The findings of the assessment of potential impacts from sound pressure and particle movement will determine whether ceasing relevant installation activities during the hours of darkness or at peak migration time could help to mitigate potential impacts from noise to both Atlantic salmon and seat trout.	Noted, thank you. The migratory routes and behaviour of diadromous fish species are presented in Section 13.4.3.4, which includes consideration for Malcolm *et al.* (2010). It should be noted that the ability of salmonids to respond to sound pressure is regarded as relatively poor with a narrow frequency span, and this species has a limited ability to discriminate between sounds, and a low overall sensitivity to underwater noise (Gill and Bartlett, 2010).
NatureScot	The particle vibration component of sound is noted for marine shellfish. However, this also applies for fish and therefore should be considered. We are aware that this issue remains understudied, but a recent Good Practice Guide may be useful.	The consideration of sensitivity to particle motion is included within the assessment of underwater noise, as demonstrated in Section 13.6.2.1.
NatureScot	We suggest that EMF for both buried cables and for cables that are floating/hanging in the water column needs to be considered, as the EMF intensity between them is likely to be different.	The export cables will be surface laid with cable protection. The umbilical cables will be partially surface laid and in the water column. The assessment of EMF impacts in Section 13.6.3.4 considers the sections of the umbilical cables which are surface laid and in the water column.
NatureScot	Due to the naval history of the area the potential requirement for unexploded ordnance (UXO) clearance during installation, and its effects, should be identified for consideration within the assessment.	The potential for UXO to be present within the Fall of Warness site is considered to be very low as the Offshore Site has been an operational area for a number of years. Furthermore, surveys completed by Aquaterra (2005) did not identify any UXO, so it is therefore not assessed within this EIAR.
NatureScot	Whilst we agree that increased suspended sediment/turbidity (including release of drill cuttings) can be scoped out as not important for diadromous fish during deployment (table 7.3, page 49), once operational (table 7.4, page 50) there is the potential for longer term changes to the sediment and hydrodynamic regime from the subsurface and seabed devices. This has the potential to impact upon diadromous fish. Therefore, changes to the sediment and hydrodynamic regime during operation should be considered as potentially important for diadromous fish.	Noted, thank you. Diadromous fish are scoped out as a receptor for potential increased suspended sediment impacts and scoped in for potential changes to sediment and hydrodynamic regime, as detailed in Table 13-6.
NatureScot	The scoping report has focused on adult fish, which is appropriate for most fish as eggs/larvae are pelagic. However, herring and sandeels lay their eggs on the seabed and should be considered separately – due to the likelihood of suitable	Impacts to herring, sandeel eggs, and common skate are considered separately within the assessment, where appropriate due to their increased

CONSULTEE	COMMENT	EMEC RESPONSE
	habitat in proximity of the proposed site, especially for smothering from suspended sediments and drill cuttings.	vulnerability to seabed disturbance / smothering impacts. This is provided in Section 13.6.2.2.1.
NatureScot	We are content with the approach to the cumulative impact assessment, as outlined in Section 7.5.	Noted, thank you. The cumulative effects assessment is provided in Section 13.7.
NatureScot	The desk-based review suggested for the noise assessment in Section 7.6, page 54, should be sufficient for both deployment and decommissioning, for which the relevant impact pathway is drilling and disturbance from vessel activity/presence, for which there are relevant literature available. The assessment will need to be clear as to the level of installation activity, including likely duration of any simultaneous or sequential drilling.	The duration of construction activities has been considered in the assessment of underwater noise from foundation/mooring installation (see Section 13.5.4 and 13.6.2.1).
NatureScot	The scoping report suggests that a noise assessment for the operational and maintenance phase will be assessed by a desk-based review. The project envelope includes a wide range of tidal device types, and there is currently limited information regarding the sound characteristics of most devices. It may therefore be difficult to undertake this task solely by reviewing the literature.	Underwater noise modelling has been conducted for the operational turbines for the Project (Volume 2, Appendix D: Underwater Noise Modelling Technical Note). The most relevant threshold criteria for fish are presented in Popper *et al*. (2014). The operational noise of the turbines represents a continuous noise source, and for most fish groups, only qualitative threshold criteria are available, with the risk being 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). Only quantitative criteria are available for the “Fish with swim bladder involved in hearing” for recoverable injury (170 dB rms for 48 hours) and Temporary Threshold Shift (TTS) (158 dB rms for 12 hours) (Popper *et al.,* 2014). Therefore, quantitative noise modelling could only be conducted for this hearing group and for the recoverable injury and TTS impacts. This is considered to provide minimal additional value to the assessment given that it is unlikely that operational turbine noise from turbines would result in injury for fish (Lossent *et al.,* 2018). Therefore, the assessment of underwater noise is mostly qualitative and reference is made to underwater sound signatures from representative turbine models proposed for use at EMEC (e.g. Risch *et al*., 2020; 2023). The assessment has been informed by the best available scientific literature, including recent studies on individual turbine noise emissions, fish hearing sensitivity, and known avoidance behaviours. These sources provide a precautionary basis for evaluating potential impacts in the absence of site-specific cumulative noise data.

CONSULTEE	COMMENT	EMEC RESPONSE
		The qualitative assessment considers key factors such as sound propagation characteristics, device spacing, fish sensory capabilities, and the existing high-energy acoustic environment of the site. Together, these elements support the conclusion that while turbine noise may be detectable by fish, it is unlikely to result in significant adverse effects, particularly given the likelihood of avoidance behaviour and the rapid attenuation of sound with distance.
NatureScot	There may be some modelling required for operational noise. For example, the assessment should consider the worst-case scenario of 35 simultaneous devices operating in the area and what this may mean cumulatively for the soundscape of the Fall of Warness (i.e. consider the entire Fall of Warness as the array). This assessment is likely to need modelling. As with the installation assessment, this should consider the possibility of whether the operational noise could result in displacement/avoidance of the area. Useful references are provided in the footnote below.	Response as provided to NatureScot above, noting that up to 60 operational devices (40 small and 20 large) are now being assessed.
NatureScot	Collision risk modelling was discussed with EMEC at a recent meeting on 5 July 2022. We will continue to work with EMEC as they work through the detailed assessment.	Quantitative collision risk modelling has been conducted for Atlantic salmon and is presented in Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report. This has informed the assessment of potential injury or death from collision with turbine blades to Atlantic salmon in Section 13.6.3.6.
HRA SCREENING RESPONSE		
MD-LOT on behalf of Scottish Ministers	MD-LOT advises that due to the current uncertainty on distribution and behaviour of diadromous fish species within marine waters, these should be screened out from the HRA and instead must be considered through the Environmental Impact Assessment ("EIA") Report for the Proposed Development in line with the NatureScot representation.	Noted, impacts to Atlantic salmon are considered in the EIAR only and are screened out of the HRA, as outlined within the Fall of Warness HRA Screening Report (EMEC, 2022).
NATURESCOT WRITTEN ADVICE 2025		
NatureScot	NatureScot notes that the proposed study area for the fish and shellfish receptor (ICES rectangle 47E7) lacks justification, particularly regarding its spatial extent (10 km east, 15 km south). They recommend that the study area should instead be defined based on the maximum extent of impact pathways, such as suspended sediment concentration (SSC) or underwater noise, which typically influence fish and shellfish over greater distances. NatureScot highlighted two additional data sources that may be helpful in the assessment of impacts to this receptor (ScotMER and NatureScot Guidance Note).	Noted. For the purposes of assessing potential impacts on fish and shellfish within the EIA, the Study Area has been defined using ICES statistical rectangles rather than tidal excursion or suspended sediment concentration distances typically applied in benthic assessments. ICES rectangles provide a standardised spatial framework that aligns with fisheries data collection and management practices, allowing for the

CONSULTEE	COMMENT	EMEC RESPONSE
		integration of commercial landings data, stock assessments, and species distribution records. Using ICES rectangles for fish and shellfish ensures that the assessment is consistent with regional fisheries datasets, facilitates comparability across studies. Fish and mobile shellfish species often exhibit broad spatial distributions, with movements influenced by life stage, seasonal migrations, and environmental conditions rather than sediment transport or deposition. Therefore, in addition to ICES rectangle 47E7, rivers which have been identified as having potential connectivity to the Offshore Site, and adjacent ICES rectangles are included to provide perspective on overall habitat usage and extent of species which are present in waters relevant to the Offshore Site.
NatureScot	NatureScot acknowledges that the inclusion of: North-west Orkney NCMPA for sandeels, River Thurso, River Naver, River Borgie and Berriedale and Langwell SACs for Atlantic salmon (Salmo Salar) and River Foinaven and Little Gruinard SACs for freshwater pearl mussel, aligns with their Scoping advice for diadromous species. However, they note that it is unclear whether other relevant sites were considered and subsequently scoped out. They also recommend updating the names of protected sites to match those used in official Conservation Advice documents, such as: • Berriedale and Langwell Waters SAC • Foinaven SAC • Little Gruinard River SAC	Noted. Names of sites (Berriedale and Langwell Waters SAC, Foinaven SAC and Little Gruinard River SAC) have been amended throughout in line with official Conservation Advice documents (See Section 13.4.3.1). Due to the uncertainties around the migratory patterns of Atlantic salmon post-smolts and adult homing salmon, there is the potential for individuals from rivers further away (which may include other SACs) to be affected by the Project. However, only those on the north coast of Scotland have been specifically listed within this EIAR chapter as the most likely to have connectivity with the Project.
NatureScot	NatureScot is broadly satisfied with the impacts and receptors identified for assessment in relation to fish and shellfish ecology. However, they note that knowledge of diadromous and migratory fish species movements within Orkney waters is limited. Species such as European eel, sea trout, and Atlantic salmon are Priority Marine Features (PMFs) and are believed to be present in the area. These species should be considered in the assessment, taking into account their life history stages and potential impact pathways, including collision risk.	Noted. Potential impacts on diadromous fish, including Atlantic salmon, European eel and sea trout have been assessed, including EMF effects (See Section 13.6.3.4.2).

CONSULTEE	COMMENT	EMEC RESPONSE
	NatureScot also advises that potential impacts from Electromagnetic Fields (EMF) on diadromous and migratory fish should be included in the assessment. They acknowledge that understanding of EMF effects remains limited, particularly regarding in-field measurements and their implications for sensitive receptors. They highlight an ongoing ScotMER project aimed at improving understanding of EMF impact pathways, which may offer useful synergies with the current assessment.	
NatureScot	NatureScot supports the inclusion of marine shellfish as a receptor in the Environmental Impact Assessment (EIA) for both the installation/decommissioning and operation/maintenance phases. This is due to emerging research indicating that some shellfish species can detect particle motion, making them potentially sensitive to underwater noise. This approach aligns with NatureScot's previous Scoping advice. They also note that EIA will use underwater sound signatures from representative turbine models to assess worst-case cumulative impacts from 35 operational devices. However, NatureScot highlights that the current proposal involves 60 simultaneous devices (40 small and 20 large), not 35. It is therefore unclear whether the underwater noise modelling has been updated to reflect this increased number of devices.	Noted. The potential for impact from underwater noise from the 60 operational devices (40 small and 20 large) has been assessed in Section 13.6.3.2. While the assessment has taken a qualitative approach, this reflects the current evidence gap regarding the cumulative effects of underwater noise from large-scale tidal turbine arrays on fish, particularly in relation to behavioural and physiological responses. At present, there is insufficient empirical data to support a robust quantitative model for fish responses to cumulative underwater noise from tidal energy developments of this scale. In light of this, the assessment has been informed by the best available scientific literature, including recent studies on individual turbine noise emissions, fish hearing sensitivity, and known avoidance behaviours. These sources provide a precautionary basis for evaluating potential impacts in the absence of site-specific cumulative noise data. The qualitative assessment considers key factors such as sound propagation characteristics, device spacing, fish sensory capabilities, and the existing high-energy acoustic environment of the site. Together, these elements support the conclusion that while turbine noise may be detectable by fish, it is unlikely to result in significant adverse effects, particularly given the likelihood of avoidance behaviour and the rapid attenuation of sound with distance.
NatureScot	NatureScot advises that the potential for collision with tidal turbine devices should be assessed quantitatively for Atlantic salmon and qualitatively for all other diadromous fish species. They recommend referring to their guidance note titled "Assessing collision risk between underwater turbines and marine wildlife" to support this assessment.	Quantitative collision modelling has been conducted for Atlantic salmon and is presented in Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report. This has informed the assessment of potential injury or death from collision with turbine blades to Atlantic salmon in Section 13.6.3.6.

13.4 Baseline Characterisation

This section provides a description of fish and shellfish species of conservation importance, economic value and those which are particularly abundant in the Offshore Site. The characterisation of the current environment is established from a desk-based study and consultation with key stakeholders.

13.4.1 Study Area

The following areas are referred to in this impact assessment:

- Offshore Site – the area encompassing EMEC's Fall of Warness tidal test site and offshore export cable corridor, as defined;
- Fall of Warness tidal test site (tidal test site) - the area where the tidal units will be located within the Offshore Site, as defined;
- Offshore export cable corridor - the area within which the offshore export cable(s) will be located; and
- Study Area – The Study Area for Fish and Shellfish Ecology is identified as the International Council for the Exploration of the Sea (ICES) rectangle 47E7 boundary. In addition, rivers which have been identified as having potential connectivity to the Offshore Site, and adjacent ICES rectangles are included to provide perspective on overall habitat usage and extent of species which are present in waters relevant to the Offshore Site.

13.4.2 Sources of Information

A review was undertaken of the literature and data relevant to this assessment and was used to give an overview of all the existing environment. The key data sources used in the preparation of this chapter are listed below in Table 13-2. Other relevant grey and peer reviewed literature have also been reviewed and are referenced within the baseline characterisation where relevant. Section 13.6.1 details data gaps and uncertainties, and how these are mitigated within the assessment.

Table 13-2 Summary of key sources of information used to inform the Fish and Shellfish Ecology baseline

TITLE	SOURCE	YEAR	AUTHOR
Orkney Islands State of the Environment Assessment	https://www.orkney.gov.uk/our-services/planning-and-building/development-and-marine-planning-policy/marine-planning/state-of-the-environment-assessment/	2020	Orkney Islands Council
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*.
Updating Fisheries Sensitivity Maps in British Waters	https://www.gov.scot/publications/scottish-marine-freshwater-science-volume-5-number-10-updating-fisheries/documents/	2014	Aires *et al.*
Spawning grounds of Atlantic cod (*Gadus morhua)* in the North Sea	https://academic.oup.com/icesjms/article/73/2/304/2614292	2016a	González-Irusta and Wright
Spawning grounds of whiting (*Merlangius merlangus*)	https://pubag.nal.usda.gov/catalog/5733845	2016b	González-Irusta and Wright

TITLE	SOURCE	YEAR	AUTHOR
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	2019, 2020 and 2021	IHLS
Developing Essential Fish Habitat maps for fish and shellfish species in Scotland	https://www.gov.scot/publications/developing-essential-fish-habitat-maps-fish-shellfish-species-scotland-report/	2023	Franco, *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://www.gov.uk/government/statistics/uk-sea-fisheries-annual-statistics-report-2023	2024	MMO
JNCC SAC information	https://sac.jncc.gov.uk/	2020	JNCC
International Union for Conservation of Nature (IUCN) Red List of Threatened Species	https://www.iucnredlist.org/	2021	IUCN
ScotMER Diadromous Fish Evidence Map	https://www.gov.scot/publications/diadromous-fish-specialist-receptor-group/	2024	ScotMER
ScotMER Fish and Fisheries Evidence Map	https://www.gov.scot/publications/fish-and-fisheries-specialist-receptor-group/	2024	ScotMER
Diadromous Fish in the Context of Offshore Wind – Review of Current Knowledge & Future Research (and references therein)	https://data.marine.gov.scot/dataset/review-migratory-routes-and-behaviour-atlantic-salmon-sea-trout-and-european-eel-scotland%E2%80%99s	2024	Honkanen *et al.*
Salmon fishing: proposed river gradings for 2025 season	https://www.gov.scot/publications/salmon-fishing-proposed-river-gradings-for-2025-season/	2024	Scottish Government

13.4.3 Baseline Description

Aside from anecdotal observations during benthic surveys and seabed investigations, there has been no targeted survey of fish and shellfish within the Study Area. However, it is possible to make reasonable assertions as to the likely species to be present, based primarily upon the habitats and physical conditions at the site. Sources such as Coull *et al*., (1998) and Ellis *et al*., (2012) provide broadscale and generic information on spawning and nursery areas and times which has been corroborated by Franco, *et al.,* (2023).

13.4.3.1 Protected Sites

There are no Special Areas of Conservation (SACs) or Nature Conservation Marine Protected Areas (NCMPAs) for fish or shellfish features located within the area immediately adjacent to the Offshore Site. The closest protected relevant sites are detailed within Table 13-3. The river SACs in Table 13-3 have been selected as they have been identified as having potential connectivity to the Offshore Site due to the potential for diadromous fish emigrating from/returning to those rivers, in particular Atlantic salmon, to pass through the Offshore Site. However, due to the uncertainties around the migratory patterns of Atlantic salmon post-smolts and adult homing salmon, there is the potential for individuals from rivers further away (which may include other SACs) to be affected by the Project. However, only those on the north coast of Scotland have been listed here as the most likely to have connectivity with the Project. The relevant designated sites are shown in Figure 13-1.

Table 13-3 Summary of Fish and Shellfish Ecology features of designated sites

SITE NAME	SITE DESCRIPTION	RELEVANT DESIGNATED FEATURE	DISTANCE TO OFFSHORE SITE
North-west Orkney NCMPA	The primary qualifying species is sandeels. Newly hatched sandeel larvae from the North-west Orkney MPA are exported by currents to sandeel grounds around Shetland and south of the Moray Firth. Due to the distance between the Project area and MPA and the non-migratory nature of sandeels, the Project is not expected to interact with the NCMPA.	Sandeels	32 km
River Thurso SAC	There is considered to be some evidence of limited movement of Atlantic salmon into Orkney waters. As such, these protected sites will be considered in the forthcoming assessment.	Atlantic salmon	70 km
River Naver SAC	There is considered to be some evidence of limited movement of Atlantic salmon into Orkney waters. As such, these protected sites will be considered in the forthcoming assessment.	Atlantic salmon	100 km
River Borgie SAC	There is considered to be some evidence of limited movement of Atlantic salmon into Orkney waters. As such, these protected sites will be considered in the forthcoming assessment.	Atlantic salmon	101 km
Berriedale and Langwell Waters SAC	There is considered to be potential for connectivity to this SAC. As such, these protected sites will be considered in the forthcoming assessment.	Atlantic salmon	110 km
Foinaven SAC	There is considered to be potential for connectivity to this SAC. As such, these protected sites will be considered in the forthcoming assessment. The Project only has the potential to impact freshwater pearl mussel indirectly through effects on Atlantic salmon or sea trout.	Freshwater pearl mussel	145 km
Little Gruinard River SAC	There is considered to be potential for connectivity to this SAC. As such, these protected sites will be considered in the forthcoming assessment.	Atlantic salmon	210 km

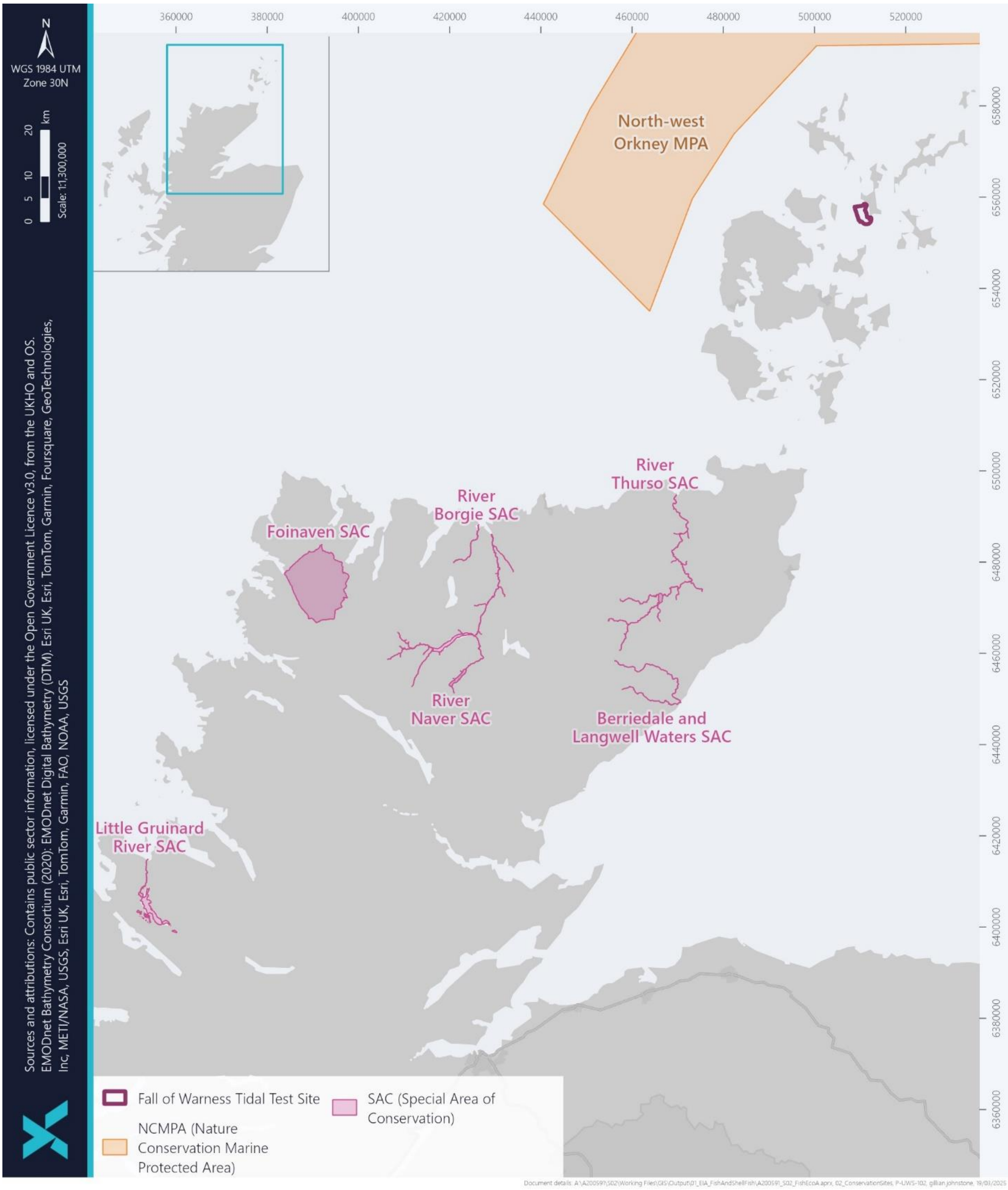

Figure 13-1 **Relevant designated sites for fish and shellfish receptors**

13.4.3.2 Overview of Seabed Habitat and Sediments

The predicted EUNIS broad-scale habitat classifications (2007 classification) within the Offshore Site are: Atlantic and Mediterranean high-energy (A4.1) and moderate energy (A4.2) circalittoral rock, and Atlantic and Mediterranean high-energy (A3.1) and moderate energy (A3.2) infralittoral rock (EMODnet, 2022) (see Volume 1, Chapter 8: Benthic Environment).

13.4.3.3 Fish and Shellfish Spawning and Nursery Grounds

The waters off the north of Scotland and within Orkney, where the Offshore Site is located, are potential spawning and nursery areas for a number of species of commercial and conservation importance (see Table 13-4; Figure 13-2; Figure 13-3; Figure 13-4). 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. The Scottish Government also released a new report on Essential Fish Habitat for fish and shellfish species in Scotland (Franco, *et al.,* 2023), detailing the potential for aggregations (presence or absence, high or low confidence).

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*) sprat (*Sprattus sprattus*) and herring (*Clupea harengus*) – all of which are potentially sensitive to impacts caused by the construction, operation and maintenance or decommissioning of tidal arrays due to seabed dependence (sandeel, herring) or noise sensitivity (herring, cod). Additionally, oviparous elasmobranchs, that deposit egg cases which subsequently hatch may also be vulnerable to disturbance. For example, the waters around Orkney are known to be important for common skate egg laying. The identification of two separate species previously known as common skate occurred in 2010, flapper skate (*Dipturus intermedius*) and blue skate (*Dipturus flossada*) (NatureScot, 2025). Flapper skate are distributed across the northern North Sea (including off the coasts of Orkney and Shetland) and off the north-west coast of Scotland. In contrast, blue skate have a more southerly distribution, although there is an overlap with the geographical range of flapper skate (Delaval *et al*., 2021). Considering the more southerly distribution of blue skate, the predominant species at the Offshore Site is expected to be flapper skate. However, for simplicity, and in line with the terminology used across several baseline data sources, the term common skate is used throughout this chapter.

As herring, sandeels and common skate 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, increases to suspended sediment and smothering, 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 Site.

Table 13-4 **Spawning and nursery grounds of fish and shellfish species within ICES rectangle 47E7 (Coull *et al*., 1998 and Ellis *et al*., 2012)**

FISH SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CONSERVATION IMPORTANCE (IUCN, 2021; OSPAR COMMISSION, 2022; JNCC, 2019)
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 PMFs
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 PMFs
Common skate	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (critically endangered) Scottish PMFs 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

FISH SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CONSERVATION IMPORTANCE (IUCN, 2021; OSPAR COMMISSION, 2022; JNCC, 2019)
Herring	N	N	N	N	N	N	N	SN	SN	N	N	N	Scottish PMFs 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 PMFs
Mackerel	N	N	N	N	N	N	N	N	N	N	N	N	Scottish PMFs Scottish Biodiversity List
Norway pout	N	N	N	N	N	N	N	N	N	N	N	N	Scottish Biodiversity List Scottish PMFs
Saithe	N	N	N	N	N	N	N	N	N	N	N	N	Scottish PMFs
Sandeels	SN	SN	N	N	N	N	N	N	N	N	SN	SN	UK List of Priority Habitats and Species Scottish Biodiversity List Scottish PMFs
Spotted ray	N	N	N	N	N	N	N	N	N	N	N	N	OSPAR List of Threatened and/or Declining Species and Habitats
Sprat	N	N	N	N	S*N	S*N	SN	SN	N	N	N	N	-

FISH SPECIES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CONSERVATION IMPORTANCE (IUCN, 2021; OSPAR COMMISSION, 2022; JNCC, 2019)
Spurdog	N	N	N	N	N	N	N	N	N	N	N	N	IUCN Red List (vulnerable) Scottish PMFs OSPAR List of Threatened and/or Declining Species and Habitats UK List of Priority Habitats and Species
Whiting #	N	N	N	N	N	N	N	N	N	N	N	N	Scottish PMFs UK List of Priority Habitats and Species Scottish Biodiversity List

S = Spawning, N = Nursery, SN = Spawning and Nursery; * = peak spawning; #= Species with a high nursery intensity as per Ellis *et al.,* 2012.

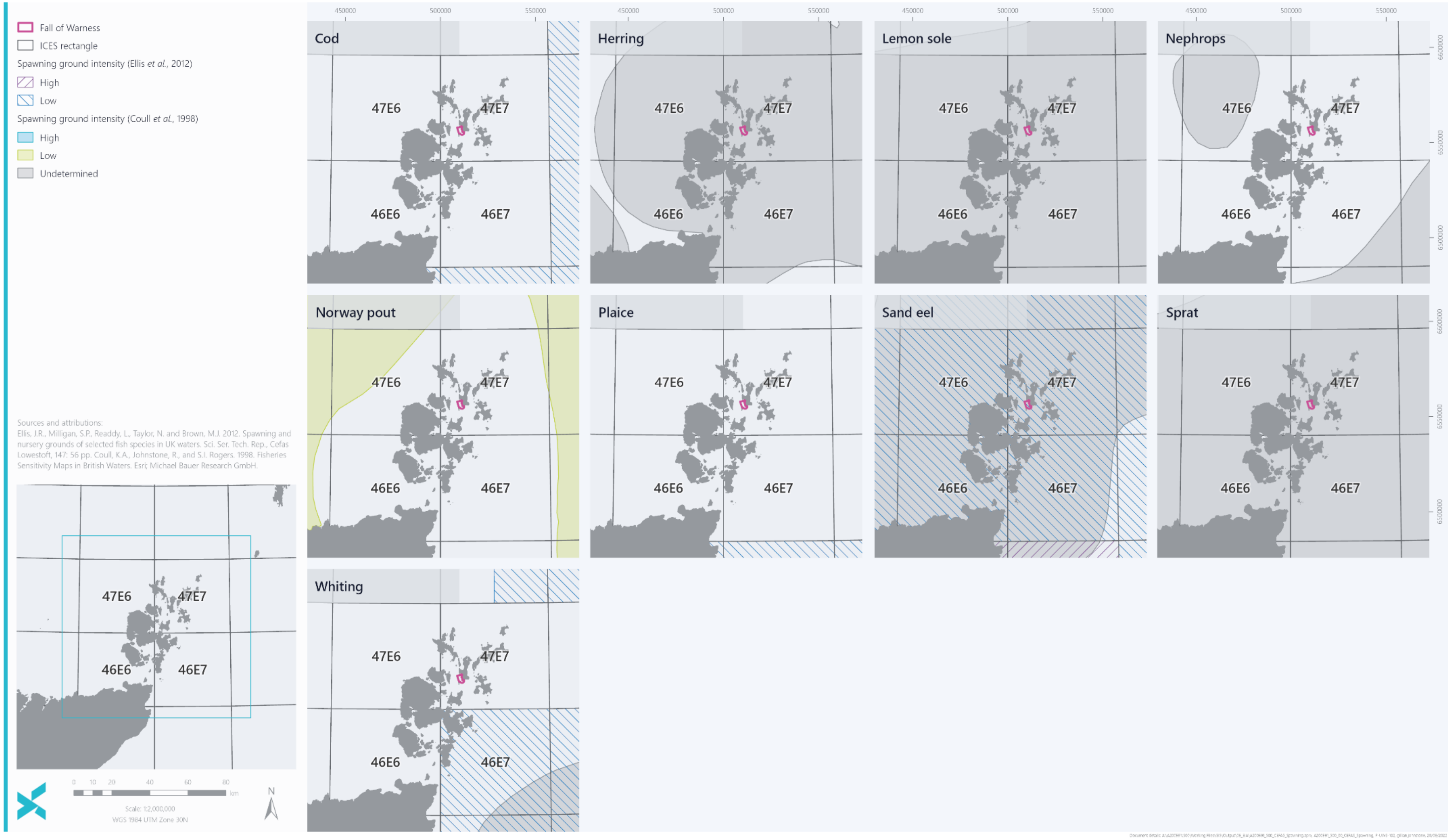

Figure 13-2 **Spawning grounds (Coull *et al*., 1998; Ellis *et al*., 2012)**

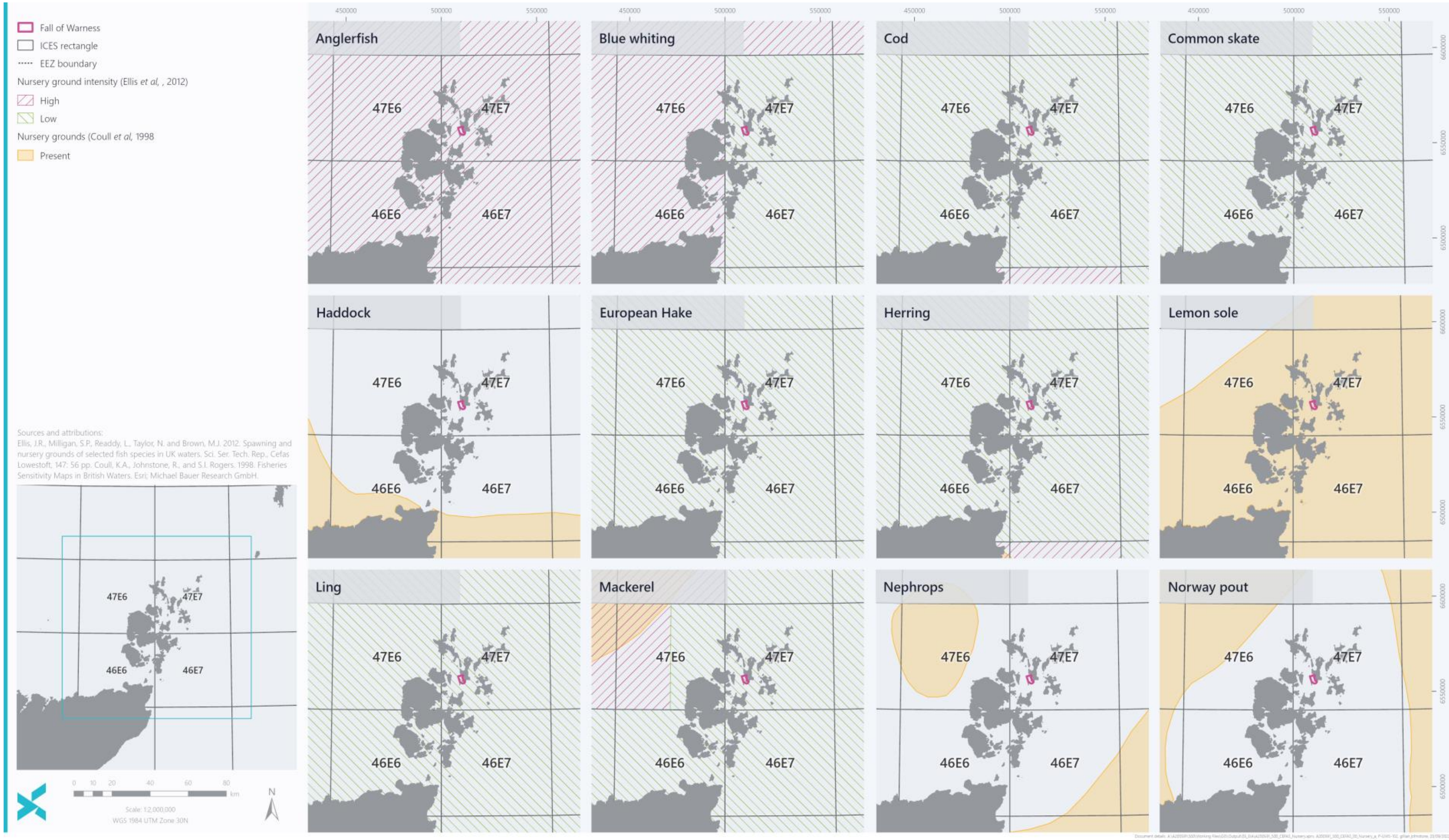

Figure 13-3 Nursery grounds part 1 (Coull *et al*., 1998; Ellis *et al*., 2012)

Figure 13-4 Nursery grounds part 2 (Coull *et al*., 1998; Ellis *et al.*, 2012)

Spawning grounds for cod, haddock and whiting have been further updated by González-Irusta and Wright (2016a; 2016b; 2017) (Figure 13-5). Due to the lack of spatial coverage within the Offshore Site for this data source, only data for the wider Study Area is available, including part of ICES Statistical Rectangle 47E7, within which the Offshore Site is located, and also in adjacent ICES Statistical Rectangles.

Within ICES Statistical Rectangle 47E7, there are some areas of recurrent grounds for cod spawning in the south east, however, the majority of this ICES rectangle is classified as occasional and unfavourable grounds for cod spawning. The same is true for ICES Statistical Rectangle 46E7. The majority of the ICES Statistical Rectangles 47E6 and 46E6 contain areas of occasional and rare grounds for cod spawning with sporadic areas of unfavourable grounds.

The ICES Statistical Rectangles 46E6 and 47E7 are predominantly classified as unsuitable for haddock spawning. ICES Statistical Rectangle 46E7, located to the south east of the Offshore Site, supports large areas predicted to be more important for haddock spawning. There are also some smaller areas located in the Stronsay Firth within close proximity of the Offshore Site, which support less important grounds for haddock spawning. The ICES Statistical Rectangle 47E6, located to the west of the Offshore Site, is characterised by a mix of varying grounds from less important to more important grounds for spawning haddock.

The data from the ICES Statistical Rectangles included within and adjacent to the Study Area support mostly grounds unsuitable for spawning whiting. There is an area, which has been classified as more important grounds for spawning whiting located within ICES Statistical Rectangle 47E7, to the east of the Offshore Site. There are also some smaller areas located in the Stronsay Firth within close proximity of the Offshore Site, which are classified as being unsuitable grounds for whiting spawning.

Additionally, Aires *et al*. (2014) use the findings of Coull *et al.* (1998) and Ellis *et al.* (2012) along with International Bottom Trawl Survey (IBTS) data, beam trawl survey data, IHLS data and other independent surveys to summarise the probability of aggregations of individuals in the first year of their life, known as 0-group, and/or larvae of key commercial species. The probability of 0-group aggregations occurring within the Study Area is presented in Figure 13-6. As described above for González-Irusta and Wright (2016a; 2016b; 2017), there is limited spatial coverage of the Offshore Site for this data source, with coverage of the wider Study Area only. The probability of 0-group aggregations is low to moderate for anglerfish, blue whiting, hake, herring, horse mackerel, mackerel, plaice, sole, and sprat, and moderate to high for cod, haddock, Norway pout, whiting (Aires *et al.*, 2014). Generally, there is a higher probability of 0-group aggregations for cod, haddock, Norway pout and whiting in and adjacent to Orkney waters (Figure 13-6).

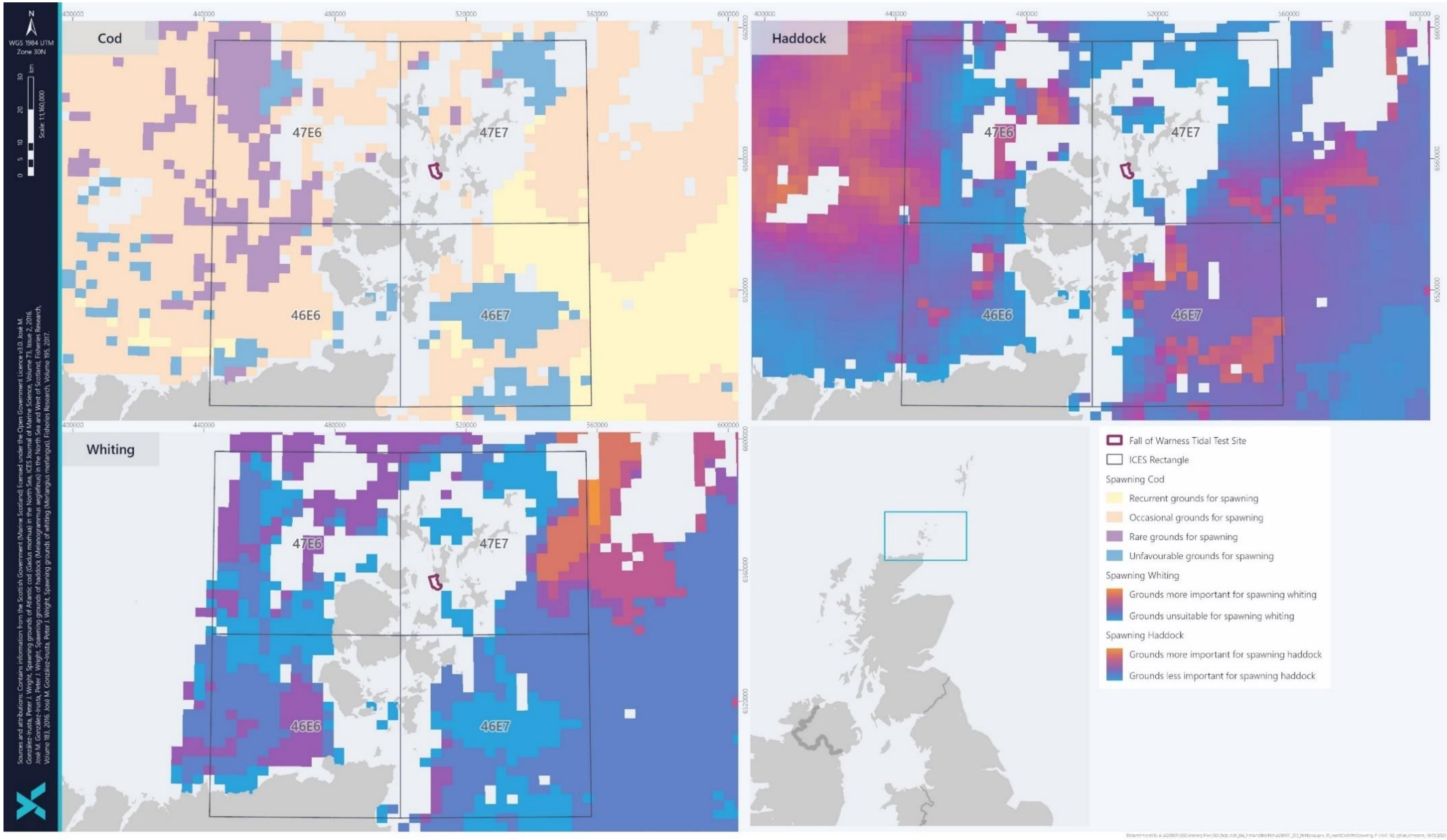

Figure 13-5 **Spawning grounds for cod, haddock, and whiting (González-Irusta and Wright, 2016a; 2016b; 2017)**

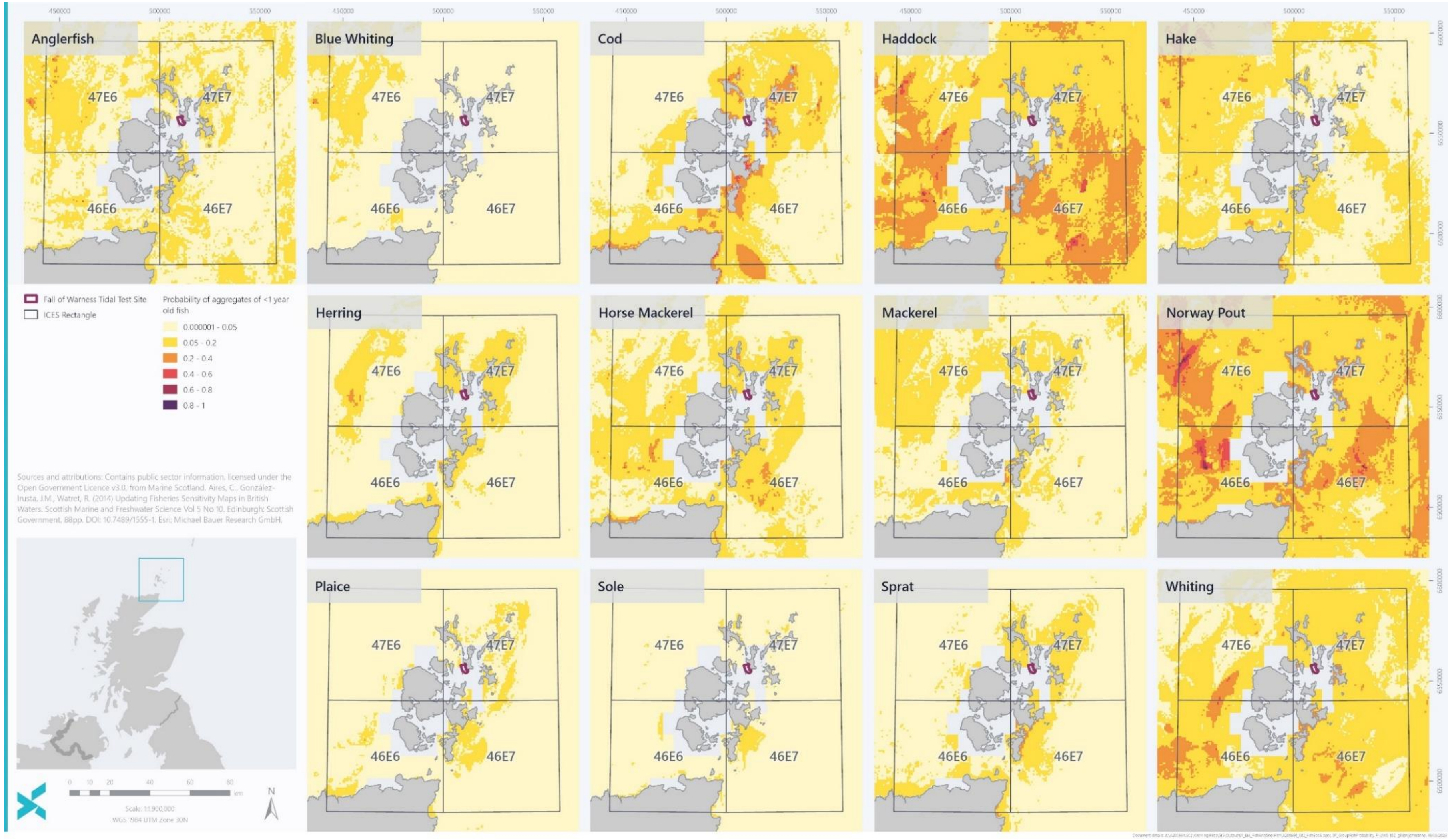

Figure 13-6 Probability of aggregations of 0-group fish (Aires *et al*., 2014)

13.4.3.3.1 Herring Spawning Habitat

Herring spawn on the seabed and gather in shoals in shallow water (less than 40 m depth) or offshore banks (up to 200 m depth), in areas of coarse sediments, gravel, and shells, to deposit their sticky eggs (Ellis *et al.,* 2012).

Herring spawn once per annum, over a short timeframe, across multiple waves. Herring congregate and each female produces a single clutch of eggs, resulting in an 'egg carpet' which may have several layers and cover a large area. The timeframe for eggs to hatch is dependent on the temperature of the sea but will usually last two to three weeks. Newly hatched herring larvae are dependent on reserves in the yolk sac and, as a result, stay on the seabed for a period between 3 and 20 days, until the yolk is absorbed. The yolk sac absorption rate is dependent on sea temperature (Russell, 1976). Once the yolk sac is absorbed, the larvae then become pelagic and utilise the surface currents to move towards nursery grounds (Dickey-Collas, 2004). Larvae experience a metamorphosis into juvenile herring between April and July (Dickey-Collas, 2004), maturing into adults at around 2-3 years (Frost and Diele, 2022).

The Study Area is mostly dominated by exposed rock, with little, if any, mobile sediment deposits. Therefore, the area is unlikely to be suitable for herring spawning. The suitability of sediments for herring spawning within the Study Area, using BGS broadscale seabed sediment data is shown in Figure 13-7, using the sediment preferences outlined in Kyle-Henney *et al.,* (2024) which identify the following sediment types as 'preferred' (i.e. favourable) and 'marginal' (i.e. suitable but less favourable) herring spawning habitat:

- Preferred: Gravel and sandy Gravel; and
- Marginal: gravelly Sand.

All other sediment types are predicted to be unsuitable for herring spawning.

The BGS broadscale seabed sediment data, shown in Figure 13-7, has limited spatial coverage within the Westray Firth. There are two small patches of marginal gravelly sand spawning habitat located to the south west of the Offshore Site, however, no data is available for the Offshore Site itself. In contrast, the outer seas surrounding Orkney contain a more varied habitat, including marginal gravelly Sand, preferred sandy Gravel, and sporadic small areas of Gravel.

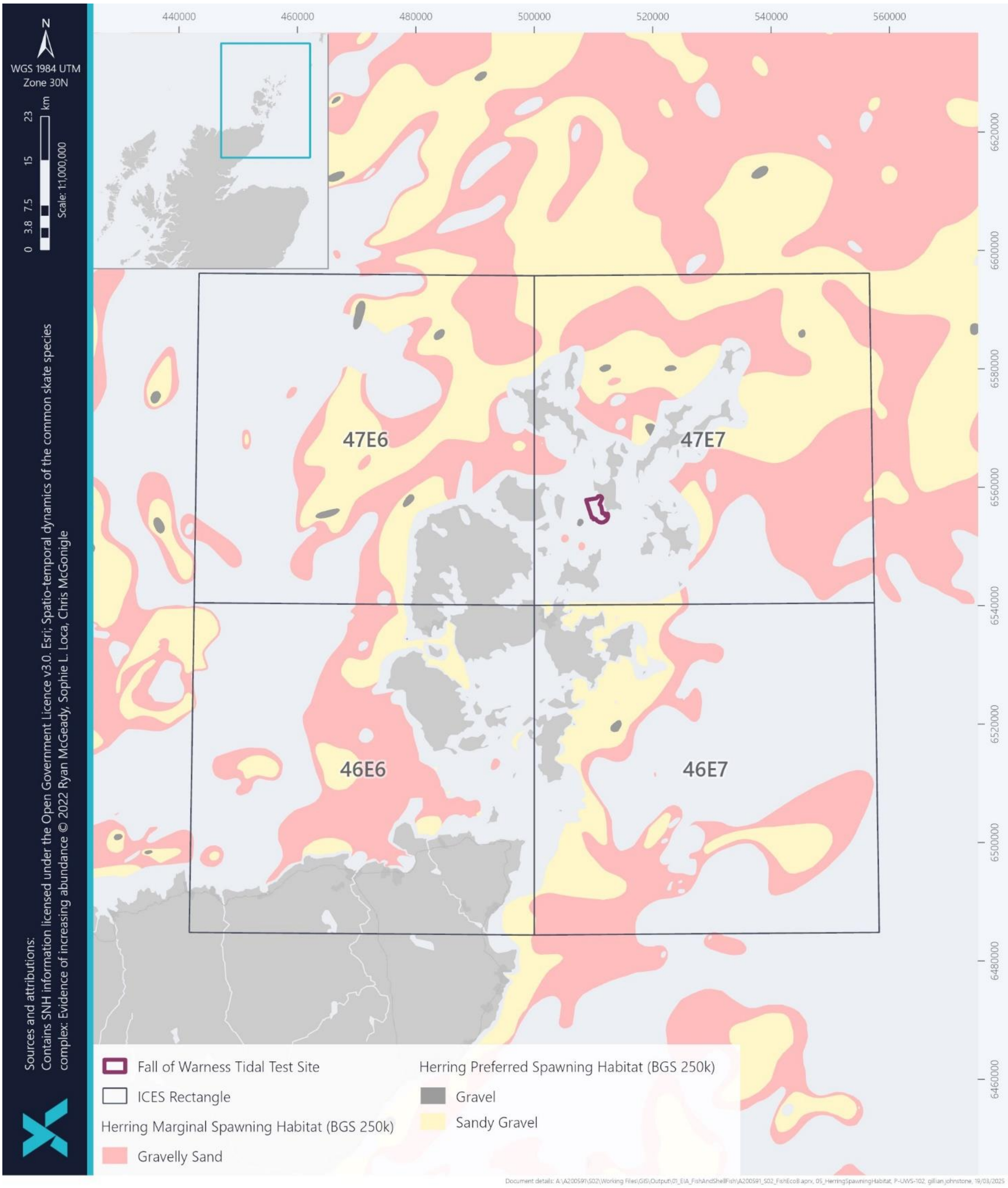

Figure 13-7 **Potential herring spawning habitat suitability**

13.4.3.3.2 Sandeel Habitat

Sandeel are dependent on the seabed for the majority of their juvenile and adult life cycles and inhabit burrows, except when feeding and spawning (Van Deurs *et al.*, 2011; Tien *et al.*, 2017). Sandeel spawning usually occurs in sandy sediments with a high proportion of medium and coarse sand, and a low silt content (Holland *et al.*, 2005; BEIS, 2022). Based on their dependence on the seabed, sandeel are generally considered to be sensitive to disturbance and habitat loss. The Scottish Government Feature Activity Sensitivity Tool (FeAST) states that sandeel have a high sensitivity to sub-surface abrasion or penetration and a medium sensitivity to surface abrasion (Scottish Government, 2023).

As described in Latto *et al.,* (2013) and Reach *et al.,* (2024), there is a substantial amount of broadscale suitable habitat for sandeel throughout the North Sea. Reach *et al*. (2024) assign the following sediment types are assigned as 'preferred' (i.e. favourable) and 'marginal' (i.e. suitable but less favourable) sandeel habitat:

- Preferred: gravelly Sand, Sand, and slightly gravelly Sand; and
- Marginal: sandy Gravel.

All other sediment types are predicted to be unsuitable for sandeel.

The Study Area is mostly dominated by exposed rock, with little, if any, mobile sediment deposits. Therefore, the area is unlikely to be suitable for sandeel spawning.

Figure 13-8 shows the BGS broadscale seabed sediment which characterises the area surrounding the Project. Based on the sandeel habitat preferences (Reach *et al.,* 2024), Figure 13-8 shows that there is very limited preferred habitat located in close proximity of the Offshore Site and within the Stronsay Firth and Westray Firth, noting the lack of spatial coverage for the BGS sediment data within Offshore Site. The preferred sandeel habitat increases significantly in the seabed surrounding Orkney with larger areas of preferred and marginal seabed habitat present.

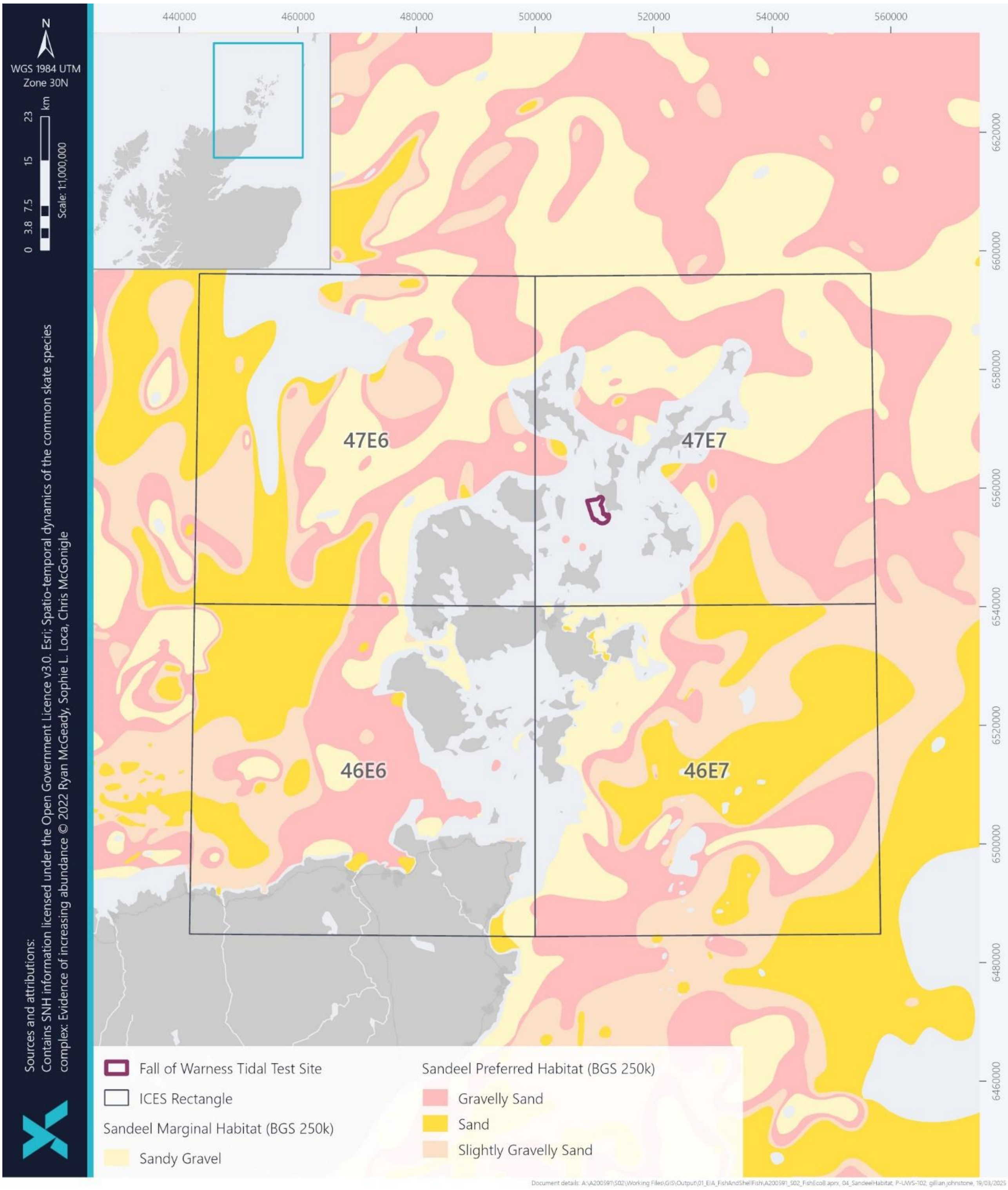

Figure 13-8 **Potential sandeel spawning habitat suitability**

13.4.3.3.3 Common Skate Habitat

As noted above, common skate are oviparous and lay egg cases on the seabed which subsequently hatch. Phillips *et al.,* (2021) characterised the habitat preferences for common skate egg laying in the waters around Orkney by analysing records of detached egg cases, diver observations and camera surveys. The preferred egg laying habitats identified by Phillips *et al*. (2021) were those with significant current flow (0.3 to 2.8 knots) with low sedimentation, boulder or rocky substrates and a water depth >20 m.

The Study Area is mostly dominated by exposed rock, with little, if any, mobile sediment deposits. Seabed depths range between 34 and 51 m within the Offshore Site and the average flow speeds on a neap and spring tide are approximately 1.4 to 3.6 m/s (i.e. 2.7-7.0 knots) (Volume 1, Chapter 7: Hydrodynamic and Physical Processes). Therefore, it is likely that common skate egg laying habitat maybe present in some parts of the Offshore Site. However, it is important to highlight that the predicted habitat preferences for common skate, described by Phillips *et al.,* (2021) are relatively broad and indicate the potential presence of common skate egg laying grounds, rather than confirmed locations.

13.4.3.4 Diadromous Fish

Atlantic salmon, sea trout and European eel are present in Orkney waters. Some of these may utilise rivers on Orkney (for salmon, this is restricted to larger rivers on Orkney Mainland and the island of Hoy). There is also a possibility that some diadromous fish in Orkney waters may utilise rivers on mainland Scotland.

13.4.3.4.1 Atlantic Salmon

Atlantic salmon is an Annex II species under the Habitat Directive and a qualifying feature of a number of Scottish rivers designated as SACs, such as those listed in Table 13-3. Atlantic salmon is also on the Scottish Biodiversity List species, a Scottish PMF species, and is of cultural, recreational and commercial importance in Scotland. Importantly, Atlantic salmon has experienced declines in populations across Scotland (Scottish Government, 2024; Adams *et al.,* 2022).

Atlantic salmon are diadromous, spending most of their adult lives at sea, returning to freshwater rivers during autumn / winter to spawn (MarLin, 2022a). 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 while they grow and transform to allow them to adapt to salt water. After maturing to approximately 12 cm in length at around two years old, they undergo a physiological change to enable them to live in sea water. Atlantic salmon (at this stage known as post-smolts) undertake their coastal migration to deep-sea feeding grounds, mostly located in the North Atlantic, in late spring to June (NatureScot, 2020a).

The migration routes of salmon leaving and entering river systems is currently not fully understood. The outward post-smolt migration to offshore feeding grounds occurs in April to June, with individuals spending either a single winter (One Sea-Winter (1SW) or grilse) or Multiple Winters (MSW) at sea. The offshore post-smolt migratory routes, patterns and behaviours is an area of growing research (e.g. Atlantic Salmon Trust West Coast and Moray Firth Tracking Projects and Newton *et al.,* 2021).

Unlike many other regions, Orkney does not have large rivers, therefore local salmon populations are limited. However, adult salmon returning to Scotland from northern marine foraging grounds do occur in the seas around Orkney and take a number of potential routes through and around the Northern Isles (Figure 13-99). They might take a route to the east of Shetland and Orkney *en route* to rivers emerging into the North Sea (route 1; Figure 13-9); they may approach to the west of Shetland and Orkney *en route* to rivers of western Scotland (route 2; Figure 13-9); or they may need to move east or west around or between the Northern Isles (routes 3, 4 and 5; Figure 13-9).

Although it is possible that salmon can and do take a route between the islands of Orkney (route 4; 9), it is likely that this is a very small proportion of returners, due to the alternative, less convoluted routes through the Fair Isle Channel (between Orkney and Shetland) or the Pentland Firth.

Figure 13-9 Potential routes taken by Atlantic salmon returning to Scottish rivers. The location of the Offshore Site is indicated by an orange dot.

A number of post-smolt tracking studies have been published in recent years which provide a greater insight into post-smolt migratory patterns. A study at the River Dee on the east coast of Scotland indicates that post-smolts travel in an easterly direction in their initial stage of migration, and the results of epi-pelagic trawling around the northeast of Scotland conducted by MD-SEDD also indicate that post-smolts are widely distributed across offshore area, with higher Catch Per Unit Effort (CPUE) off the east (Aberdeenshire and Angus) coast and lower catch rates in the outer Moray Firth (Main, 2021; Newton, 2021; Newton, 2023). Therefore, it is unlikely that post-smolts from this region interact with the Offshore Site. There is currently no equivalent published data on migratory patterns or aggregations of post-smolts in the vicinity of the Offshore Site, and therefore, the abundance or importance of the area for post-smolts remains unknown. Current tracking findings from Rodger *et al.* (2024) show that, overall, post-smolts from the rivers Solway, Clyde, Boyne, Bush, and Foyle, which enter the Irish Sea and Firth of Clyde, tended to migrate in a northerly direction, being detected passing through the North Channel at the northern end of the Irish Sea. Furthermore, evidence from the west coast of Scotland shows that smolts use a range of migratory routes in the initial stages of their migration, with some migrating through the Pentland Firth (Newton, 2025[3]). It is expected that post-smolts entering the sea from rivers on the west of north coast of Scotland could pass through the Pentland Firth and could occur within the Offshore Site.

It is expected that post-smolts utilise both passive drifting and active direct swimming on these migrations (Ounsley *et al.,* 2020: Newton *et al.,* 2017; McIlvenny *et al.,* 2021). The Wick Smolt Tracking Project (Del Villar-Guerra *et al.,* 2016) analysed the movement of salmon post-smolts in relation to marine renewable energy developments in northern Scotland. The study applied acoustic tagging to track migration patterns, revealing that post-smolts from different tributaries migrated at varying times and speeds, with most moving at night to avoid predators. The findings indicate that local tidal flows significantly influence smolt movement, but the fish were able to move away from these currents within a tidal cycle.

Atlantic salmon return to their natal river as adults to spawn, which usually occurs from November to December, but in some areas it can extend from October to February (NatureScot, 2024). There is limited information on migratory patterns of Atlantic salmon returning to natal rivers, however, it is expected that salmon may follow a convoluted route, entering multiple rivers in addition to their natal river (Honkanen *et al.,* 2024).

Given the relative size of the channel where the Offshore Site is located, only a small fraction of the returning salmon population is expected to pass through the broader channel. Based on an annual emigration of over eight million smolts (Xodus, 2012), approximately 104,000 post-smolts are estimated to migrate through the Offshore Site each year -around 1.25% of the total (Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report). This figure is likely conservative, considering the availability of alternative marine migration routes. Recent research by Newton *et al*. (2021) shows that Atlantic salmon post-smolts typically swim near the sea surface (mostly between 0.5 and 1.0 metres deep) at a speed of roughly 1.2 body lengths per second after leaving Scottish rivers (Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report).

13.4.3.4.2 Sea Trout

Sea trout, the sea-run form of brown trout (*Salmo trutta*) are also likely to be present in the Study Area and this species is also of conservation concern as it is on the IUCN Red List (Least Concern), a Scottish PMF species and UK BAP species. As per Atlantic salmon, this species also supports recreational and coastal fisheries in Scotland which have undergone a decline in catches over the last few decades (Moffat *et al*., 2020).

Sea trout are anadromous, 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, 2022b).

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 (Atlantic Salmon Trust, 2018). Female sea trout return to the rivers they were born in to lay their eggs in gravel depressions (NatureScot, 2022b). 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).

[3] Based on information presented by Newton (2025) at the 7th ScotMER Symposium. This data has not yet been published (as of July 2025) but is expected to be available in 2025.

13.4.3.4.3 European Eel

European eels are listed as Critically Endangered according to IUCN (2022) and are therefore a conservation priority. They are also a Scottish Biodiversity List species, a UK BAP species, an OSPAR Annex V species, and a Scottish PMF species. European eels are also diadromous but are catadromous, 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). A recent tagging study of silver eels in the Azores archipelago, an area *en route* to the Sargasso Sea from the northeast Atlantic, has shed light on European eel spawning migrations. Importantly, this study builds on previous evidence of European eel migration and further improves the understanding of the migratory routes used by this species (Wright *et al.,* 2022). Once the eggs hatch in the Sargasso Sea, larvae drift eastwards towards Europe. Most eels on the coast of Scotland are expected to be glass eels (juvenile eels prior to entering freshwater) destined for Scottish rivers. European eel remain in freshwater for more than 20 years before migrating to the Sargasso Sea to spawn (NatureScot, 2020b; Wright *et al.*, 2022). European eel may use the Study Area as a migratory route, and the nearshore areas as habitat.

13.4.3.5 Marine Fish

The Study Area is likely to support a wide range of marine fish species, some of which are Scottish PMFs. Different species will utilise the Offshore Site in different ways, not only for feeding and transit, but some potentially for reproduction or as a nursery ground. Pelagic fish are likely to include key species such as herring and mackerel. Demersal species are likely to include various gadoids (e.g. cod, saithe), butterfish (*Pholis gunnellus*), gobies and, on sandier substrates, sandeels. Elasmobranchs, including common skate and spurdog, may also be found. Diver observations during benthic surveys have made particular note of shoals of saithe. Each of these species are considered below.

13.4.3.5.1 Herring

Herring are a PMF, a Scottish Biodiversity List species due to its role as a key prey species (Franco *et al.,* 2023) and is known to be commercially exploited throughout the UK. The Orkney 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. Herring are demersal and deposit their sticky eggs on coarse sand, gravel, small stones and rock. As outlined in Section 13.4.3.3.1, the Study Area is unlikely to be suitable for herring spawning due the limited presence of mobile sediments (Figure 13-2). The 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, 2019; 2020; 2021), which is corroborated by Franco *et al*., (2023).

13.4.3.5.2 Mackerel

Mackerel are a Scottish PMF and a Scottish Biodiversity List species. Mackerel is a pelagic fish not dissimilar to herring in its ecological importance and in the manner in which it uses sites such as the Fall of Warness. Mackerel swim in large schools near the surface, and over winter, will move into deeper waters. In spring, they will then move closer to the shore when water temperatures range between 11-14 degrees (FishBase, 2022a).

13.4.3.5.3 Cod

Atlantic cod are considered to be a Vulnerable species on the IUCN Red List. They are also listed on the OSPAR List of Threatened and/or Declining Species and Habitats, UK BAP, on the Scottish

Biodiversity List, and Scottish PMFs. Cod are widely distributed species that are found in a variety of habitats. Juveniles are typically found in shallow depths between 10-30 m sublittoral waters with complex habitats, such as seagrass beds, areas with gravel, rocks, or boulder, which provide protection from predators (Franco *et al.,* 2023). Adults are typically found in deeper, cooler waters. Spawning occurs in winter and beginning of spring and occurs in offshore waters, at or near the bottom, in 50-200 m depth (FishBase, 2022b).

13.4.3.5.4 Saithe

Saithe occur in inshore and offshore waters. They enter coastal waters in spring and return to deeper waters in winter. Smaller fish typically stay in inshore waters to feed on small crustaceans and small fish, and adult saithe will prey on fish (FishBase, 2022c).

13.4.3.5.5 Butterfish

Butterfish is a small eel-like fish that is usual found in rockpools or shallow seas within the UK. Typically in winter they will descend to 100 m or more to spawn (November – January) (FishBase, 2022d). They usual feed on small crustaceans, molluscs and fish eggs (Wildlife Trust, 2022; FishBase, 2022d).

13.4.3.5.6 Common Goby

The common goby is considered to be a species of Least Concern on the IUCN Red List. This species is commonly found along all British and Irish coasts. Gobies are often found in depths down to 11 m in tide-pools, estuaries, salt marshes and brackish land-locked lagoons. The common goby prefers open water are of bare muddy or sandy sediment (MarLIN, 2022b).

13.4.3.5.7 Sandeels

The North West Orkney NCMPA is designated for the protection of sandeel. This NCMPA is 32 km to the west of the Offshore Site, west of Orkney mainland. 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), 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.

Langton *et al*. (2021) developed a distribution model for the lesser sandeel (*Ammodytes marinus*), aiming to predict the probability and density of buried sandeel across the North Sea. Using this model, sandeel are predicted to be patchily present throughout the Study Area, as shown in Figure 13-10, concentrated on the north and west coasts of Orkney (Langton *et al*., 2021). The distribution model does not overlap the Offshore Site directly, however, considering the seabed sediments present in the Offshore Site (see Section 13.4.3.3.2), there is considered to be a low potential for sandeel presence.

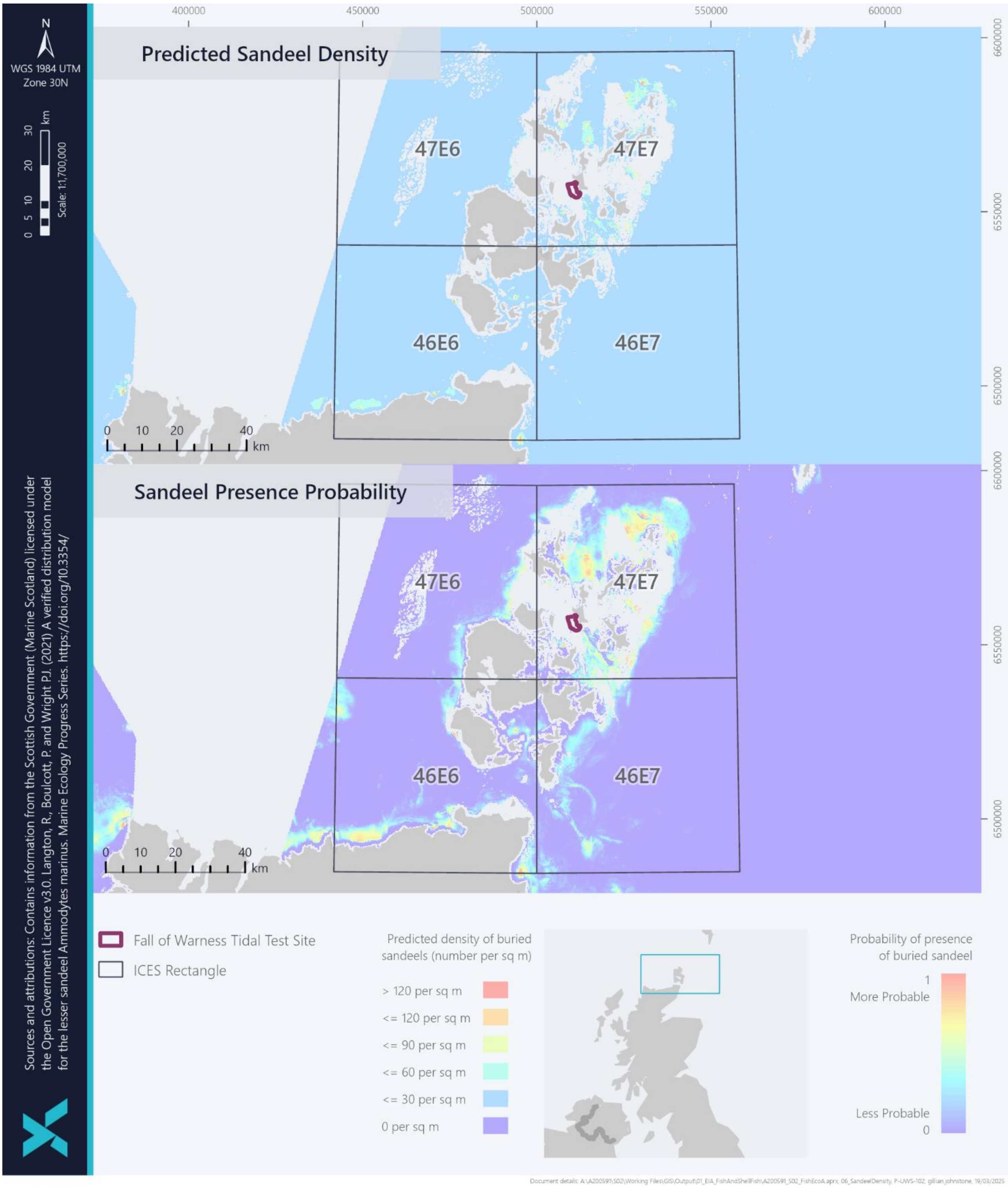

Figure 13-10 Predicted sandeel burrow density and presence probability (Langton *et al*., 2021)

13.4.3.5.8 Common Skate

Common skate (now recognised as two different species; blue skate and flapper skate, as previously outlined in Section 13.4.3.3.3) are considered to be a Critically Endangered species on the IUCN Red List, as well as being a Scottish PMF species, on the OSPAR List of Threatened and/or Declining Species and Habitats, a UK BAP species and Scottish Biodiversity List species. Common skate is one of the largest, yet most endangered elasmobranch species in the North-East Atlantic (NatureScot, 2022).

Common skate typically occupy waters at depths between 20 and 225 m and recent research on the west coast of Scotland indicates a migration to shallower waters (25 – 75 m) in winter months and a higher occupancy of deep waters (100 – 150 m) over summer (Thorburn *et al.,* 2021). A recent distribution model by McGeady *et al.* (2022) indicates that the Study Area has a relatively low potential for common skate presence. Importantly, this in the context of areas of much higher probability of presence for inshore areas to the west coast of Scotland.

According to McGeady *et al*. (2022) (Figure 13-11) the probability of common skate is higher off the west coast of Mainland Orkney and Hoy, in ICES Statistical Rectangles 47E6 and 46E6. The presence of common skate becomes less probable in the water to the east of Orkney. It is acknowledged that there is a lack of data coverage between the islands in Orkney. However, it can be assumed that there may be common skate present within the Stronsay Firth and Westray Firth, including the areas around the Offshore Site, although it is notable that no common skate were identified in the Baited Remote Underwater Video (BRUV) deployments in the south of the Westray Firth (Orkney Skate Trust, 2025).

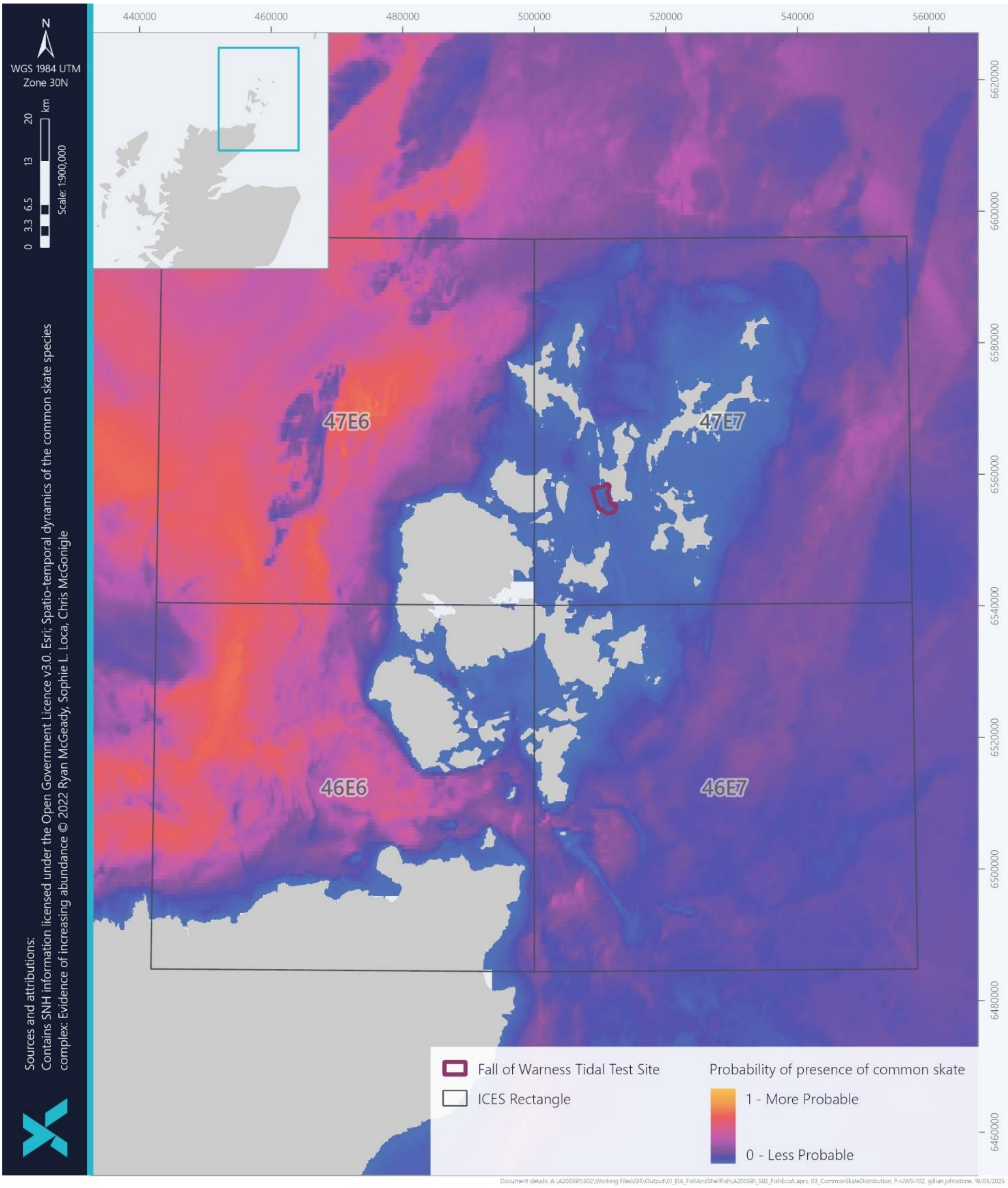

Figure 13-11 Probability of common skate presence (2018-2020) (McGeady *et al.*, 2022)

13.4.3.5.9 Spurdog

Spurdog are considered to be a Vulnerable species on the IUCN Red List, as well as being a Scottish PMF species, on the OSPAR List of Threatened and/or Declining Species and Habitats and a UK BAP species. Spurdogs are a small member of the dogfish family, and are widely distributed throughout the British and Irish coastal waters. They are benthopelagic species that occur in inshore and offshore of the upper continental shelf (MarLIN, 2022d).

13.4.3.6 Marine Shellfish

Diver observations during benthic surveys have observed scallops (on sandy/gravelly margins of site) and various crustaceans, including lobsters, brown crabs and squat lobsters (EMEC, 2014). The latter two are more likely to occur on the softer sand substrates. A variety of other less conspicuous and/or ubiquitous species are also likely to occur across the site, but are not expected to be unique to the locality.

13.4.3.6.1 Scallop

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).

13.4.3.6.2 European Lobster

European lobster can be found from the intertidal zone to 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. 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).

13.4.3.6.3 Brown Crab

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).

13.4.3.6.4 Squat Lobster

Squat lobsters are an abundant species that is not presently threatened (NWT, 2022; Rock Pool Project, 2022). Despite their name, this species is actually closer to a hermit or crab rather than a lobster. They are typically found in extremely low shore and sub-littoral, rocky environments. Squat lobsters are filter feeders and scavengers that eat both vegetable and animal matter.

13.4.3.6.5 Freshwater Pearl Mussel

Freshwater pearl mussel (*Margaritifera margaritifera*) is listed as Endangered on the IUCN Red list and is essential to aquatic ecosystems. Freshwater pearl mussel can be found in rivers throughout the UK, with the majority of the population found in Scotland (Moorkens *et al.,* 2024; NatureScot

2023). These large, long-lived filter feeders have a complex life cycle and are closely tied to juvenile salmonid fish (Atlantic salmon and sea trout) during the larval stage when they attach to the gills of salmonid fish (NatureScot 2023). Freshwater pearl mussel are highly sensitive to environmental changes and disturbances; however, they are particularly vulnerable to elevated suspended sediment levels and resulting sedimentation, which can smother and suffocate them. This risk is especially critical during their sedentary overwintering period when females brood their eggs.

Freshwater pearl mussel is a designated feature of the Foinaven SAC and Little Gruinard River SAC. Both of these sites are located 145 and 210 km (respectively) from their nearest point to the Offshore Site. The Project only has the potential to impact freshwater pearl mussel indirectly through effects on Atlantic salmon or sea trout.

13.4.3.7 Commercially Important Species

An indication of the characteristic commercially important species within the Study Area can be obtained from commercial landings data from the ICES statistical rectangle 47E7. Commercial fisheries landings data from ICES statistical rectangle 47E7 from 2019 to 2023 have been analysed to identify key commercially important species (MMO, 2024). However, it is acknowledged that an accurate representation of species composition cannot be provided by commercial landings data alone, as the data is influenced by factors, such as the fishing methods used, seasonality, quotas, bycatch and Total Allowable Catch (TAC) limits.

Between 2019 and 2023, pelagic and shellfish species dominated total recorded live weights (tonnes), while demersal species contributed less in terms of live weight and economic value (Table 13-5). Among pelagic species, herring was the most valuable, both in landed weight and economic importance, making it the key targeted pelagic species during this period. Herring fisheries peak seasonally in July and August (MMO, 2024). Other high-value targeted species included scallops, crabs, and lobsters (Table 13-5).

Demersal species of commercial importance in the area include haddock, cod, whiting, monkfish or anglerfish, plaice, and hake (*Merluccius merluccius*). Smaller quantities of saithe, ling (*Molva molva*), and red gurnard (*Chelidonichthys cuculus)* were also landed. These species are fished year-round, with peak landings occurring in autumn and winter (MMO, 2024). Notably, spurdog landings were recorded at a live weight of 139.95 tonnes in 2023.

Among shellfish, the most commercially significant species, in terms of live weight and value, include scallops, crabs, velvet crabs (*Necora puber*), green crabs (*Carcinus maenas*), *Nephrops*, whelk (*Buccinum undatum*), and lobster (MMO, 2024; Table 13-5).

Table 13-5 Top fish and shellfish species by Live weight (tonnes) and Value (Great British Pounds (£)) from 2019 to 2023 in ICES Rectangle 47E7 (MMO, 2024). Top three values from both weight and value are highlighted in blue, for each respective year.

SPECIES	YEAR									
	2019		2020		2021		2022		2023	
	LIVE WEIGHT (TONNES)	TOTAL VALUE	LIVE WEIGHT (TONNES)	TOTAL VALUE	LIVE WEIGHT (TONNES)	TOTAL VALUE	LIVE WEIGHT (TONNES)	TOTAL VALUE	LIVE WEIGHT (TONNES)	TOTAL VALUE
Mackerel	240.96	£185,355.20	18.34	£19,545.69	22.16	£12,587.83	10.95	£12,178.45	89.69	£68,506.45
Horse mackerel	7.64	£4,671.42	N/A	N/A	N/A	N/A	1.36	£909.54	6.27	£4,102.68
Herring	23,998.06	£13,760,310.89	10,391.71	£6,262,344.20	19,459.14	£12,724,693.12	27,611.35	£20,068,887.52	13,676.03	£9,478,378.20
Nephrops	0.97	£2,891.12	0.32	£663.03		£1,683.71	6.54	£21,529.66	1.94	£5,921.57
Haddock	125.67	£172,140.29	205.15	£283,788.65	26.26	£152,180.40	43.63	£32,041.58	34.14	£50,308.20
Cod	45.44	£120,776.34	40.05	£118,400.15	4.96	£17,216.32	1.36	£4603.51	13.00	£54,648.22
Monks or Anglers	5.41	£18,091.23	16.57	£49,726.85	3.69	£9,319.93	4.02	£13,498.04	1.80	£6,301.55
Saithe	4.48	£3,280.46	21.13	£22,971.84	3.15	£2,356.90	2.89	£3,939.06	1.50	£2,096.51
Scallops	237.00	£842,303.58	166.36	£573,568.96	291.30	£936,055.98	287.77	£1,095,230.53	304.23	£1,111,044.64
Crabs (C.P mixed sexes)	408.17	£786,446.93	240.50	£391,259.83	139.10	£258,476.82	125.95	£289,927.28	145.76	£397,179.70
Whelks	112.00	£135,131.87	153.44	£171,235.96	107.74	£106,824.14	N/A	N/A	140.00	£140,298.61
Plaice	5.40	£12,011.99	12.53	£20,925.77	6.01	£5,950.68	2.99	£6,004.41	5.80	£10,779.73
Ling	1.80	£3,306.84	1.76	£2,807.38	4.40	£6,628.77	1.81	£3,599.04	5.32	£13,969.14
Velvet crab	187.17	£564,227.08	175.84	£507,966.67	197.35	£653,829.06	206.57	£755,001.87	156.81	£664,979.51
Spurdog	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	139.95	£17,275.01
Lobsters	34.65	£471,519.75	43.18	£553,228.43	42.10	£644,995.51	47.05	£721,202.44	72.81	£1,104,454.06
Green crab	27.65	£24,407.32	26.29	£23,594.35	26.47	£25,832.70	15.51	£13,515.14	12.99	£14,950.22
Red gurnard	1.30	£495.93	0.08	£43.68	1.82	£844.60	0.05	£27.01	6.80	£7,764.40
Whiting	10.11	£11,229.47	47.54	£53,327.09	10.01	£16,463.71	1.51	£2,687.88	1.04	£1,090.70

13.4.4 Future Baseline

Section 13.4.3 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.

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 lifetime of the Offshore Site.

13.5 Assessment Methodology

13.5.1 Identified Receptors and Effects

13.5.1.1 Scoping Assessment Changes

Several amendments have been made to the impacts scoped in since the EIA Scoping Report (EMEC, 2022):

- Marine shellfish have been scoped in for underwater noise assessments. This is due to recent research suggesting some shellfish species are able to detect particle motion (Roberts *et al*., 2016; Miller *et al*., 2016), in addition to comments received in the Scoping Opinion (Table 13-1); and
- The benthic habitat loss/damage impact has been reworded to “spawning and nursery ground habitat loss/damage” to make it more specific to Fish and Shellfish Ecology receptors;.

13.5.1.2 Identified Receptors and Effects

The EIA Scoping Report outlined the potential activities / effect pathways regarded as ‘important’ or ‘potentially important’, representing the activities / effect pathways to be scoped in or out of this EIAR, respectively (EMEC, 2022). Receptors and potential activities / impact pathways identified during the Scoping process and to be assessed within this EIAR, in addition to those added back in as a result of comments received in the Scoping Opinion (MD-LOT, 2022) (Table 13-1) are summarised in Table 13-6.

Table 13-6 Summary overview of receptors and impact pathways scoped into the EIA

ACTIVITY POTENTIAL/IMPACT PATHWAY	DIADROMOUS FISH	MARINE FISH	MARINE SHELLFISH
CONSTRUCTION AND DECOMMISSIONING			
Installation vessel transits and manoeuvring leading to disturbance	Scoped out	Scoped out	Scoped out
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance	Scoped in	Scoped in	Scoped in
Increased suspended sediment/turbidity (including release of drill cuttings)	Scoped out	Scoped in	Scoped in
Smothering because of drill cuttings or re-settlement of sediments	Scoped out	Scoped in	Scoped in
Spawning and nursery ground habitat loss/damage	Scoped out	Scoped in	Scoped in
Introduction of marine non-native species (MNNS) via vessels, devices or other equipment	Scoped out	Scoped out	Scoped out

ACTIVITY POTENTIAL/IMPACT PATHWAY	DIADROMOUS FISH	MARINE FISH	MARINE SHELLFISH
OPERATION AND MAINTENANCE			
Vessel transits and manoeuvring as part of maintenance activities, leading to disturbance	Scoped out	Scoped out	Scoped out
Habitat creation and fish aggregation effect	Scoped out	Scoped in	Scoped in
Underwater noise from tidal devices operation	Scoped in	Scoped in	Scoped in
Changes to sediment and hydrodynamic regime	Scoped in	Scoped in	Scoped in
Introduction of marine non-native species (MNNS)	Scoped out	Scoped out	Scoped out
Electromagnetic Field (EMF) effects	Scoped in	Scoped in	Scoped in
Presence of tidal devices and associated infrastructure leading to a barrier effect	Scoped in	Scoped in	Scoped out
Collision with turbine blades leading to injury or death	Scoped in	Scoped in	Scoped out

13.5.2 Assessment Approach

The EIA process and methodology are described in detail in Volume 1, Chapter 5: EIA Methodology. Project specific criteria have been developed for the sensitivity of the receptor (incorporating value, vulnerability, adaptability, tolerance and recoverability). The magnitude of impact (incorporating likelihood, duration, frequency, seasonality and geographic extent) is set out in Table 13-7 and is also detailed in Volume 1, Chapter 5: EIA Methodology.

The sensitivity of the receptor is combined with the magnitude of impact to determine the impact significance, supported by expert judgement and industry best practice, to arrive at an impact significance for each impact under consideration. The significance of effect is then directly informed by the determined impact significance as summarised in Volume 1, Chapter 5: EIA Methodology. Within this EIAR, impact significance of moderate or greater is generally considered to lead to effects which are 'significant' in EIA terms, while impact significance of minor or negligible are considered to lead to effects which are ‘not significant’ in EIA terms.

Table 13-7 Magnitude criteria for Fish and Shellfish Ecology

MAGNITUDE	CRITERIA
High	Impact occurs over a large spatial extent resulting in widespread, long term or permanent changes in baseline conditions or affecting a large proportion of receptor / receptor population. The impact is very likely to occur and / or will occur at a high frequency or intensity.
Moderate	Impact occurs over a local to medium extent, with short to medium term change to baseline conditions or affecting a moderate proportion of receptor / receptor population. The impact is likely to occur and / or will occur at a moderate frequency or intensity.
Low	Impact is localised and temporary or short term, leading to detectable change in baseline conditions or noticeable effect on small proportion of receptor / receptor population. The impact is unlikely to occur or may occur but at low frequency or intensity.
Negligible	Impact is highly localised and short term with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or receptor / receptor population. The impact is very unlikely to occur and if it does will occur at very low frequency or intensity.
No Change	No change from baseline conditions.

Table 13-8 Sensitivity criteria for Fish and Shellfish Ecology

SENSITIVITY OF RECEPTOR	DEFINITION
Very High	• Receptor with no capacity to accommodate a particular effect and no ability to recover or adapt. Receptor is of high importance or rarity and / or is an interest feature designated at an international-level or located within a designated site. • Receptor has no ability to adapt behaviour so that individual vital rates (survival and reproduction) are highly likely to be significantly affected. • Receptor with a very limited distribution. Very highly dependent on a specific area.
High	• Receptor with very low capacity to accommodate a particular effect with low ability to recover or adapt. Receptor is of high importance or rarity and / or is an interest feature designated at an international-level or located within a designated site. • Receptor with a limited distribution. Highly dependent on a specific area.
Moderate	• Receptor with moderate capacity to accommodate a particular effect with moderate ability to recover or adapt. Receptor is of moderate importance or rarity and / or is an interest feature designated at a national-level and not located within a designated site. Receptor provides a pathway for impacts on high to very high sensitivity receptor. • Receptor with moderate distribution. Dependent on a limited area.
Low	• Receptor has some tolerance to accommodate a particular effect or will be able to recover or adapt. Receptor is of low importance or rarity and / or is not designated. • Receptor marginally and temporarily alters a pathway which modifies the supporting mechanism of designated interest features that are considered to have moderate to high capacity to accommodate a particular effect. • Receptor with extensive distribution. Ability to utilise a wider area.
Negligible	• Receptor is generally tolerant and can accommodate a particular effect without the need to recover or adapt. Receptor is of low importance or rarity and is generally abundant around the UK with no specific value or conservation concern. • Receptor with extensive distribution. Able to utilise a wide area.

13.5.3 Project Mitigation, Monitoring and Research

In addition to regulatory requirements, a number of designed-in measures have been proposed to reduce the potential for impacts to the environment. Embedded Project measures relevant to Fish and Shellfish Ecology are described in Table 13-9. As there is a commitment to implementing these measures, they are considered inherently part of the design of the Project and have therefore been considered within the completed impact assessment for Fish and Shellfish Ecology receptors in the determination of magnitude of impact. Therefore, significance of effects assumes implementation of these measures.

Table 13-9 Fish and Shellfish Ecology specific mitigation, monitoring or research requirements [

MANAGEMENT PLANS / EMBEDED MITIGATION	JUSTIFICATION	EMEC / CLIENT
	MANAGEMENT PLANS	
Project-specific Environmental Management Plan (PEMP)	Through the EIA process, conclusions have been drawn on the potential environmental impact of developing the Fall of Warness tidal test site. Where required, a monitoring or research programme will be put in place to provide further evidence to support the assessment conclusions and provide information for future sector developments. The PEMP will help to understand impacts arising from the Fall of Warness tidal test site test site on the topic receptors. Clients are expected to seek advice from EMEC and key stakeholders identified for each receptor topic regarding mitigation, monitoring and research activities that could be incorporated into their testing programme. The PEMP will be an interactive document and will be reviewed on a regular basis to ensure consent compliance is maintained and mitigation and monitoring measures reflect best available practices at the time.	EMEC
Construction Environmental Management Plan (CEMP)	A sub-plan within the PEMP, is the CEMP, which sets 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.	EMEC and Client
Operation Environmental Management Plan (OEMP)	A sub-plan within the PEMP is the OEMP, which will set out the procedures for managing and delivering the specific environmental commitments.	Client
Cable Plan	The Cable Plan will detail the location/ route and cable laying techniques for the Project. This will include information on cable protection that will reduce EMF effects by increasing the separation distance from the cables to the receptor.	EMEC
	EMBEDDED PROJECT MITIGATION	
Foundation design	Consideration of foundation options suitable to the environmental conditions and minimising adverse impacts.	Client
Minimum spacing of turbines within the Array Area	The Project has been designed in consideration of the minimum spacing of tidal devices to allow passage of marine mammals and fish through the area, avoiding the potential for a physical barrier effect and reducing the likelihood of an acoustic barrier.	EMEC
Regular inspection of operational devices	During the operation and maintenance phase of the Project, regular maintenance of tidal devices and associated infrastructure will be undertaken (approximately 3-12 months). This regular maintenance of devices will allow for the identification and timely removal of any lost or discarded fishing gear that has become entangled on Project infrastructure.	EMEC
Marine Pollution Contingency Plan (MPCP)	A MPCP will be prepared to provide guidance to personnel and contractors on the action and reporting requirements. Adopting these protocols will reduce risk	Client

MANAGEMENT PLANS / EMBEDED MITIGATION	JUSTIFICATION	EMEC / CLIENT
	in relation to spread of marine invasive non-native species (INNS) across all Project phases.	
Adherence with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention)	Ballast water discharges from vessels will be managed under the BWM Convention which aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control of ships' ballast water and sediments. This will be covered under the Marine Licence Process, specifically within the site-wide and device-specific PEMP.	EMEC and Client

13.5.4 Worst Case Scenario

Table 13-10 below presents the worst-case scenario for potential impact pathways related to Fish and Shellfish Ecology during construction, operation and maintenance and decommissioning phases of the Project. The worst-case scenario has been determined by considering the worst-case parameter values of Project components included within the Project Design Envelope that could interact with Fish and Shellfish Ecology receptors, ensuring a comprehensive assessment of the identified impacts. Where there are a number of options for the various Project Design Envelope properties, e.g. parameters relating to small or large devices, the worst-case scenario represents the option(s) which has the largest potential impact on Fish and Shellfish Ecology receptors.

Table 13-10 Worst Case Scenario (WCS) Impacts

POTENTIAL IMPACT PATHWAY	WORST CASE SCENARIO	JUSTIFICATION
CONSTRUCTION AND DECOMMISSIONING		
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance	• Anchor parameters: - Up to six anchors for large devices and four anchors for small devices, total of 280; - Maximum drilling duration per anchor (hours): 1.5; and - Maximum of four devices being installed simultaneously. • Cable landfall open cut trenching (OCT) over 24 months via jetting, rock cutting, mechanical trencher. • Vessel requirements: - Maximum of 15 vessels on site at any one time, including tugs, workboats, dive support vessels, survey vessels, anchor handler tub, jack-up barge, crane barge, and cable laying vessel.	These parameters represent the maximum duration and number of devices, anchors and other project parameters which have the potential to emit underwater noise during construction, which will be installed as part of the Project. Drilled anchors are selected as the worst-case anchor option over screw or gravity options as the option with the greatest potential to emit underwater noise during in construction. Furthermore, OCT is selected as the worst-case landfall method over HDD as this installation method will introduce underwater noise into the water column, whereas HDD works would predominantly be below the seabed. Further construction parameters are defined in Volume 1, Chapter 4: Project Description.
Increased suspended sediment/turbidity (including release of drill cuttings)	The worst-case scenario for this impact is presented in Volume 1, Chapter 7: Hydrodynamics and Physical Processes.	This covers the largest spatial area of impact associated with construction activities with the potential to disturb the seabed and the greatest potential to result in increases in SSC. Of the landfall options, the OCT solution, which may rely on jetting, rock cutting or use of a mechanical trencher will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to represent the maximum adverse scenario for sediment dispersion. In addition, OCT (when compared to HDD), requires greater volumes of material to be excavated and stored adjacent to the trench in the form of spoil berms. The worst-case scenario with regards to this impact is presented in full in Volume 1, Chapter 7: Hydrodynamic and Physical Processes.

POTENTIAL IMPACT PATHWAY	WORST CASE SCENARIO	JUSTIFICATION
Smothering because of drill cuttings or re-settlement of sediments	The worst-case scenario for this impact is presented in Volume 1, Chapter 7: Hydrodynamics and Physical Processes.	This covers the largest spatial area of impact associated with seabed preparation activities, construction activities with the potential to disturb the seabed, as these activities have the greatest potential to result in increases in SSC and associated resettlement of sediments. The worst-case scenario with regards to this impact is presented in full in Volume 1, **Chapter 7: Hydrodynamic and Physical Processes.**
Spawning and nursery ground habitat loss/damage	**Temporary impacts** • Cable landfall via OCT: - OCT excavation method: jetting, rock cutting or mechanical trencher. Excavated material is to be stored as sediment berms adjacent to the trench, with the trench backfilled on completion. Option includes for use of a cofferdam during landfall installation with a footprint of 37,500 m^2; - OCT seabed footprint (associated with unconsolidated material) (m^2): 2,000; - Trench volume associated with unconsolidated material (excavated footprint) (m^3): 2,175; and - Total berm seabed footprint (unconsolidated material) (m^2): 830. • Site preparation activities: - Total area subject to boulder clearance for all tidal devices (m^2): 112,500; - Total area subject to boulder clearance for all umbilical's (m^2): 300,000; - Total area subject to boulder clearance for export cables (m^2): 1,500,000; • Anchor installation: - Maximum drill volume of anchors for all devices (m^3): 5,000. **Total temporary impacted area: 1,952,830 m^2 (1.952 km^2).** **Long-term impacts** • Tidal devices: - Total maximum tidal device seabed footprint (m^2): 29,000;	These areas represent the largest spatial area and duration of impacts to the seabed that may result in loss/ damage to sensitive fish spawning and/ or nursery grounds. Any seabed disturbance associated with boulder clearance would be located within the areas where cable installation occurs. OCT represents the largest footprint of temporary impacts. However, for long-term impacts, the greatest seabed footprint is associated with HDD.

POTENTIAL IMPACT PATHWAY	WORST CASE SCENARIO	JUSTIFICATION
	- Total direct anchor seabed coverage for all tidal devices (m^2): 17,000; and - Total maximum protection footprint of anchors for tidal devices (m^2): 10,000. • Umbilicals: - Total seabed swept area for all umbilical's (m^2): 15,000; - Total maximum umbilical cable protection footprint (m^2): 120,000; • Export cable protection: - Maximum cable protection footprint, all cables (m^2): 750,000; • Protection for HDD pits: - Total concrete mass/rock placement for the HDD pits (m^2): 200; • Electrical hubs: - Total maximum seabed footprint of electrical hubs (m^2): 1,500; • Swept area of mooring lines: - Total seabed swept area for all mooring lines (m^2): 104,000. **Total long-term impacted area: 1,046,700 m^2 (1.05 km^2).**	
OPERATION AND MAINTENANCE		
Habitat creation and fish aggregation effect	• Device characteristics: - Number of simultaneous devices: 60 (40 small and 20 large); - Design Life 25 years; - Maximum surface area of device structures (m^2): 780; - Maximum device seabed footprint (m^2): 750 for large devices and 350 for small devices (29,000 m^2 in total); - Maximum spacing between devices (m): 15 (small devices) and 100 (large devices). • Subsea cables between devices and/ or electrical hub (umbilical cables): - Umbilical cable length per cable (km) per umbilical: 1; - Maximum number of umbilicals: 60; - Proportion of umbilical cable in water column per umbilical (m): 500; - Maximum umbilical cable protection width per umbilical (m): 4; - Maximum umbilical cable protection height per umbilical (m): 1; and - Maximum umbilical cable protection footprint (per umbilical) (m^2): 2,000; and	Subsea infrastructure from the presence of tidal devices and associated infrastructure can lead to habitat creation and fish aggregation effect. The area occupied by infrastructure both of the seabed and in the water, column may have this effect and therefore the primary parameters for defining this impact are based on the surface area of the Project infrastructure.

POTENTIAL IMPACT PATHWAY	WORST CASE SCENARIO	JUSTIFICATION
	- **Total maximum umbilical cable protection footprint (m²): 120,000** • Export cables: - Maximum number of export cables: 15; - Maximum length of each export cable (km): 5; - Minimum cable separation (m): 1; - Maximum cable protection width (m): 10; - Maximum cable protection height (m): 5; and - Maximum cable protection footprint, all cables (m²): 750,000 • Electrical hub parameters: - Maximum number of electrical hubs: 10; - Maximum seabed footprint per hub (m²): 100; - Width (m): 8; - Length (m): 8; and - Height (m): 8. • Anchor parameters: - Maximum number of anchors per device: 4 (small devices) and 6 (large devices); and - Total direct anchor seabed coverage for all tidal devices (m²): 17,000; and - Total maximum protection footprint of anchors for tidal devices (m²): 10,000. • Total concrete mass / rock placement for the HDD pits (m²): 200. **Total area new habitat created – 951,700 m² (0.951 km²).**	
Underwater noise from tidal devices operation	• Device characteristics: - Number of simultaneous devices: 60 (40 small and 20 large); - Maximum spacing between devices (m): 15; - Maximum rotor rotation speed (rpm): 30 (small devices) and 50 (large devices); - Monthly proportion of time operational (percentage): 85; and - Design life: 25 years.	These parameters represent the maximum number of devices, duration of design life and the monthly proportion of time the devices will be operational, and thus, represents the scenario with the greatest potential to emit underwater noise during the operation and maintenance phase.
Changes to sediment and hydrodynamic regime	The worst-case scenario for this impact is presented in Volume 1, Chapter 7: Hydrodynamics and Physical Processes.	The worst-case scenario with regards to this impact is presented in fill in Volume 1, Chapter 7: Hydrodynamic and Physical Processes.

POTENTIAL IMPACT PATHWAY	WORST CASE SCENARIO	JUSTIFICATION
Electromagnetic Field (EMF) effects	• Umbilicals - Umbilical cable length per umbilical (m): 1,000; - Maximum cable protection length per umbilical (m): 500; - Maximum number of umbilicals: 60; - Umbilical cable lay: surface laid; - Umbilical cable size (kV): 11; - Proportion of umbilical cable on seabed per umbilical (m): 500; - Maximum umbilical cable protection height per umbilical (m): 1; - Maximum umbilical cable protection width per umbilical (m): 4; - Maximum umbilical cable protection footprint per umbilical (m^2): 2,000. • Export cable - Maximum cable length (per export cable) (m): 5,000; - Maximum number of export cables: 15; - Minimum cable separation (m): 1; - Maximum cable protection length (per export cable) (m): 5,000; - Maximum cable protection width (m): 10; - Maximum cable protection height (m): 3; - Maximum cable protection footprint, all cables (m^2): 750,000; - Cable lay: surface laid; and - Cable size (kV): 33. • Operational life of 25 years.	The maximum number and length of umbilical and export cables will result in the greatest EMF effects.
Presence of tidal devices and associated infrastructure leading to a barrier effect	• Device characteristics: - Number of simultaneous devices: 60 (40 small and 20 large); - Rotor depth (m) (minimum rotor hub height above seabed / below sea surface): 2.5; - Maximum rotor blade width (m): 2.5 (small devices) and 3 (large devices); - Maximum rotor blade length (m): 7 (small devices) and 12 (large devices); - Minimum blade tip clearance above seabed (m): 2; - Minimum blade tip height below sea surface (m): 0.5; - Design life: 25 years; - Maximum device seabed footprint (m^2): 750 for large devices and 350 for small devices (29,000 m^2 in total); and - Maximum spacing between devices (m): 15 (small devices) and 100 (large devices).	Subsea infrastructure from the presence of tidal devices and associated infrastructure can lead to barrier effect for mobile marine species. The area occupied by infrastructure both on the seabed and in the water column may have this effect and therefore the primary parameters for defining this impact are based on the surface area of the Project infrastructure.

POTENTIAL IMPACT PATHWAY	WORST CASE SCENARIO	JUSTIFICATION
	• Electrical hub parameters: - Maximum number of electrical hubs: 10; - Maximum seabed footprint per hub (m^2): 100; - Width (m): 8; - Length (m): 8; and - Height (m): 8. • Mooring parameters: - Maximum number of moorings per device: 4 (small devices) and 6 (large devices); - Maximum length of each mooring line (m): 200 (small devices) and 600 (large devices; - Maximum length of mooring line on the seabed (m): 100 (small devices) and 300 (large devices); - Maximum mooring line swept area per device (m^2): 3,600 for large device and 800 for small device; and - Maximum total mooring line swept area (m^2): 104,000.	
Collision with turbine blades leading to injury or death	The worst-case scenario for this impact is presented in Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report.	These parameters represent the maximum worst-case scenario with regards to rotating turbine blade and the collision with mobile marine species, leading to potential injury or death during the operation and maintenance phase.

13.6 Assessment of Potentially Significant Effects

The Project Design is set out in Volume 1, Chapter 4: Project Description and the worst-case scenarios relevant to the impact assessment of Fish and Shellfish Ecology are detailed in Table 13-10.

13.6.1 Data Gaps and Uncertainties

Whilst worst-case seabed footprints for seabed preparation, devices and moorings are known, the total surface area (including vertical and underhanging surfaces) for each device and foundation is not known.

As noted in Section 13.4, there are several data sources that do not cover the Orkney inshore waters and/or do not cover the Offshore Site (e.g. Aires *et al*. 2014; Langton *et al*., 2021 and Franco *et al.,* 2023). Relevant information from these data sources has been used to understand the regional baseline and also to characterise the baseline environment within the Study Area.

A number of data gaps for Fish and Shellfish Ecology have been outlined in the two recently updated ScotMER evidence maps: fish and fisheries and diadromous fish (ScotMER, 2024a; 2024b). This includes:

- EMF:
    - There is currently a lack of understanding on current levels of EMF emissions from in-situ cables and relevance of some literature describing effects and impacts;
    - There are no policies or regulations related to EMF;
    - Lack of understanding on how pelagic and migratory species (e.g. sharks, fish) may react to dynamic cables (i.e. sections of cables suspended in the water column) (Copping *et al.,* 2020; Garavelli *et al.*, 2024); and
    - Sensitivity ranges for magnetic and electric field detection in general is better understood for some taxa, such as elasmobranchs, but less so compared to others, such as shellfish (Hutchison *et al*., 2020).
- Collision risk: observing animal behaviour around tidal devices is challenging, and there is limited field data on fish interactions with tidal turbines. To date, only a few observations have recorded fish coming into contact with turbines or other marine renewable energy infrastructure, with no evident harm. Consequently, collisions or close encounters between fish and turbines are considered rare (Xoubanova and Lawrence, 2022; Copping *et al.,* 2020; Copping *et al.*, 2023).
- Fish aggregation: there is limited research distinguishing whether fish aggregation around offshore renewable structures results from temporary sheltering or provides long-term ecological benefits, such as improved feeding, nursery, or spawning habitats. More studies are needed to understand how these changes in fish assemblages impact ecosystem dynamics and whether they lead to broader ecological benefits or unintended consequences (Xoubanova and Lawrence, 2022).
- Diadromous fish migrations: recent tagging studies, such as the West Coast Tracking Project[4] and the Wick Smolt Tracking Project[5], have been conducted on the east and west coasts of

[4] https://atlanticsalmontrust.org/our-work/west-coast-tracking-project/

[5] https://www.fcrt.org/wp-content/uploads/2021/04/Smolt-tracking-Report-FCRT-2016.pdf

Scotland. The majority of studies have however been conducted in coastal environments, providing an indication of smolt behaviour / movement from freshwater to coastal environments. Despite these studies, there is still limited available information on sea trout, European eel, and sea lamprey migration. Tagging studies have been conducted in rivers in the east of Scotland (e.g. Main, 2021), and data is also available via Marine Directorate's epipelagic trawl surveys for post-smolts at sea, yet the migratory patterns of Atlantic salmon remain relatively unknown and research is ongoing (ScotMER, 2024b). The collision risk assessment has been based on the assumption that a small proportion of returning adult salmon may pass through the tidal turbine array.

- Other data gaps and uncertainties, particularly in relation to diadromous fish include:
  - Migratory routes for Atlantic salmon, sea trout, European eel, river lamprey and sea lamprey juveniles and adults;
  - Specific timing of migrations;
  - The abundance / proximity of diadromous fish to the Project;
  - Salmon and sea trout post-smolt migratory behaviour (beyond the coastal environment) and migratory routes; and
  - River of origin of diadromous fish within the Study Area.

In recognition of the data gaps and uncertainties outlined above, the assessment within this chapter has taken a precautionary approach with regards to the species present within the Offshore Site and assumptions have been described. Any limitations in the data and our understanding of likely effects on fish and shellfish species are considered.

13.6.2 Effects During Construction and Decommissioning

13.6.2.1 Underwater Noise from Foundation/Mooring Installation Methods and Vessels Leading to Auditory Injury, Death or Disturbance

Sound generated during offshore construction activities, such as non-percussive drilling of anchors, is considered to be anthropogenic noise. Anthropogenic noise is now identified as a pollutant of international concern. Fish and shellfish disturbed by increases in underwater noise can affect acoustic communication, reproductive success, foraging, predator avoidance and navigation. In extreme cases, underwater noise can cause physical injury or mortality to fish and shellfish species.

Underwater noise has both a pressure and particle motion component. The majority of research on the impact of underwater noise on marine species focuses on the effects of sound pressure (Nedelec *et al.,* 2016); however, it is known that both physical properties of sound can be relevant to how fish detect sound (Popper *et al.,* 2014; Popper and Hawkins, 2018).

Fish with a swim bladder may also be able to detect sound pressure changes, as the gas within the swim bladder expands and contracts as a result of the sound pressure waves. Where the swim bladder is connected to the hearing system, or is in close proximity to it, this can result in greater hearing sensitivity as the swim bladder radiates additional particle motion (Popper *et al.,* 2014). Possession of a swim bladder also makes fish more prone to injury and, potentially, mortality via sound pressure-induced barotrauma. Fish without a swim bladder are generally not considered sensitive to sound pressure. However, all fish species are able to detect particle motion using otolithic organs in their inner ear, with species which possess a lateral line additionally being able to detect particle motion via the sensory hair cells contained within this structure (Popper and Hawkins, 2018).

The auditory system of shellfish is comparatively poorly understood, but it is believed they are primarily sensitive to particle motion, likely through sensory cells linked to hairs or statocysts, or via vibrations of their exoskeletons (Popper and Hawkins, 2018).

This section focuses on the underwater noise impacts from the following activities on sensitive fish and shellfish species:

- Non-percussive drilling during anchor installation;
- Open cut trenching (OCT);
- Cable laying activities (including placement of rock protection); and
- Construction vessels operational noise.

The worst-case scenarios of which have been outlined in Table 13-10.

For 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 drilled piles, noise emitted will be continuous resulting in considerably lower noise emissions than impact/hammer piling operations, owing to the pile being installed through rotary penetration and so giving rise to only low levels of noise and vibrations. Similarly, underwater sound associated with landfall activities (OCT, cable laying and cable construction vessels) also represent continuous sound sources. The sound characteristics of activities associated with construction phase of the Project have been presented in Table 13-11 and are based on the existing literature. Where a range of sound source levels were identified for an activity, a reasonable, realistic worst-case level has been assumed for the assessment.

Table 13-11 Characteristics of underwater sound sources generated during construction phase of the Project

UNDERWATER SOUND GENERATING ACTIVITY	FREQUENCY RANGE OF GENERATED SOUND (kHz)	INDICATIVE SOURCE LEVEL SPL ($SPL_{rms}{}^2$ dB re 1µPa) at 1 m
Non-percussive drilling	Main energy below 1 kHz	178 (Nedwell *et al.,* 2010)
Trenching (including OCT)	Main energy below 1 kHz	178 (Nedwell *et al.*, 2003)
Cable laying	Main energy below 1 kHz	188 (Wyatt, 2008)
Construction vessels	Main energy below 1 kHz	190.3* (Hannay *et al.*, 2004)
*** SPL for anchor piling vessel used as having the largest underwater noise footprint**		

The most common and best-studied continuous sounds in the oceans are those produced by ships as well as smaller vessels. 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.

The most relevant criteria for considering potential impacts on fish and shellfish from the construction activities are considered to be those provided in the Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*., 2014). The criteria for the different types of sources include a range of indices; Sound Exposure Level (SEL), root mean square (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 motion 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).

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).

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

- Group 1: Fish that lack swim bladders (e.g. flatfish, sharks, skates and rays) that are sensitive to particle motion and therefore only show sensitivity to a narrow band of frequencies;
- Group 2: fish with swim bladders that do not appear to play a role in hearing (e.g. salmonids and some tuna). Therefore, they are only sensitive to particle motion and only show sensitivity to a narrow band of frequencies;
- Group 3: Fish with swim bladders that are connected to the ear but not intimately connected (e.g. eels and some gadoid fish). These species are sensitive to both particle motion and sound pressure extending up to around 500 Hertz (Hz); and
- Group 4: Fish with structures mechanically linking the swim bladder to their ear (e.g. herring and sprat). 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.

The injury, impairment and behavioural impact criteria from Popper *et al.* (2014) for shipping and other continuous noise sources (Table 13-12) are relevant to the noise sources presented in Table 13-11. Qualitative criteria are presented for all impacts and species groups with the exception of recoverable injury and TTS for Group 3 and 4 fish. For all fish, the risk of mortality and injury is low even at near distances to the source (i.e. tens of metres). The risk of impairment is higher at distances near to the source with a moderate risk for Group 1 and 2 fish of TTS at tens of metres from the source and a high risk of masking effects at near of intermediate distances from the source (i.e. hundreds of metres) for all fish groups. The risk of behavioural impacts is moderate at distances near or intermediate to the source for all groups except Group 3 and 4 fish which have a high risk of behavioural impacts at near distances to the source (Popper *et al*. 2014).

Table 13-12 Fish impact thresholds to non-impulsive sounds (Popper *et al*., 2014)

TYPE OF ANIMAL	MORTALITY AND POTENTIAL INJURY	IMPAIRMENT			BEHAVIOUR
		RECOVERABLE INJURY	TTS	MASKING	
Group 1: Fish with no swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	N) Moderate (I) Moderate (F) Low
Group 2: Fish with swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	N) Moderate (I) Moderate (F) Low
Group 3 and 4: Fish with swim bladder involved in hearing (primarily sound pressure detection)	(N) Low (I) Low (F) Low	170 dB re 1 uPa (rms) for 48 h	158 dB re 1 uPa (rms) for 48 h	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	N) Moderate (I) Moderate (F) Low

Although elevations in underwater noise from drilling operations will occur, such operations will be short-term, relatively localised, and to some extent masked by the naturally loud environment in a tidally active channel with regular vessel traffic (see Volume 1, Chapter 15: Shipping and Navigation). There will be a maximum of four devices being installed simultaneously and a maximum drilling duration of 1.5 hours per anchor (i.e. 420 hours for 280 anchors) (Table 13-10).

The device types and substrate on site neither necessitate nor allow noisy pile-driving operations, which would otherwise have potential disturbance impacts (impact piling is explicitly excluded from the project envelope). The sections below present the assessment of underwater noise during the construction phase for all relevant receptors. Herring and sandeel have been assessed separately, as their ecology (i.e. demersal spawners), making them more vulnerable to impacts.

13.6.2.1.1 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.

13.6.2.1.1.1 Sandeels (Group 1)

Sandeels are demersal spawners and burrow into sediment. Therefore, they are considered to be stationary receptors.

Ellis *et al.,* (2012) data suggests the Offshore Site overlaps with low intensity sandeel spawning (Figure 13-2) and low density nursery grounds (Figure **13-4**) (Section 13.4.3.3). However, sandeel preferred habitats and spawning grounds are widely distributed across Scottish and English waters.

Sandeels are a protected species and are considered to have **moderate sensitivity** to underwater noise generated from construction activities, as according to Popper *et al*., (2014) criteria, the hearing sensitivity of Group 1 fish is low. Based on the localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. In addition, based on the short-term duration of construction events and the fact that noise will not be continuous throughout construction (i.e. there would be periods of quiet between drilling 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**.

As it is anticipated that the overall effect of underwater noise generated from construction activities on sandeel 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.

13.6.2.1.1.2 Herring (Group 4)

Herring are also demersal spawners and are a Group 4 species, meaning they are potentially sensitive to underwater noise. For these reasons Herring are also assessed separately to other fish and shellfish.

Herring are considered as stationary receptors as larvae and mobile receptors as adults. The IHLS estimates of herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2019; 2020; 2021). Ellis *et al.,* (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds (Figure 13-2) but overlaps with low intensity nursery grounds (Figure 13-3) (Section 13.4.3.3). 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. Therefore, the assessment below focusses on impacts to adult herring.

Herring are highly protected and are highly sensitive to underwater noise. However, considering herring are mobile species that are likely to flee the area, and 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 within the Offshore Site. Based on the highly localised spatial and temporal change and low frequency of construction events, which are intermittent and short term, impacts are unlikely to affect long term functioning of the herring populations. Therefore, for herring the **magnitude of impact** is defined as being **low** 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.

13.6.2.1.1.3 All Other Marine And Diadromous Fish Species

The remaining fish receptors (excluding herring and sandeel) are listed in Table 13-13, 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 Project 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.

Table 13-13 Fish receptors relevant to the Offshore Site

GROUP	FISH RECEPTORS RELEVANT TO THE OFFSHORE SITE
Group 1	Flatfish such as lemon sole, elasmobranchs, such as common skate, spotted ray, spurdog, and mackerel.
Group 2	Salmonids such as Atlantic salmon and sea trout.
Group 3	Gadoids such as cod, ling, saithe, whiting, blue whiting, hake, and European eel.
Group 4	Fish with structures mechanically linking the swim bladder to their ear (e.g. sprat).

When a fleeing animal is assumed, the range for mortality, potential mortality injury or recoverable injury decreases. 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.

Eggs and larvae are also potentially vulnerable to underwater noise and vibration due to their smaller size and limited mobility (Popper *et al.,* 2014). 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.

Many of the fish species predicted to utilise the Offshore Site are highly protected. However, the Offshore Site is not located within any peak or high concentration spawning grounds for any species. It does overlap with high intensity nursery grounds for anglerfish and whiting. Whiting are gadoids and are therefore classed a Group 3 species and are potentially sensitive to noise. The Offshore Site also overlaps with low intensity spawning and/or nursery grounds for several other gadoid species (cod, sprat, blue whiting, ling and saithe) (Group 3) and also 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 **moderate sensitivity** to underwater noise generated from construction activities at the Offshore Site. Based on the localised spatial and temporal change and low frequency of construction events, and on the basis that all of the species considered here are pelagic spawners, the **magnitude of impact** is defined as being **low**. In addition, the effect will be short-term, and therefore migratory success 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.**

13.6.2.1.1.4 Marine 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 Fish and Shellfish Rcology 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, not continuous. Considering this, as well as the widespread presence of the shellfish species present in the Study Area throughout UK waters, the **magnitude of impact** is defined as being **low**. Therefore, the overall effect is **minor** and **not significant**.

13.6.2.1.2 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 drilling noise and other continuous noise sources. 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 national 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 Site 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.

13.6.2.1.2.1 Sandeels (Group 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 (Figure 13-2) and low-density nursery grounds for sandeels (Figure 13-4), however, these grounds extend over a large area (Section 13.4.3.3). Construction activities will occur over a small proportion of this wider available habitat. According to the qualitive data provide by Popper et al., (2014), the risk of auditory masking in sandeel is expected to be high in the near and intermediate field (i.e. tens to hundreds of metres from the source), and the risk of behavioural effects are moderate in the near and intermediate field.

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 (Figure 13-2 and Figure 13-4). Considering this and the fact that sandeel have a low hearing sensitivity, according to Popper *et al.,* (2014) sandeels are assessed as having a **moderate 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 events, the **magnitude of impact** is defined as being **low**. In addition, based on the short-term duration (not continuous) of construction activities, any effects are unlikely to affect long term functioning of the sandeel populations, with recovery expected. Additionally, it is important to note that drilling activities will occur in areas of exposed bedrock which have no potential to support sandeels. Therefore, the overall effect to sandeel receptors is considered to be **minor** and **not significant.**

As it is predicted that there will be a minor and not significant impact on sandeel 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 bird species. Therefore, there will not be a significant impact upon predator species.

13.6.2.1.2.2 Herring (Group 4)

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 (Figure 13-2 and Figure 13-3). 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.

Herring are highly protected. The Offshore Site is not located in key herring spawning or nursery grounds and the impact will be short term and not continuous. Therefore, although behavioural effects or auditory masking in herring from drilling are expected to be low and moderate in the far field and moderate and high in the near field (Popper *et al*., 2014), herring are considered to have low vulnerability to drilling 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 construction activities at the Offshore Site. Based on the localised spatial and temporal change, low frequency of construction events, the **magnitude of impact** is defined as being **low**. 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, with recovery expected. 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 bird species. Therefore, there will not be a significant impact upon predator species.

13.6.2.1.2.3 All Other Marine And Diadromous Fish Species

For all other fish species, these are considered to be mobile receptors as discussed previously in Section 13.6.2.1.1, with the exception of eggs and larvae.

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 drilling activity. Considering the Popper *et al.,* (2014) criteria, the risk of auditory masking in fish species from continuous noise sources are expected to be high for Group 3 and 4 species, and high at all distances for Group 1 and 2 species except in the far-field (i.e. thousands of metres from the source) where the risk reduces to moderate. For Group 3 and 4 species, the risk of 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. Behavioural effects range from moderate at near or intermediate distances from the source to low at far distances from the source (Popper *et al.,* 2014).

For eggs and larvae, Popper *et al.,* (2014) assesses the relative risk of auditory masking to individuals as high at distances near to the source (tens of metres), moderate at distances intermediate to the source (hundreds of metres) and low at distances far from the source (thousands of metres). The risk of behavioural effects is moderate at distances near or intermediate to the source and low at distances far from the source.

Many of the fish predicted to utilise the Offshore Site are highly protected. Fish and shellfish species have a **moderate sensitivity** to underwater noise generated from construction activities at the Offshore Site. Based on the localised spatial and temporal change (not continuous) and low frequency of construction events, and given that all other fish species considered here are pelagic spawners, the **magnitude of impact** is defined as being **low.** 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.**

13.6.2.1.2.4 Marine shellfish

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. 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**.

13.6.2.2 Increased Suspended Sediment / Turbidity (Including Release of Drill Cuttings)

Project activities likely to result in seabed disturbance and increases in SSC include boulder clearance, anchor and mooring installation and landfall works. Cable laying and installation of any protection are not considered to bring about an increase SSC, and are therefore not assessed here. Disturbance footprints and volumes are described in detail in Volume 1, Chapter 7: Hydrodynamic and Physical Process and summarised below.

The proportion of the total disturbed sediment volume across the Offshore Site which will enter into suspension and be distributed in a temporary plume will be dependent on the nature and composition of the sediment within the Offshore Site (see Volume 1, Chapter 7: Hydrodynamic and Physical Processes for further details). Assumptions regarding tool parameters and aspects of the physical environment (e.g. flows and sediments), which all affect SSC and deposition, are fully described in Volume 1, Chapter 7: Hydrodynamic and Physical Processes.

Boulder clearance will result in low level mechanical disturbance of the seabed. There is an absence of loose sediment on the exposed bedrock at the Offshore Site and therefore, the increase in SSC from this activity is considered to be minimal. Any increase in SSC will be temporary and localised to the clearance event.

The worst-case seabed disturbance that is expected to cause an increase in SSC is in relation to drilling operations for seabed attachment mechanisms and foundation structures such as anchor pin-piles, which release drill cuttings on to the seabed. The volume of drill cuttings released will be up to 150 m^3 from drilling, per device, with a total of 500 m^3 for all devices. Drill cuttings would be flushed from the drilled pile hole, where finer material has the potential to disperse more widely, and coarser material would quickly settle out to form a cuttings mound. Disaggregation of the bedrock during drilling operations has the potential to generate material of varying sizes. As a worst-case assumption for widespread dispersion is that the material is comprised of 100% fine grains. Conversely, the associated conservative assumption for highest levels of deposition is that this material is comprised of 100% coarse grains (i.e. sands and gravels) (see Section 13.6.2.3). The most likely outcome is some combination of this, with material comprising both fine- and coarse-grained material.

The plume excursion distance associated with drilling activities is predicted to be a maximum of approximately 20 km with suspended sediments settling out over several hours, associated with peak flows of approximately 3.6 m/s. The flow speeds reduce with distance from the Offshore Site, and this decrease in flow speed will likely mean that sediment suspended during drilling operations has the potential to be transported over 20 km, rapidly depositing as the flow speeds reduce as the tide progresses. In reality, the plume would be very transient due to the high current flow regime in the Offshore Site, with sediment concentrations decreasing as suspended sediments are advected up to the indicated maximum distance, returning the SSC back to ambient concentrations of <1 mg/l.

In a similar fashion to drill cuttings, OCT or HDD at the landfall has the potential to increase in SSC. The excavation of unconsolidated and consolidated sediments has the potential to release sediments of varying sizes within the water column. For HDD, the excavated volume per exit pit is up to 360 m^3 per pit and 2,880 m^3 for all eight pits. Excavation of the exit pits would be completed using rock cutting or mechanical trencher or a backhoe excavator. OCT relies upon the use of jetting or rock cutting tools or a mechanical trencher due to the occurrence of hard substrate. Therefore, the potential sediment disturbance associated with the landfall works could be greater associated with OCT. It is anticipated, where unconsolidated material prevails a maximum trench width of 16 m and trench depth of 1.45 m will occur, with a narrower and shallower trench associated with consolidated sediments / bedrock. Consequently in unconsolidated sediments trenching would displace up to 2,175 m^3 of material for all 15 export cables, whereas if soils are found to be consolidated the volume of material displaced would be significantly reduced due to the proposed smaller trench (see Volume 1, Chapter 4: Project Description). Due to the potential use of jetting tools, OCT has therefore been considered as the worst-case, despite the larger volume associated with HDD. Given the flow speed of up to 0.5 m/s near the landfall and surficial sediment of medium sand, the majority of sediment disturbed as a result of jetting (with material being ejected up to 5 m above the seabed) would only be transported in suspension approximately 50 m before resettling. With fine sand, material would travel approximately up to 250 m before settling out, while gravels would be redeposited within a few metres. The low proportion of fines i.e. silts and clays could be transported up to 2.5 km in the direction of the tidal flow. Instantaneous concentrations associated with the initial disturbance would potentially be hundreds of thousands of mg/l, but as the coarse material quickly settles out and fine sediments are rapidly advected, SSC would quickly return to background levels of a few mg/l within hundreds of metres of the disturbance.

As has been stated previously, the Offshore Site lies within a spawning area for herring, sprat, sandeel and lemon sole, a potential common skate egg laying ground (Figure 13-2) and is a nursery site for sixteen species (Figure 13-3 and Figure 13-4). As has been described in Section 13.4.3.3, these species' spawning and nursery areas extend widely beyond the Offshore Site and Study Area, covering large portions of Scottish and English waters and therefore any disturbance from construction activities associated with the Project will affect only a small proportion of available habitat (Coull *et al.,* 1998, Ellis *et al.,* 2012).

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 on common skate due to their reliance on the seabed for laying egg cases; therefore, these species are considered separately below.

13.6.2.2.1 Marine fish

Herring and sandeel are the most sensitive to increases in suspended sediments and turbidity as they are demersal spawners and their eggs are not mobile, which could lead to smothering of any spawned eggs. Sandeel also remain in burrows for the majority of their juvenile and adult lives and may be susceptible to smothering.

13.6.2.2.1.1 Sandeels

Sandeels are also demersal spawners and are known to burrow into the sediment as juveniles and adults. Ellis *et al.,* (2012) data suggests the tidal test site overlaps with low intensity spawning and nursery grounds (Figure 13-2). 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 Site will affect only a small proportion of available habitat.

Sandeels are considered to be high value receptors as a Scottish PMF species with a **moderate sensitivity** to increases in SSC and turbidity associated with Project activities as they are demersal spawners. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, since any impacts are unlikely to affect long term functioning of the sandeel population. Therefore, the overall effect to sandeels is considered to be **minor** and **not significant.**

13.6.2.2.1.2 Herring

Herring eggs have been reported to be sensitive to increases in suspended sediments (Faber *et al.,* 2007). The IHLS estimates herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2019; 2020; 2021). Ellis *et al.* (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds (Figure 13-2) and overlaps with low intensity nursery ground (Figure 13-3). 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 considered to be high value receptors as a Scottish PMF species with a **moderate sensitivity** to increases in suspended sediments and turbidity at the Offshore Site as they are demersal spawners. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, since any impacts are unlikely to affect long term functioning of the herring population. Therefore, the overall effect to herring is considered to be **minor** and **not significant.**

13.6.2.2.1.3 Common Skate

Adult skate can navigate away from areas experiencing short-term increases in SSC, and low levels of sedimentation are unlikely to affect either adults or their egg cases (Scottish Government, 2025). Based on this assessment, common skate are considered to have a low vulnerability to increased SSC and associated deposition. When factoring in the international importance of common skate as a critically endangered species, they are assessed as having a **moderate sensitivity.**

Any increases in SSC and associated smothering would be temporary, intermittent and highly localised. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, since any impacts are unlikely to affect long term functioning of the common skate population. Therefore, the overall effect to is considered to be **minor** and **not significant.**

13.6.2.2.1.4 All Other Marine Fish

All other marine fish species other than herring, sandeel and common skate are less vulnerable to increases in suspended sediments and turbidity. 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 SSC 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.

Therefore, other marine fish species are considered to be of **low sensitivity** to increases in suspended sediments and turbidity within the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. Many other marine fish species within the are considered to be high value receptors due to their conservation status. However, all other marine fish species have low sensitivity to increases in suspended sediments and turbidity, since any impacts are unlikely to affect long term functioning of the other marine fish species populations. Therefore, the overall effect to all other marine fish species is considered to be **minor** and **not significant.**

13.6.2.2.2 Marine Shellfish

Mobile crustaceans can move away from areas of increased suspended sediment / turbidity (although to a lesser extent in comparison to most fish) and mortality as a result of increased SSC is considered unlikely (Neal & Wilson, 2008). However, shellfish with reduced mobility such as buried crab, lobster, and scallops are vulnerable to increased SSC. Increased suspended sediment / turbidity 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).

Therefore, shellfish are considered to be of **moderate sensitivity** to increased suspended sediment / turbidity at the Offshore Site. However, the impact to shellfish will be localised to the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. Since any impacts are unlikely to affect long term functioning of the shellfish population. Therefore, the overall effect to shellfish is considered to be **minor** and **not significant.**

13.6.2.3 Smothering Because of Drill Cuttings or Re-Settlement of Sediments

The production of drill cuttings, in addition to disturbance of existing seabed surface sediments during construction operations, introduces the potential for smothering of receptors as disturbed material settles on the seabed within the Study Area. As described above and in Volume 1, Chapter 7: Hydrodynamic and Physical Processes, boulder clearance may result in a low level of mechanical disturbance to the surface of the seabed only. Therefore, this section focusses on the potential presents of drill cuttings piles following anchor installation and spoil berms following landfall works.

The substrate across most of the tidal test site is bedrock and boulders, with little to no sediment cover. Volume 1, Chapter 7: Hydrodynamic and Physical Processes presents the assumed grain sixes and associated settling velocities for fine, medium and coarse sediment. As a worst-case, it is assumed that material is comprised of 100% coarse grains (i.e. sands and gravels), which will result in the highest level of deposition but only a limited dispersion.

If any drill cuttings mounds are formed, the sediment contained within the mound would most likely be winnowed down and dispersed in the water column due to the fast flow tidal environment. The worst-case cuttings mound footprint was based on the assumption of up to four drill cuttings piles for a small device and six drill cuttings piles for a large device. Estimated drill volumes for the small and large devices are 50 m^3 and 150 m^3 per small and large device, respectively. The total direct seabed coverage for all the devices of 23,037 m^2 (see Volume 1, Chapter 7: Hydrodynamic and Physical Processes).

In addition to the frequent exceedance of sediment settling velocities during normal conditions, periodic natural storm events are expected to entrain sediment that is present in more sheltered areas of the Offshore Site. These events are also likely to mobilise sediment from outside of the Offshore Site into the water column, which may then pass through or potentially be deposited within the Offshore Site once energetic conditions subside. Following such events, any sediment deposited in areas of the Offshore Site experiencing regular high current speeds will likely be re-suspended and transported northwest or southeast out of the Fall of Warness channel, or re-settle in one of the more sheltered locations within the Study Area, such as Sealskerry Bay.

Spoil berms constructed during HDD or OCT landfall, have the potential to generate temporary mounds of approximately 20 m wide and 5 m high, adjacent to the trench. This will be limited to a maximum duration of 12 months, with the seabed and intertidal area reinstated on completion of these works. Any fine sediment contained within the sediment berms constructed adjacent to the trench, could be winnowed away, leaving just the coarser material, which would be used to reinstate the seabed. The drilling and the excavation works at the landfall are not predicted to cause any alteration of seabed characteristics as the same geology occurs throughout the drill (or excavation) depth and will deposit sediment cuttings of the same sediment type.

Based on the flow axes through the Fall of Warness, disturbed sediment within the tidal test site would primarily move towards the northwest and southeast (depending on the flood or ebb tidal state) in line with the fast flow speeds and rectilinear current and in low quantities. Furthermore, SSC generally reduces with increasing distance from the point of disturbance, diluted and advected by the fast flow speeds. Any deposition of sediment would be highly limited, equating to a thin veneer of sediments native to the area.

13.6.2.3.1 Marine Fish

13.6.2.3.1.1 Sandeel

Sandeel are seabed dependent as demersal spawners that live in burrows for the majority of their life cycle, they are potentially vulnerable to smothering that could result from the presence of the pile drill cuttings and temporary presence of spoil berms.

Sandeels is a Scottish PMF species and are considered to be of **moderate sensitivity** to potential smothering caused by the pile drill cuttings and spoil berms at the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, any impacts are unlikely to affect long term functioning of the sandeel population. Therefore, the **overall effect** to sandeels is considered to be **minor** and **not significant**

13.6.2.3.1.2 Herring

Herring are demersal spawners, and therefore, their spawning grounds and eggs and larvae are vulnerable to smothering impacts potentially resulting from the pile drill cuttings and temporary presence of spoil berms. The Offshore Site is not expected to be an important herring spawning ground (Figure 13-2), and therefore, herring larvae and eggs are not expected to be in the area in high numbers.

Despite the low presence of herring, they are considered to be high value receptors as a Scottish PMF species and are considered to be of **moderate sensitivity** to their susceptibility to smothering effects caused by the drill cuttings piles at the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, any impacts are unlikely to affect long term functioning of the herring population. Therefore, the **overall effect** to herring is considered to be **minor** and **not significant.**

13.6.2.3.1.3 Common Skate

Common skate lay their egg cases on the seabed and are potentially vulnerable to smothering that could result from the presence of the pile drill cuttings and temporary presence of spoil berms. However, taking the highly localised nature of any sediment deposits associated with the Project, there will be no adverse effects inflicted on the breeding population of common skate, and no long-term population effects would be anticipated as a result of increased SSC and associated deposition. As noted above it is expected that material that enters suspension will be transported away from the Offshore Site area and deposited over a wide area that is considered unlikely to result in smothering of egg cases. It is expected that breeding populations of common skate would be able to return to the Offshore Site for egg laying following cessation of construction.

Common skate is a Scottish PMF species and Critically Endangered on the IUCN Red List. Common skate egg cases are potentially vulnerable to smothering impacts, however, the breeding population is expected to be able to recover from this impact following cessation of construction and acknowledging that sediments will be deposited over a wide area. Therefore, this receptor is assigned as having a **moderate sensitivity** to this impact. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, any impacts are unlikely to affect long term functioning of the common skate population. Therefore, the **overall effect** to common skate is considered to be **minor** and **not significant.**

13.6.2.3.1.4 All Other Marine Fish

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

Many other marine fish species within the are considered to be high value receptors due to their various conservation statuses and are considered to be of **low sensitivity** to potential smothering caused by the pile drill cuttings and spoil berms at the Offshore Site, due to the mobile nature of the majority of these species being able to avoid areas of high sediment load. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, impact will be localised to the Offshore Site, since any impacts are unlikely to affect long term functioning of the other marine fish species populations. Therefore, the **overall effect** to all other marine fish species is considered to be **minor** and **not significant.**

13.6.2.3.2 Marine Shellfish

Shellfish with reduced mobility such as buried crab, lobster, and scallops are vulnerable to any potential smothering caused by the drill cuttings piles and temporary presence of spoil berms.

Shellfish within the Offshore Site are considered to be high value receptors with a **moderate sensitivity** to potential smothering caused by the pile drill cuttings and spoil berms at the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the **magnitude of impact** is defined as being **low**. However, the impact to shellfish will be localised to the Offshore Site and impacts are unlikely to affect long term functioning of any shellfish population. Therefore, the **overall effect** to shellfish is considered to be **minor** and **not significant.** They are potentially vulnerable to sediment deposition as their eggs need regular aeration (Neal and Wilson, 2008).

13.6.2.4 Spawning and Nursery Ground Habitat Loss/Damage

Long-term habitat loss / damage is expected to occur due to covering of habitat with device / mooring and electrical hub foundations, anchors, cables and cable protection material. The loss / damage is considered long-term because it will last for the lifetime of the Offshore Site, however, as this impact occurs during construction it is assessed here, rather than as an operation and maintenance impact (see Section 13.6.3).

Additional temporary habitat loss / damage is expected to occur during seabed preparation for installation of device foundations and cables. This short-term habitat loss / damage is expected to extend outside the permanent footprint of the structures, but recovery will be possible on completion of construction operations. The area of seabed where long-term and short-term habitat loss / damage will occur is summarised in Table 13-14, based on the maximum envelope parameters set out in Table 13-10.

It should be noted that some of the area of seabed subject to short-term disturbance (also equating to loss / damage) during seabed preparation (boulder clearance) for each device foundation and for the subsea cables will subsequently be subject to long-term disturbance from the placement of the foundations themselves (e.g. where permanent infrastructure is placed in areas where boulder clearance takes place).

As noted in Volume 1, Chapter 4: Project Description, foundations may incorporate drilled piles. These will be located within the “device foundation direct seabed coverage” presented in Table 13-14 and have not therefore been included as separate items contributing to the total seabed habitat loss / damage area.

It should be noted that additional seabed disturbance may occur during the operation and maintenance phase, for example as a result of cable replacement activities and placement of mattress / cable protection. The seabed footprint associated with these activities will be within the long-term seabed disturbance footprint presented in Table 13-14.

Table 13-14 **Temporary and short-term habitat loss / damage during construction**

ITEM	AREA PER ITEM	QUANTITY	TEMPORARY SEABED HABITAT LOSS / DAMAGE	LONG-TERM SEABED HABITAT LOSS DAMAGE
Total boulder clearance for all devices (m^2)	1,875 m^2	40 small devices 20 large devices	112,500 m^2	-
Total boulder clearance for all umbilicals (m^2)	Boulder clearance per umbilical cable: 5,000 m^2	40 umbilicals for small devices 20 umbilicals for large devices	300,000 m^2	-
Total boulder clearance for export cables (m^2)	Boulder clearance per export cable: 100,000 m^2	Maximum number of export cables: 15	1,500,000	-
Device foundation direct seabed footprint	350 m^2 (small devices) 750 m^2 (large devices)	40 small devices 20 large devices	-	29,000 m^2

ITEM	AREA PER ITEM	QUANTITY	TEMPORARY SEABED HABITAT LOSS / DAMAGE	LONG-TERM SEABED HABITAT LOSS DAMAGE
Seabed swept area (m²) for umbilicals	250 m²	40 small devices 20 large devices	-	15,000 m²
Maximum umbilical cable protection footprint (m²)	2,000 m²	40 small devices 20 large devices	-	120,000 m²
Maximum cable protection footprint, all cables (m²)	-	-		750,000 m²
Total maximum seabed footprint of electrical hubs (m²)	100 m²	15	-	1,500 m²
Open cut trench (OCT) area associated with unconsolidated material (m²) (excavated footprint)	2,000 m²	1	2,000 m²	-
Total berm seabed footprint (m²) (unconsolidated material)	-	-	830 m²	-
Seabed footprint of the cofferdam (m²)	Width of the cofferdam: 300 m Length of the cofferdam: 125 m	1	37,500 m²	-
Total mooring swept area (m²)	800 m² (small device) 3,600 m² (large device)	40 small devices 20 large devices	-	104,000 m²
Total direct anchor seabed coverage for anchors for all devices (m²)	200 m² (small devices) 450 m² (large devices)	4 anchors per small device 6 anchors per large device 40 small devices 20 large devices	-	17,000 m²
Total maximum protection footprint of anchors for devices (m²)	100 m² cable protection footprint of anchors per small device 300 m² cable protection footprint of anchors per large device	40 small devices 20 large devices	-	10,000 m²
Horizontal directional drilling (HDD) exit ducts concrete mattresses/rock placement (m²)	25 m²	8	-	200 m²
Total			**1,952,830 m²**	**1,046,700 m²**

13.6.2.4.1 Marine Fish

13.6.2.4.1.1 Sandeels

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 or damage.

Sandeels are considered to be high value receptors as a Scottish PMF species and of **moderate sensitivity** to potential habitat loss or damage at the Offshore Site. Based on localised spatial change, and the fact that this change will not represent a substantial change in habitats present (noting the limited sediment present at the Offshore Site), the **magnitude of impact** is defined as being **negligible.** However, the impact to sandeels will be localised to the Offshore Site and any impacts are unlikely to affect long term functioning of the sandeel population. Therefore, the overall effect to sandeels is considered to be **minor** and **not significant.**

13.6.2.4.1.2 Herring

Herring are demersal spawners, and therefore, their spawning grounds and eggs and larvae are vulnerable to any habitat loss or damage. The Offshore Site is not expected to be an important herring spawning ground (Figure 13-2), and therefore, herring larvae and eggs are not expected to be in the area in high numbers.

Herring are considered to be high value receptors as a Scottish PMF species and of **moderate sensitivity** to potential habitat loss or damage at the Offshore Site. The impact to herring will be localised to the Offshore Site, and any impacts are unlikely to affect long term functioning of the herring population. Therefore, the **magnitude of impact** is defined as being **negligible.** The overall effect to herring is considered to be **minor** and **not significant.**

13.6.2.4.1.3 Common Skate

Common skate are oviparous and are potentially vulnerable to seabed disturbance that could damage any egg cases laid in the Offshore Site. Furthermore, any relocation of boulders in the Offshore Site could also result in a loss of suitable habitat over a localised area. However, boulders will likely only be moved a short distance and a recovery of the habitat would be expected, meaning that there would be no long-term habitat loss.

Common skate are considered to be high value receptors as a Scottish PMF species and as Critically Endangered on the IUCN Red List. This species is considered to be vulnerable to habitat disturbance and loss. The movement of mooring lines and umbilical cables on the seabed may result in repeated disturbance over a highly localised area, however, it is anticipated that the population will be able to sufficiently recover from the loss of a very small proportion of available habitat. Furthermore, it is important to note that the introduction of cables with cable protection will not result in a major shift in the baseline characterisation across the Offshore Site, which already consists of hard substrate potentially suitable for common skate egg laying. Therefore, common skate are assigned as having a **high sensitivity** to potential habitat loss or damage at the Offshore Site. Based on localised spatial change, the **magnitude of impact** is defined as being **negligible** Therefore, the overall effect to common skate is considered to be **minor** and **not significant.**

13.6.2.4.1.4 All Other Marine Fish

All other marine fish species other than herring, sandeel and common skate are less vulnerable to habitat loss or damage, as these species are pelagic spawners without any specific seabed habitat requirements for spawning. Many other marine fish species within the are considered to be high value receptors due to various conservation status outlined in Table 13-4. Therefore, other marine fish species are considered to be of **low sensitivity** to potential habitat loss or damage at the Offshore Site.

As the activities will affect a small area of seabed and there will not be a substantial change in baseline conditions, as noted above. Therefore, the **magnitude of impact** is defined as being **negligible**. Any impacts are unlikely to affect long term functioning of the other marine fish species populations. Therefore, the overall effect to all other marine fish species is considered to be **minor** and **not significant.**

13.6.2.4.2 Marine Shellfish

Shellfish with reduced mobility such as buried crab, lobster, and scallops are vulnerable to any potential habitat loss or damage. Depending on the life-cycle stage, some shellfish show a degree of mobility (e.g. scallop jet propulsion), whereas others are predominantly immobile (e.g. 'berried' female crabs and lobsters). Immobile shellfish may be vulnerable to physical abrasion of the seabed.

Shellfish are considered to be of **moderate sensitivity** to potential habitat loss or damage at the Offshore Site. As the construction activities will occur intermittently, only a small area of seabed is expected to be disturbed at any one time, although long-term habitat loss will be continuous. Overall, given the highly localised nature of the impact, the **magnitude of impact** is defined as being **negligible**. Any impacts are unlikely to affect long term functioning of the shellfish populations. Therefore, the **overall effect** to shellfish is considered to be **minor** and **not significant.**

13.6.3 Effects During Operation and Maintenance

13.6.3.1 Habitat Creation and Fish Aggregation Effect

Subsea infrastructure from tidal arrays may acts as artificial reefs and can provide new habitats for fish and shellfish species. The introduction of new hard substrate (foundations, moorings and cable protection) on the seabed will create new habitat that will replace the existing natural habitat for the duration of its presence, potentially increasing habitat complexity and biodiversity of the area (Degraer *et al*., 2020). The total area of seabed habitat replaced in this way will be equal to the area affected by long-term disturbance noted in Table 13-14. It is anticipated that the surface are of device structures, per device will be up to 780 m^2.

The introduction of new infrastructure in the water column will create a new type of habitat in the area, with novel suspended, vertical and underhanging hard surfaces within the Offshore Site which will be available for colonisation by flora and fauna. The total area of this new habitat in the water column is not possible to estimate at the current development stage, therefore a qualitative assessment is presented.

The surface of any hard structure placed in the marine environment could 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 Fish Aggregation Device (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). Although post-construction fish and shellfish monitoring has been conducted at numerous UK offshore wind farms, clear conclusions on potential reef and fish aggregation effects have not been established from the findings (Xoubanova and Lawrence, 2022). Early findings from the Predators and Prey Around Renewable Energy Developments (PrePARED) project, which involved BRUV monitoring at operational offshore wind farms along Scotland's east coast in 2022, suggest that demersal fish species near wind turbines exhibit greater abundance, larger sizes, and higher mean energy content compared to those at reference sites farther from turbine foundations. The study recorded 2.5 times more flatfish and three times more haddock within 30 m of turbines at the Beatrice Offshore Wind Farm. At the Moray East Offshore Wind Farm, the increase was less pronounced, with no rise in flatfish numbers but twice as many haddock (PrePARED, 2024). The degree to which these monitoring results could apply to the Offshore Site is uncertain given the difference in the potential nature of the impact for a tidal array versus an offshore wind array.

It remains uncertain whether similar changes would occur at this Offshore Site, whether any effects would be significant, or if the impact on fish and shellfish communities would be positive, negative, or neutral. If no antifouling treatments are applied to the subsea infrastructure, biofouling will occur on all of these surfaces.

In the context of the Project, the surfaces provided by any installed structures will only provide minimal surface area for colonisation within the wider Offshore Site, due to the Project design. Hence, the artificial reef effect of the Project is likely to be small and is unlikely to significantly increase the productivity of the area. It is also important to note that the sediments across the Offshore Site are relatively heterogeneous, therefore, the introduction of hard substrate is less likely to cause a shift in baseline conditions as hard substrates are already present, when compared to areas with soft sediments. As a result, fish production in the area is unlikely to increase significantly, as it is expected that the devices will be painted in a low-toxicity anti-fouling paint. Devices, anchors and mooring lines will be regularly inspected (approximately 3 – 12 months), and subsequent biofouling removal will occur.

13.6.3.1.1 All Marine Fish and Shellfish Species

Many of the fish predicted to utilise the Study Area are highly protected. 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 this and the localised spatial extent of the area available for colonisation and the embedded mitigation measures outlined above the **magnitude of impact** is defined as being **negligible**. 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**.

13.6.3.2 Underwater Noise from Tidal Devices Operation

Anthropogenic effects on acoustic conditions are a key concern for maintaining healthy coastal ecosystems. Underwater sound, both the sound pressure and particle motion components, as generated by tidal turbines may also affect marine life, including invertebrates and fish (Kunc and Schmidt, 2019; Southall *et al.,* 2019). While risk of auditory injury from turbine underwater sound is predicted to be low for fish (Lossent *et al.,* 2018), other potential impacts include behavioural disturbance, as well as acoustic masking (Pine *et al*., 2019) and barrier effects, which may result in habitat exclusion (Polagye *et al.,* 2011; Risch *et al.,* 2020).

Fish are generally sensitive to low-frequency sounds, with most species capable of detecting frequencies within the range of 30 Hz to 1 kHz (Popper and Hawkins, 2019). The primary acoustic stimulus for all fishes is particle motion, although some species - particularly those with specialised anatomical adaptations, such as a swim bladder involved in hearing - can also detect sound pressure (see Section 12.6.2.1).

The operational turbines will produce continuous noise, defined as sustained sound with relatively stable amplitude and frequency, such as vessel engine noise, drilling, and the operational hum of underwater infrastructure. Fish may respond to continuous noise through behavioural changes, stress responses, or masking of biologically important sounds used for communication or predator detection. Impulsive noise, by contrast, is characterised by short-duration, high-intensity sounds with rapid onset, such as pile driving, seismic surveys, and underwater explosions. Impulsive noise is typically more likely to cause physical injury or temporary hearing loss, especially at close range, compared with continuous noise.

Tidal devices typically produce continuous low-frequency noise below 1 kHz - within the hearing range of most fish species. As such, turbine noise may be detectable and could potentially interfere with biologically relevant sounds. Several recent opportunities to characterise tidal turbine sound emissions have begun to fill knowledge gaps. A study on underwater turbine noise was conducted at the MeyGen tidal test site located in the Pentland Firth. The underwater turbines produced a frequency modulated tonal signal with harmonics as well as peak sound levels between 100 and 1,000 Hz. The turbine emissions elevate noise levels by about 30 – 40 dB above ambient in low sea states, making the signal measurable at ranges of over 2,000 m from the turbine. An increase in sound levels was found to be linked to an increase with turbine rotations per minute (rpm) and current speeds (Risch *et al.,* 2020).

More recent monitoring has reinforced the conclusion that the risk of injury or mortality to fish from operational turbines is minimal. Risch *et al.,* (2023) reported median underwater noise levels between 125 and 140 dB re 1 µPa (100–1,000 Hz) within 20 m of the Atlantis turbine. Similar levels were observed for the Andritz turbine, albeit with greater variability. These levels are well below those expected to cause auditory injury, especially considering the rapid attenuation of sound with distance. The relatively low rotational speeds (Atlantis: 7–9 rpm; Andritz: 10–14 rpm) further contribute to the modest acoustic output identified by Risch *et al.* (2023). While the Project's turbines may operate at up to 50 rpm, this remains within a range unlikely to cause physiological harm, as supported by findings from Lossent *et al.,* (2018).

As mentioned in Section 13.6.2.1, noise is known to affect fish and shellfish in a number of ways causing injury and, in extreme cases, mortality. However, only Group 3 and 4 fish (e.g., herring) with swim bladders involved in hearing are considered potentially vulnerable to operational noise. Criteria from Popper *et al.,* (2014) for continuous noise sources such as shipping have been outlined in Table 13-12. Underwater noise modelling has been conducted to understand the distances over which injurious or behavioural impacts could occur (Volume 2, Appendix D: Underwater Noise Modelling Technical Note). However, as noted in Table 13-12, quantitative noise threshold criteria is only available for recoverable injury and TTS impacts to Group 3 and 4 fish. The modelling indicates that recoverable auditory injury would only occur within 2 m of the operating turbine and would require the individual to remain within this distance for a period of 48 hours which is considered highly unlikely. Based on the qualitative criteria for continuous noise (Table 13-12) there is a moderate level of risk of disturbance to fish (including eggs and larvae) up to 'tens of metres' (except for fish with swim bladders were the risk remains high), moderate risk at distances of hundreds of metres, and low beyond this (i.e., 'far'). For eggs and larvae, the risk is moderate close to the centre of activity (tens of metres) and low beyond this point.

It is more likely that operational noise produced by the underwater turbines will result in avoidance behaviour, rather than the fish getting close enough to the devices to suffer from injury or death from noise, as noted above. Analysis from ABPmer (2010) suggests that hearing sensitive fish (such as herring) may be able to detect and avoid individual operational tidal stream devices at distances between approximately 120 to 300 m. As turbine noise decreases with distance, sound levels diminish rapidly beyond the immediate vicinity of the devices, further reducing the likelihood of adverse effects on fish. There may be a large number of operational devices (up to 60 devices, 40 small and 20 large) producing simultaneous, continuous noise during the operational phase of the Project, however, the devices will have large spacing between them (15 m, Table 13-10). The spatial configuration of the Offshore Site does not resemble a channel fully obstructed by turbines; therefore, it does not present a barrier effect. Fish, including diadromous species, that utilise the area will be able to navigate around or through the site due to the minimum turbine spacing and the surrounding geography. This layout allows fish to avoid close proximity to individual devices, thereby reducing the risk of noise-related injury.

Additionally, the existing acoustic environment - characterised by vessel traffic, strong tidal flows, and high tidal energy - means that fish in the area are already exposed to elevated background noise levels. This environmental baseline is likely to mask the operational noise emitted by the turbines, particularly at greater distances (Tougaard *et al.,* 2020). Any avoidance or masking effects are anticipated to be limited to a localised area around the operating turbines.

Importantly, turbine noise may also function as a deterrent. As fish approach the source of the sound, they are likely to exhibit avoidance or fleeing behaviour, which further reduces the likelihood of collision with the turbine blades (Section 13.6.3.6). This behavioural response, combined with the site's spatial design and existing acoustic conditions, supports the conclusion that the risk of harm to fish from underwater noise and physical interaction with the devices is minimal.

While existing studies provide valuable insights into the acoustic impacts of individual tidal turbines, there remains a significant data gap regarding the cumulative effects of large-scale arrays with high numbers of devices. Further research is needed to understand how increased turbine density may influence underwater sound propagation and its potential behavioural or physiological effects on marine species.

13.6.3.2.1 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.

Ellis *et al.,* (2012) data suggests the Offshore Site overlaps with low intensity sandeel spawning (Figure 13-2) and low-density nursery grounds (Figure 13-4). However, sandeel preferred habitats and spawning grounds are widely distributed across Scottish and English waters (Figure 13-8).

Sandeels are a protected species and are considered to have **low sensitivity** to underwater noise generated from the operation of tidal devices Offshore Site, as according to Popper *et al*., (2014) criteria, the hearing sensitivity of Group 1 fish is low. Based on localised spatial change, the **magnitude of impact** is defined as being **low**. In addition, 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**.

As it is anticipated that the overall effect of underwater noise during operation on sandeel 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.

13.6.3.2.2 Herring (Group 4)

Herring are also demersal spawners and are classified as a Group 4 species in relation to sensitivity to 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. The IHLS estimates of herring larvae abundance are predicted to be low in the vicinity of the Offshore Site (IHLS, 2019; 2020; 2021). Ellis *et al.,* (2012) data also suggests the Offshore Site does not overlap with herring spawning grounds (Figure 13-2) but overlaps with low intensity nursery ground (Figure 13-3). 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.

Herring are highly protected and are highly sensitive to underwater noise. However, considering the Offshore Site is not located within a key spawning or nursery ground for this species and that adult herring are a mobile species that are unlikely to be exposed to noise for an extended length of time. Modelling of the underwater sound of operational tidal turbines (Volume 2, Appendix D: Underwater Noise Modelling Technical Note) further determined that there was no realistic potential for fish to experience mortality or recoverable injury as a result of the turbine operational sound, accounting for worst-case assumptions.

In line with Popper *et al*. (2014), adult herring are considered to be at high risk of behavioural impacts to 'tens of metres' of the turbines. Risk of disturbance is considered 'moderate' at distances within 100s of metres, and low at distances beyond this. Eggs and larvae are considered to be at moderate risk of behavioural effects within hundreds of metres, with behavioural impacts considered low beyond these distances.

Consequently, herring have been assessed to have **moderate sensitivity** to underwater noise at the Offshore Site. Based on the highly localised spatial change, impacts are unlikely to affect long term functioning of the herring populations. Therefore, for herring the **magnitude of impact** is defined as being **low** 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 during operation 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.

13.6.3.2.3 All Other Marine And Diadromous Fish Species

The remaining fish receptors (excluding herring and sandeel) are listed in Table 13-13, 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 Site 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).

Mobile fish are unlikely 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. 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 anglerfish and whiting (Figure 13-3). 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 (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 (Figure 13-2, Figure 13-3 and Figure 13-4). 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 moderate sensitivity to underwater noise at the Offshore Site. Based on localised spatial change, and on the basis that all of the species considered here are pelagic spawners, the **magnitude of impact** is defined as being **low**.

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.**

13.6.3.2.4 Marine 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 Section 13.6.3.2.3 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 and American lobster (Roberts *et al*., 2016; Miller *et al.,* 2016). Therefore, it is assumed that the shellfish present in the Offshore Site, 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. Considering the widespread presence of the shellfish species present in the Study Area throughout UK waters, the **magnitude of impact** is defined as being **low**. Therefore, the overall effect is **minor** and **not significant**.

13.6.3.3 Changes To Sediment and Hydrodynamic Regime

The purpose of the development is to harness some of the tidal energy that flows through the site; introduction of new structures and associated protection on the seabed and in the water column will also disrupt the existing hydrodynamic regime and associated sedimentary processes. Full details on the potential changes to the sediment and hydrodynamic regime are presented in Volume 1, Chapter 7: Hydrodynamic and Physical Processes.

While changes to the hydrodynamic regime based on this conservative estimate would not likely be noticeable at the Offshore Site level, changes are likely to be detectable on a very localised level, for example to the immediate lee side of tidal energy devices and associated structures, especially those on or near the seabed.

As described in Volume 1, Chapter 7: Hydrodynamic and Physical Processes, based on worst-case assumptions, decreases in the bed shear stress can be expected to occur associated with the Offshore Site due to the presence of floating or seabed structured resulting in blockage effects. The largest reductions would be expected to occur within Westray Firth, and reduce further with increasing distance from the Offshore Site. With the change in bed shear stresses, there would be the potential for changes to the mobilisation / deposition of sediment, with a reduction in shear stresses resulting in increased sediment deposition and vice versa. Given the limited sediment cover and propensity for exposed bedrock due to the fast tidal flows, any sediment deposition within the Offshore Site or Westray Firth, would originate from elsewhere within the Orkney region. However, as described in Volume 1, Chapter 7: Hydrodynamic and Physical Processes, there is expected to be little fine sediment at the Offshore Site and in the wider Orkney region. It is expected that the submerged protection heights are not enough to alter the water levels downstream or either side of the protection berms, so there will be no change to the prevailing flow characteristics and patterns. Some local blockage effects could occur, with the structure potentially acting as a localised sink for coarse sediments. However, this would be temporary as over time (over months to years) it is expected that sediment previously deposited locally, would bypass, pass through or overtop the protection.

As there are no mobile sediments present in the Offshore Site, no scour effects are expected to occur (Volume 1, Chapter 7: Hydrodynamic and Physical Processes).

13.6.3.3.1 All Marine Fish and Shellfish

The changes to sediment and hydrodynamic regime resulting from extraction of tidal energy will potentially impact on fish and shellfish habitats and species that are sensitive to changes in tidal flows and wave exposure. For fish species, herring spawning grounds, sandeels and common skate egg laying grounds are the most sensitive species due to their reliance on the benthic region for spawning. They therefore have medium to high vulnerability to changes to sediment and hydrodynamic regime (Faber Maunsell, 2007).

The Offshore Site is not expected to be an important herring or sandeel spawning ground and sediment characteristics at the Offshore Site indicate that burrowing sandeel are also unlikely to be present (Figure 13-2), and therefore, herring/sandeel larvae and eggs are not expected to be in the area in high numbers. Therefore, the **sensitivity** of receptor is considered **low**. Potential changes to the hydrodynamic regime in relation to the Offshore Site was assessed to be low in Volume 1, Chapter 7: Hydrodynamic and Physical Processes. Any impacts on hydrodynamics and sediment processes are considered insufficient to alter the distribution of available habitat for sandeels or herring. Therefore the **magnitude of impact** is considered to be **negligible.** Therefore, the overall effect is **negligible** and **not significant**.

In relation to common skate, it is assumed that there could be the potential for common skate egg laying in the Offshore Site. Given the conservation importance of this species, as Critically Endangered on the IUCN Red List and a Scottish PMF species, the sensitivity is assigned as **moderate.** However, given the highly localised nature of impact, assessed in Volume 1, Chapter 7: Hydrodynamic and Physical Processes which concludes there will be no scour of the seabed due the lack of mobile sediments, the **magnitude of impact** is assessed as **negligible**. Therefore, the overall effect is **minor** and **not significant**.

13.6.3.4 Electromagnetic Field (EMF) Effects

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 elasmobranchs (e.g. sharks, rays, skates), salmonids (e.g. salmon, trout) and crustaceans (e.g. lobster, brown crab) to EMF (Hutchison *et al*., 2020; Copping *et al.,* 2020; Copping *et al.*, 2021). Both the umbilical cables (between devices / from device to the electrical hub) and export cables (from electrical hub to landfall) will emit low frequency EMFs. As summarised in Table 13-10 in relation to the worst-case scenario, up to 15 33 kV subsea export cables will be installed and laid on the seabed within the Offshore Site, with a maximum length of 5 km per cable. Where possible, a maximum cable protection width of 10 m will be used at a 3 m height above the seabed. As a worst-case, up to 60 11 kV umbilical cables will be installed, each 1 km long with 500 m surface laid with external protection and 500 m in the water column. For the surface laid section, a maximum cable protection width of 4 m and height of 1 m is assumed.

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).

It recognised that the protection of cables, such as placement of external protection, are not considered to be effective ways to mitigate magnetic emissions into the marine environment entirely. However, external protection 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.

Comparable data from other renewable developments, notably the Moray East Offshore Wind Farm, have been considered (Moray Offshore Windfarm (East) (MOW(E)) Ltd, 2019). For this development, the potential EMF impacts from a 220 kV cable have been assessed at various burial depths. It is established that burying a cable increases the distance between the sensitive biota and the source of the EMF, but it does not completely shield the EMF, which can still be measurable at the seabed and in the water column, as shown through studies on High Voltage Direct Current (HVDC) cables (300 – 500 kV) (Hutchison *et al.,* 2020). Nonetheless, voltages within this study are much higher than the proposed 33 kV subsea cable.

The 220 kV AC cable considered within the MOW(E) Ltd assessment (MOW(E)) Ltd, 2019) include a 1,000 mm^2 cable maximum EMF strength measured in micro Teslas (μT). At 0.5 m the maximum value reached 54.31 μT and at 1 m burial 16.58 μT at the seabed surface. The maximum EMF strength was also calculated 5 and 10 m above the cable. If the cable was surface laid (in the case of the Moray East Offshore Wind Farm), the maximum EMF strengths were negligible reading at 0.8697 μT and 0.2115 μT (MOW(E) Ltd, 2019).

The 66 kV AC cables considered within the MOW(E) Ltd assessment (MOW(E)) Ltd, 2019) include 240 mm^2 and 630 mm^2 cables. At the seabed surface, the EMF strength, was 13.1 μT and 37.76 μT, respectively. The EMFs experienced at the surface were considerable reduced with burial of the cable, particularly burial to 1 m depth exhibited EMF at the surface of 4 μT for the 240 mm^2 cable and 7.5 μT for the 630 mm^2. It should be noted that these calculations are conservative in that they do not include the shielding effects of armour wire or helical cable core twisting. The EMF values presented are higher than would be calculated if armour wires were incorporated in the calculations (MOW(E) Ltd, 2019).

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±0.14 μT. It is important to note that the EMF will rapidly dissipate with distance from the cables to the geomagnetic field strengths. As such fish and shellfish receptors are unlikely to detect any notable change from EMFs produced by 33 kV export cables and 11 kV umbilical cables particularly as cable protection measures will be applied for the surface laid sections.

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 33 kV and 11 kV cables, such as where cables used are High Voltage Direct Current (HVDC) cables at significantly higher voltage than that proposed for the Project. Additionally, these studies are predominantly undertaken in laboratory conditions and largely use magnetic fields which are greater than earth's magnetic field (–ca. 50 μT at the Offshore Site (NOAA, 2021a)), in order to test behavioural response.

13.6.3.4.1 Elasmobranchs

Elasmobranchs are recorded in Orkney waters 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. Gill *et al.* (2009) reported that several species of elasmobranchs showed some attraction to cables and reduced swimming activity. Gill *et al*. (2009) found that lesser spurdog and thornback ray responded to magnetic fields of 8 µT and iE-fields of 2.2 µV/m, but noted that the observed response was unpredictable and, in some instances, did not occur altogether. Hutchison *et al*. (2018; 2020) also demonstrated that little skate, a north American species, showed an increased exploratory behaviour in response to EMF exposure. But ultimately, the cable did not represent a barrier to skate movement (Hutchison *et al.,* 2018). Elasmobranchs are highly mobile, and able to roam across large distances, with any behavioural response only likely to occur within meters of the cable where magnetic field strength is observable above background.

A number of elasmobranch species have been identified in the area that are IUCN Red List species, including common skate and spurdog. In addition, spotted ray which is on the OSPAR List of Threatened and/or Declining Species. 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 Site, however, based on the highly localised spatial effects of EMF from AC cables, the **magnitude of impact** is defined as being **negligible**.

EMF emissions from the export and umbilical cables will be reduced through cable protection measures, secured through management plans, including the Cable Plan. Cables will also be insulated and sheathed to reduce EMF emission and cable protection will increase the separation distance between receptors and any localised increase in EMF caused by the Project. Considering this, the overall effect to elasmobranch species receptors is considered to be **minor** and **not significant**.

13.6.3.4.2 Diadromous Fish

Unlike elasmobranch, diadromous fish 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 export and umbilical 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 and 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).

The response of diadromous fish to anthropogenic electric and magnetic fields is still largely unknown, and further research is needed to determine the detection thresholds and behavioural effects of both natural and anthropogenic EMFs to assess potential impacts from offshore developments (Honkanen *et al.,* 2024). A study carried out by Marine Scotland (Orpwood*,* 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) also concluded that there was no identifiable behavioural response of Atlantic salmon to magnetic fields at intensities of 95 µT and below. A study on Chinook salmon migration indicated that the presence of an energised HVDC cable did not affect the probability of successful salmon migration through a river estuary, although the EMF appeared to have limited and localised effect on the migration path and timing (Wyman *et al.,* 2018).

Most migratory salmonids swim within the top 5 m of the water and would be unlikely to detect the EMFs associated with the surface laid export cables and the surface laid sections of the umbilical cables (Godfrey *et al*., 2014). Therefore, migratory salmonids are most likely to be affected by EMF associated with the portion of the umbilical cables in the water column. Eels migrate at various depths throughout the water column. Therefore, they may be affected by EMFs associated with surface laid and dynamic (i.e. in the water column) portion of cables. EMFs would only be detectable by salmonids for a short period of time as diadromous fish swim through the field associated with the dynamic cabling for the umbilical cables. Similarly, European eels, which may be found throughout the water column, including near the seabed, would likely only be within detectable range of any EMF for a short time as they swim through the field associated with export cables and umbilical cables.

High levels of EMF may have the potential to impact the migration of diadromous fish, however, they are considered to have **moderate sensitivity** to the levels being emitted. EMF will be emitted throughout the life cycle of the Project, however, based on the localised spatial change, the **magnitude of impact** is defined as being **negligible** as the levels of EMF emitted will be low.

Low levels of EMF are anticipated from the subsea cables. Cable protection measures will increase the separation distance between the cable and Fish and Shellfish Ecology receptors, thereby reducing exposure to increase EMFs. As such, the overall effect to diadromous fish species receptors is considered to be **minor** and **not significant.**

13.6.3.4.3 Marine Fish

Pelagic and demersal species will encounter EMF associated with the export and umbilical cables. Pelagic species are more likely to encounter this through proximity to the dynamic cabling for the umbilical cables. Comparatively, demersal fish species, including eggs and larvae of species which exhibit demersal reproductive strategies, may overlap with the EMF associated with the portion of the umbilical cables in the water column.

The existing knowledge base on EMF suggests that, under laboratory conditions, potential developmental, genetic and physiological implications of exposure to B-fields only occur when exposure levels are in the range of several milli Tesla (mT), rather than µT (Gill and Desender, 2020; Copping *et al.* 2021). These levels are considerably higher than would be expected to be emitted by either the export cables or umbilical cables. Furthermore, it is not expected that sandeel and herring spawning occurs at the Offshore Site, due to the sediments present, and therefore, any impact to sandeel and herring eggs is highly unlikely.

Overall, marine fish are deemed not to be vulnerable to EMF. They are highly mobile and therefore exhibit the capacity to adapt and recover to any disturbance as may be generated by EMF. However, acknowledging the lack of concrete evidence on fish responses to EMF and also considering that several marine fish species are protected as PMFs, they are considered to have a **moderate sensitivity.** EMF will be emitted throughout the life cycle of the Project, however, based on the localised spatial change, the **magnitude of impact** is defined as being **negligible** as the levels of EMF emitted will be low.

Low levels of EMF are anticipated from the subsea cables. Cable protection measures will increase the separation distance between the cable and Fish and Shellfish Ecology receptors, thereby reducing exposure to increase EMFs. As such, the overall effect to marine fish species receptors is considered to be **minor** and **not significant.**

12.1.1.1.1 Marine 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 33 kV export 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 mT of EMF, which is significantly higher and thus not comparable to the proposed 33 kV export cables.

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. 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).

Shellfish species are considered to have **moderate sensitivity** to EMF levels associated with the low levels of EMF produced by the cables. With consideration of the studies mentioned above, and that the associated magnetic field strengths experienced by shellfish receptors will be indistinguishable from the earth's own magnetic field intensity at the Offshore Site, given that cables will be sufficiently protected, the **magnitude of impact** is defined as being **negligible**.

Given the low levels of EMF that are anticipated to be emitted, due to application of cable protection measures, secured through the Cable Plan, the overall effect upon shellfish receptors is considered to be **minor** and **not significant.**

13.6.3.5 Presence Of Tidal Devices and Associated Infrastructure Leading to a Barrier Effect

Tidal array developments have the potential to form a barrier to migratory fish species (i.e. diadromous fish species). The tidal array has the potential to act as a barrier due to its physical presence, reactions of fish and shellfish to underwater noise, EMF or perceptions of devices and associated infrastructure. A barrier effect is most likely to be perceived by mobile diadromous fish species which may journey through the Offshore Site. As a precautionary approach, it is assumed that Atlantic salmon, sea trout and European eel pass through Orkney waters during their migrations.

There will be up to 60 (40 small and 20 large) devices with a rotor diameter of up to 30 m and footprint of 750 m^2 for large devices and 350 m^2 for small devices. This equates to a total device seabed footprint of 29,000 m^2. Furthermore, there will be a maximum of four moorings per small device, and six moorings per large device, with a maximum length of 200 m (small device) and 600 m (large device) and a total mooring line swept area of 104,000 m^2. There will also be a maximum of 10 electrical hubs, with a maximum footprint of 100 m^2 per electrical hub.

Overall, there is considered to be adequate space for migratory species to navigate between individual devices, with 100 metres of separation between arrays and additional open sea-room available to the west of the site. The devices will only be placed over a small proportion of the overall Offshore Site area, leaving the vast majority of the Offshore Site available for passing fish, There is the potential that the underwater noise generated by the devices during operation may add an additional barrier to that already presented by the physical presence of the devices, as well as potential EMF effects. However, given the limited area coverage of the devices and low levels of underwater noise and EMF produced by the tidal turbines during operation this is not anticipated to be significant.

13.6.3.5.1 Diadromous Fish: Atlantic Salmon, European Eel and Sea Trout

As the Fall of Warness only represents a small proportion of the total area of Orkney waters there is the potential that only a small proportion of the Atlantic salmon smolt population migrates through the Offshore Site (1.25% of estimated smolt populations, as outlined in Appendix A: Collision Risk Modelling). In areas where there are strong currents, like in the Fall of Warness, there is evidence that smolts will tend to stay close to the coast rather than move into the stronger currents (Thorstad *et al.,* 2007; Lacroix *et al.,* 2005). It is thought that post-smolts move quickly towards their feeding grounds, moving away from the coastal environment (although it is unclear if smolts may return to coastal environments with strong currents to aid in migration) (Mcilvenny *et al.,* 2021).

Adult Atlantic salmon returning to their natal rivers may also experience barrier effects. However, the majority of Atlantic salmon returning to rivers in the north of Scotland are anticipated to migrate via the Pentland Firth, with only a small percentage migrating through Orkney waters and the Fair Isle channel (Ounsley *et al.*, 2019; Guerin *et al*., 2014). There is substantial evidence that, like post-smolts, adult salmon are predominantly found in the upper few meters of the water column in both the UK and internationally. Godfrey *et al.* (2015) reported that returning Scottish adult salmon spent 72-86% of their time at depths of 0-5m, with dive depths ranging from 13 to 118 m, while a Norwegian study by Hedger *et al*., (2022) found that post-spawning salmon (kelts) primarily occupied depths of 0.3 to 6 m, with most dives ranging from 10 to 40 m, though some extended much deeper (Honkanen *et al.,* 2024).

Recent studies (Wright *et al.*, 2022) have confirmed that European eel travel far distances from the UK by moving across the Atlantic Ocean to the Sargasso Sea for breeding. Righton *et al.* (2016) showed through a tracking study that the eels migrate back to their presumed spawning grounds with some populations moving through northern Scotland. Although marine migration routes of adult European eel are well documented in coastal waters, there is a lack of understanding with regard to the UK eel population (Honkanen *et al.*, 2024). However, it could be inferred that eels from the east of Scotland may follow other European populations and migrate through northern Scotland (Righton *et al.*, 2016). Additionally, it is not possible to generate tracking data of juvenile eels, adding further uncertainty on European eel migration routes in UK waters. European eel are generally found in deeper depths of water but can be found in shallower depths at night (Honkanen *et al.*, 2024).

In general, habitat use of sea trout is relatively well understood, however, there is very limited information on the species migratory routes at sea (Honkanen *et al.*, 2024). Through observations, it is thought that once sea trout enter the sea, they typically stay in the nearshore coastal environment, within 80 km from the coast (Thorstad *et al*., 2016). Sea trout generally remain near the sea surface, with studies finding that the species are commonly found within the top 3 m of the water column (Kristensen *et al.*, 2018; Archer, 2022). However, sea trout have also been observed at 10-20 m below the sea surface (Johnstone *et al.*, 1995).

Atlantic salmon, European eel, and sea trout are all listed as Scottish PMFs and all species have experience recent population declines. Additionally, Atlantic salmon is also an Annex II species under the Habitat Directive. All species are considered to swim at depths which could be impacted by the presence of tidal devices. However, these species are expected to be tolerant to the barrier posed by the Project, given the wider availability of sea for migration. For these reasons, all diadromous species have been assessed to have a **moderate sensitivity**. Based on the small number of diadromous fish potential migrating through Orkney waters, and the small area the devices cover, diadromous fish are unlikely to be impacted to an extent which would result in long-term implications to their populations or greatly impact migration success. Therefore, the **magnitude of impact** is **low**. Therefore, the overall effect to diadromous species receptors is considered to be **minor** and **not significant.**

13.6.3.5.2 Marine Fish

As mentioned in Section 13.6.3.2, hearing sensitive fish (such as herring) may be able to detect and avoid individual operational tidal stream devices at distances between approximately 120 - 300 m. Maturing cod may also be impacted by potential physical barriers as they use tidal streams for migrating between feeding and spawning grounds (SSE, 2016). Garavelli *et al.* (2024) describe the evasion and collision risk for marine animals around turbines. For example, monitoring at the Shetland Tidal Array showed that saithe aggregations are reduced during turbine operations (compared to when turbines are stationary) with some individuals exhibiting evasion behaviour. When individuals were observed as present when turbines were rotating, they appeared to be sheltering from the main flow (Smith, 2022). Additionally, monitoring at the Voith HyTide at the Fall of Warness over a three-month period showed the presence of fish on a number of occasions, however, there is no information available on avoidance behaviour (Tethys, 2025).

The Offshore Site is not expected to be important for herring or cod as it does not overlap with high intensity nursey or spawning grounds for either species, and therefore, they are not expected to be in the area in high numbers (Figure 13-2, Figure 13-3 and Figure 13-4). The **sensitivity** of receptor is considered **low**. Based on the small area the devises cover, the **magnitude of impact** is **low**. Therefore, the overall effect to marine species receptors is considered to be **minor** and **not significant.**

13.6.3.6 Collision with Turbine Blades Leading to Injury Or Death

There is concern that tidal devices, particularly rotating underwater turbines, present an obstacle that have the potential to result in collisions with marine animals. Whilst concerns in respect to collision risk in the past have related more to marine mammals and diving birds, there is also a growing concern on fish, particularly on large fish of conservation importance such as Atlantic salmon (Scottish Government, 2022). A collision here is understood to be an interaction with a fish and a tidal device that may result in physical injury.

Garavelli *et al.* (2024) also describe the latest evidence related to the collision risk for marine animals around turbines. To date, there has only been a few observations showing fish in contact with tidal devices or other marine renewable infrastructure, resulting in no obvious damage to fish.

Collision risks may be a result of poor visibility of the devices. In relatively shallow water with low turbidity, devices are likely to be visible in the day time at distances of around 5 to 10 m. At night-time visibility of devices would be significantly lower. It is assumed that a fish would avoid an unfamiliar object, rather than swim towards the device if it was visible. In addition, the speed at which the fish is swimming can also increase the risk of collision. Relatively few UK fish species would be capable of actively swimming upstream against the high flows associated with tidal stream environments (ABPmer, 2010).

An encounter may lead to a collision, but only if the fish in question is unable to take appropriate avoidance or evasive reaction. Many fish species occupying the same part of the water column as the underwater tidal devices are predatory and/or preyed upon and are therefore considered to be manoeuvrable and aware of their environment.

For a marine animal to experience a mortal or fatal injury from collision with a tidal turbine, a series of sequential conditions must be met. This can be described in the form of a probabilistic model whereby each step has an associated probability of occurrence (Copping *et al*., 2023). An animal must be present in the vicinity of a turbine (condition 1), at the depth of the rotor (condition 2). The turbine must be rotating during operational flow velocity (condition 3) and the animal must not be avoiding the turbine or evading the rotor blades (condition 4). The animal is not deflected due to flow conditions within the rotor disc (condition 5) and thus the animal must collide with a blade (condition 6) where the collision is sufficient to cause injury or mortality (condition 7). As each condition will have an associated probability of between 0-1, the likelihood of harm (injury or mortality) is the product of seven probabilities (Figure 12-11).

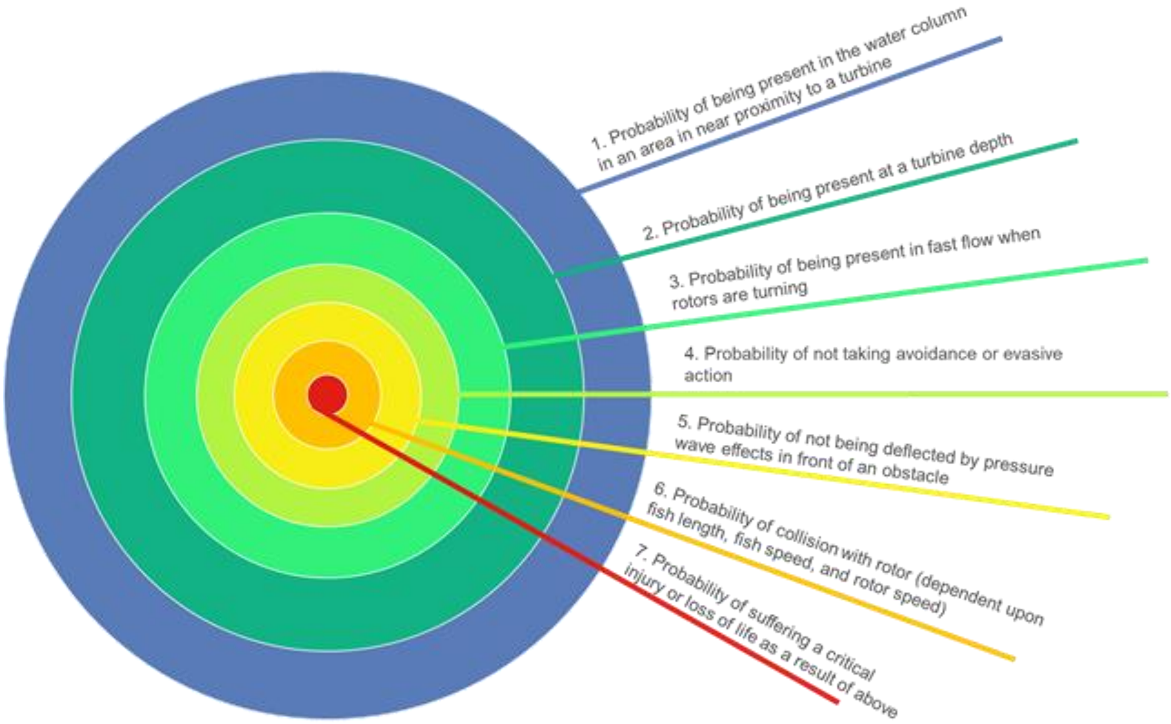

Figure 12-11 Conceptual probabilistic framework describing the likelihood of a collision between a marine animal and a tidal turbine. Recreated from Copping *et al.* (2023).

Even if the probability of every condition is as high as 0.9 (90%), the product of each probability combined results in an overall probability of 0.48. If any one of these probabilities is a very small number, then the overall probability decreases dramatically. This model (Copping *et al.* 2023) helps to illustrate that, even if fish commonly occurred within a short distance of a tidal turbine (condition 1), this does not necessarily mean that a collision is highly likely.

There will be up to 60 devices (40 small and 20 large) with a rotor diameter of up to 30 m installed at the Offshore Site. Each device will have a minimum clearance of 2.5 m from the sea surface, or 2 m to the seabed (Table 13-10). Marine shellfish are expected to pass under the device without encountering it, while pelagic and bentho-pelagic fish species are at the highest risk of collision. A number of pelagic and bentho-pelagic species of international conservation importance are expected to utilise the Study Area, such as Atlantic salmon, sea trout, European eel, spurdog and cod.

ABPmer (2010) presented risk matrices which provide an objective assessment of the potential for fish to collide with wave or tidal devices (Table 13-15). An evaluation on the contribution of the three main factors influencing collision risk included long range avoidance, close range evasion and potential physiological damage cause by collision, with different types of wet renewable devices.

Table 13-15 Risk matrices for a single horizontal axis turbine for differing fish groups (ABPmer, 2010; MeyGen, 2012)

FACTOR	PELAGIC BONY (E.G. HERRING)		PELAGIC ELASMOBRANCH (E.G. BASKING SHARK)	DEMERSAL ELASMOBRANCH (E.G. COMMON SKATE)	DEMERSAL BONY (E.G. SAITHE)		DIADROMOUS (E.G. ATLANTIC SALMON)			CONFIDENCE
HEARING SENSITIVITY[6]	HIGH	MEDIUM	LOW	LOW	MEDIUM	LOW	HIGH	MEDIUM	LOW	
Ability to avoid device at long distance	High	Very low	Very Low	Very Low	High	Very Low	High	Low	Very Low	Low
Ability to evade device at close range	Medium -High		Medium -Low	No Pathway	Medium - High		Medium - High			Low
Potential physiologic damage	Medium -High		Medium -Low	No Pathway	Medium - High		Medium -High			Low

Ability to avoid device at long distances	**High**: Exhibit signs of avoidance at distances > 50 m from device **Medium**: Exhibit signs of avoidance at distances > 20 m from device **Low**: Exhibit signs of avoidance at distances > 10 m from device **Very low**: Likely to exhibit signs of avoidance at distances <10 m from device
Ability to evade device at close range	**High**: Most fish should easily be able exhibit an evasion response with very few strikes predicted **Medium**: Most fish should easily be able to exhibit an evasion response although some strikes are possible **Low**: Some fish will have difficulty evading the device with strikes possible. **No pathway**: No pathway as an evasion response is not required.
Potential physiological damage	**High**: High risk of physiological damage and/or mortality to many individuals **Medium**: Moderate risk of physiological damage to some individuals **Low**: Low risk of physiological damage.

Note:
The different types of hearing sensitivity only apply to the ‘ability to avoid a device at long distances’. The range of hearing sensitive fish categories that were considered by APBmer (2010) reflect the availability of audiogram and/or hearing threshold information which could be applied to the matrix.

[6] The different types of hearing sensitivity only apply to the ‘ability to avoid a device at long distances’. The range of hearing sensitive fish categories that were considered by APBmer (2010) reflect the availability of audiogram and/or hearing threshold information which could be applied to the matrix.

13.6.3.6.1 Approach

Quantitative collision risk modelling has been conducted for Atlantic salmon (see Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report) as the key species of concern in relation to this impact. The collision risk assessment was carried out using the NatureScot (2016) Collision Risk Model (CRM). A number of collision risk scenarios were run to identify the worst-case scenario based on the possible parameters in the project design envelope, both for single devices and arrays of devices. The quantitative collision risk modelling was in line with NatureScot (2016) guidance. For all other relevant species/groups, including sea trout, European eel and marine fish, the assessment of collision risk is qualitative in nature.

13.6.3.6.2 Diadromous Fish - Atlantic Salmon, European Eel and Sea Trout

13.6.3.6.2.1 Atlantic Salmon Collision Risk

A number of inputs were required for the collision risk model to estimate the number of Atlantic salmon adults and post-smolts that may be at risk of collision (see Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report for further information):

- The proportion of the Adult salmon and post-smolts returning to Scottish rivers that will pass through Orkney waters each day, assumed to be 1.25% (equating to 3,633 returning adults per day and 104,000 post-smolts per day);
- Avoidance rate, assumed as a highly precautionary worst-case to be 0%, however, a range of avoidance rates have also been modelled (in line with NatureScot, 2016);
- Biological parameters (such as swim speed, body length etc);
- Project design parameters:
    - Eight scenarios were modelled which vary based on if the devices are surface-moored or seabed-mounted and the number and size of devices. One additional scenario has been modelled, reflecting the proposed SEASTAR, OCEANSTAR and the EURO-TIDES deployments at the Fall of Warness.

The worst-case scenario for Atlantic salmon adults was a combination of large and small floating devices (20 large and 40 small). The difference across scenarios can be explained by the difference in surface interval and dive profile between the two species (NatureScot, 2016).

Although it is not possible to convert the Atlantic salmon population estimate into an at-sea density, the NatureScot (2016) CRM provides a means of estimating the collision risk, assuming no avoidance, based on the width of the channel through which the fish pass, which is approx. 2,000 m at the Offshore Site, between the islands of Eday and Muckle Green Holm. Although it is challenging to determine a rate of behavioural avoidance, when considering the series of conditions that need to be met for a serious or fatal collision to occur (Copping et al., 2023; see Section 13.6.3.6) this likely means that the likelihood of a collision between a returning adult salmon or post-smolt and turbines in the tidal test site is small, and the 0% avoidance collision rate is highly precautionary.

Without any behavioural avoidance, the collision risk modelling predicted approximately 128 adult collisions per year and 1,564 post-smolt collisions per year (Table 13-16). This equates to approximately 3.5% of the adults passing each year and 1.5% of the post-smolts passing each year. It is acknowledged that the Atlantic salmon population is in decline. However, these estimates are considered to be highly precautionary given that no avoidance is assumed and also conservative assumptions on the population of Atlantic salmon passing through the Offshore Site (see Volume 2, Appendix B: Marine Mammal and Fish Collision Risk Modelling Report). According to ABPmer (2010) diadromous fish with a medium hearing sensitivity, such as Atlantic salmon, are likely to exhibit signs of avoidance at distances >10 m from device with most fish being able to exhibit an evasion response (Table 13-15). There will also be a slight diversion of water flow that occurs when turbines are operational, which may result in a low likelihood of smaller organisms (e.g. plankton and small fish) interacting with the Offshore Site (Copping *et al*., 2023). Flows are modified around the obstacle, with deceleration of flow immediately upstream, reduced velocity downstream and accelerated flow around the sides of the obstacle, creating a turbulent wake which can vary spatially, and in intensity. Micro-scale changes in swim speed, direction and orientation as a result of pressure waves and highly localised regions of complex turbulent flow close to the turbine could nevertheless be the difference between a less-damaging glancing blow and a serious direct impact.

Table 13-16 Worst-case collision scenario for Atlantic salmon for the Project alone

AVOIDANCE RATES	WORST-CASE COLLISION RATE (INDIVIDUALS PER YEAR)	
	RETURNING ADULTS	**EMIGRATING POST-SMOLTS**
0%	128	1,564
50%	64.0	782.0
90%	12.8	156.4
95%	6.4	78.2
98%	2.6	31.3
99%	1.3	15.6
99.1%	1.2	14.1
99.2%	1.0	12.5
99.3%	0.9	10.9
99.4%	0.8	9.4
99.5%	0.6	7.8
99.6%	0.5	6.3
99.7%	0.4	4.7
99.8%	0.3	3.1
99.9%	0.1	1.6

13.6.3.6.2.2 Sea trout Collision Risk

For sea trout, it is unlikely that the encounter rate will be greater than that of salmon as sea trout typically remain close to the sea surface (Kristensen *et al.*, 2018; Archer, 2022), and are less frequently found at depths of up to 20 m. Therefore, the collision risk with trout are likely to be less than that of salmon. Sea trout are considered to have a similar hearing sensitivity to Atlantic salmon and therefore have the ability to avoid operating turbines.

13.6.3.6.2.3 European Eel Collision Risk

Sand *et al.* (2000) studied the avoidance responses of downstream migrating European eels to infrasound by exposing eels to infrasound at a frequency of 11.8 Hz in a river setting. The results showed that the eels moved away from the sound source, demonstrating their ability to detect very low frequencies and respond by avoiding the area. Other studies (Bergström *et al.*, 2013; Deleau *et al.*, 2020) have also demonstrate that European eel have the ability to successfully navigate through areas, which may have potential barriers, such as offshore structures. This ability may be beneficial if the eel pass through the Offshore Site during their migration. European eel have a higher hearing sensitivity compared with Atlantic salmon (see Popper *et al.* 2014), and therefore, are considered to have a potentially higher ability to avoid tidal devices at long range (i.e. >50 m from device) (Table 13-15).

13.6.3.6.2.4 Impact Assessment

Atlantic salmon, European eel, and sea trout are all listed as Scottish PMFs and have experienced population declines in recent years. Additionally, Atlantic salmon is an Annex II species under the Habitat Directive. For Atlantic salmon, European eel and sea trout, their ability to avoid the devices at close range was assessed as medium to high, such that they should be able to evade the device from between 20 and 50 m and are unlikely to get very close to a device (Table 13-15). Therefore, all diadromous fish species have been assessed as having a **moderate sensitivity** to collision risk with the tidal devices. The CRM predicts that a small proportion of the adult and post-smolts passing through the Offshore Site will collide with operational turbines and this is likely to be highly precautionary given the conservative assumptions made for the CRM. Furthermore, existing monitoring at tidal sites indicates a limited potential for collision. The spatial set up of the Offshore Site does not function like a channel with turbines across it (no barrier effects) and any diadromous fish that do utilise the area will be able to go around or through the site and its devices based the minimum turbine spacing and surrounding geography. Therefore, the likelihood of a collision occurring is negligible. Therefore, the **magnitude of impact** is **low**. Therefore, the overall effect to marine fish species receptors is considered to be **minor** and **not significant.**

13.6.3.6.3 Marine Fish

As pelagic species, marine fish such as clupeids are smaller, less inclined to aggregate around structures and higher in the water column. Species with a higher hearing sensitivity (e.g. herring) may be more likely to avoid tidal turbines at a further distance, whereas others with a lower hearing sensitivity, have a lower likelihood of avoidance. This may explain the presence of saithe in close proximity to the Shetland Tidal Array (albeit at low numbers), indicating a lack of avoidance at close distance to the turbines (Smith *et al.,* 2022). Despite the presence of individuals in close proximity to tidal turbines, no collisions have been recorded.

Sandeels have a strong benthic association, being of relatively low mobility and having a strong preference for coarse and medium grained sands (Holland *et al.,* 2005) which notably have a low occurrence within the tidal test sites and mainly occur in bays along Eday. Consequently, the largely rocky substrate of the tidal test site is mostly unsuitable for sandeel populations of any importance. Impacts of collision, underwater noise and habitat creation are largely irrelevant to sandeels.

Many of the fish species predicted to utilise the Offshore Site are highly protected. Nonetheless, for the reasons identified above, all other fish species are considered have **moderate sensitivity** to collision risk at the Offshore Site. Based on localised spatial change, and given pelagic species are less inclined to aggregate around structures, the **magnitude of impact** is defined as being **negligible**. Therefore, the overall effect to marine fish species receptors is considered to be **minor** and **not significant**.

13.6.4 Summary of Significant of Effects

A summary of the assessment of significant effects along with relevant mitigation, monitoring or research requirements, for the construction, operation and maintenance and decommissioning Project phases are included in Table 13-17.

Table 13-17 Summary of significance of effects

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
CONSTRUCTION AND DECOMMISSIONING							
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance: Mortality, potential mortal injury and recoverable injury	Sandeels	Moderate	Low	Sandeels are a protected species and are considered to have moderate sensitivity to underwater noise generated from construction activities, as according to Popper *et al*., (2014) criteria, the hearing sensitivity of Group 1 fish is low. Based on the localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. In addition, based on the short-term duration of construction events and the fact that noise will not be continuous throughout construction (i.e. there would be periods of quiet between drilling 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.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
	Herring	Moderate	Low	Herring are highly protected and are highly sensitive to underwater noise. However, considering herring are mobile species that are likely to flee the area, and 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 within the tidal test site. Based on the highly localised spatial and temporal change and low frequency of construction events, which are intermittent and short term, impacts are unlikely to affect long term functioning of the herring populations. Therefore, for herring the magnitude of impact is defined as being low and the overall effect to herring receptors is considered to be minor and not significant.	Minor	Not significant	
	All other marine fish and diadromous fish	Moderate	Low	All other fish species are considered have low sensitivity to underwater noise generated from construction activities. Based on localised spatial and temporal change and low frequency of construction events, and on the basis that all of the species considered here are pelagic spawners, the impact is defined as being of low magnitude. Since effects are unlikely to affect the long-term functioning of the fish species populations, the overall	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				effect to fish receptors is considered to be minor and not significant.			
	Marine shellfish	Low	Low	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. The impact from construction noise will be localised and temporary, 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.	Minor	Not significant	
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance: TTS, masking and behavioural disturbance	Sandeels	Moderate	Low	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 moderate 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 events, the magnitude of impact is defined as being low. In addition, based on	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				the short-term duration (not continuous) of construction activities, any effects are unlikely to affect long term functioning of the sandeel populations. Additionally, it is important to note that drilling activities will occur in areas of exposed bedrock which have no potential to support sandeels. Therefore, the overall effect to sandeel receptors is considered to be minor and not significant.			
	Herring	Moderate	Low	Herring are highly protected. The Offshore Site is not located in key herring spawning or nursery grounds and the impact will be short term and not continuous. Therefore, although behavioural effects or auditory masking in herring from drilling are expected to be low and moderate in the far field and moderate and high in the near field (Popper *et al.*, 2014), herring are considered to have low vulnerability to drilling 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 construction activities at the Offshore Site. Based on the localised spatial and temporal change, low frequency of construction events, the magnitude of impact is defined as being low.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				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.			
	All other marine and diadromous fish species	Moderate	Low	Many of the fish predicted to utilise the Offshore Site are highly protected. Fish and shellfish species have a moderate sensitivity to underwater noise generated from construction activities at the Offshore Site. Based on the localised spatial and temporal change (not continuous) and low frequency of construction events, and given that all other fish species considered here are pelagic spawners, the magnitude of impact is defined as being low. 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.	Minor	Not significant	
	Marine shellfish	Low	Low	Shellfish are considered to be of low sensitivity to underwater noise, on the basis that shellfish do not possess a swim bladder, and	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				therefore, have a reduced hearing sensitivity. 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.			
Increased suspended sediment/turbidity (including release of drill cuttings)	Sandeels	Moderate	Low	Sandeels are considered to be high value receptors as a Scottish PMF species with a moderate sensitivity to increases in suspended sediments and turbidity associated with Project activities as they are demersal spawners. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. However, since any impacts are unlikely to affect long term functioning of the sandeel population. Therefore, the overall effect to sandeels is considered to be minor and not significant.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant
	Herring	Moderate	Low	Herring are considered to be high value receptors as a Scottish PMF species with a moderate sensitivity to increases in suspended sediments and turbidity at the Offshore Site as they are demersal spawners. Based on the transient	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. However, since any impacts are unlikely to affect long term functioning of the herring population. Therefore, the overall effect to herring is considered to be minor and not significant.			
	Common skate	Moderate	Low	Common skate as a critically endangered species, they are assessed as having a moderate sensitivity. Any increases in SSC and associated smothering would be temporary, intermittent and highly localised. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. However, since any impacts are unlikely to affect long term functioning of the common skate population. Therefore, the overall effect to is considered to be minor and not significant.	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
	All other marine fish	Low	Low	Adult fish are mobile and able to avoid areas with high sediment loads. These species are also pelagic spawners with buoyant eggs and are therefore less vulnerable to smothering. Therefore, other marine fish species are considered to be of low sensitivity to increases in suspended sediments and turbidity within the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. Many other marine fish species within the are considered to be high value receptors due to their conservation status. However, all other marine fish species have low sensitivity to increases in suspended sediments and turbidity, since any impacts are unlikely to affect long term functioning of the other marine fish species populations. Therefore, the overall effect to all other marine fish species is considered to be minor and not significant.	Minor	Not significant	
	Marine shellfish	Moderate	Low	Shellfish are considered to be of moderate sensitivity to increased suspended sediment/turbidity. Based on localised spatial and temporal change and low frequency of construction events, the impact magnitude is defined as being of low. Therefore, the overall effect to	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				shellfish is considered to be minor and not significant.			
Smothering because of drill cuttings or re-settlement of sediments	Sandeels	Moderate	Low	Sandeels are considered to be high value receptors as a Scottish PMF species with a moderate sensitivity to increases in suspended sediments and turbidity associated with Project activities as they are demersal spawners. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. However, since any impacts are unlikely to affect long term functioning of the sandeel population. Therefore, the overall effect to sandeels is considered to be minor and not significant.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in **Volume 1,** Chapter 4: Project Description as it was concluded that the impact was not significant.
	Herring	Moderate	Low	Herring are considered to be high value receptors as a Scottish PMF species with a moderate sensitivity to increases in suspended sediments and turbidity at the Offshore Site as they are demersal spawners. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the magnitude	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				of impact is defined as being low. However, since any impacts are unlikely to affect long term functioning of the herring population. Therefore, the overall effect to herring is considered to be minor and not significant.			
	Common skate	Moderate	Low	Common skate as a critically endangered species, they are assessed as having a moderate sensitivity. Any increases in SSC and associated smothering would be temporary, intermittent and highly localised. Based on the transient nature of any plume this would not lead to increased suspended sediment/turbidity for long periods. The localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being low. However, since any impacts are unlikely to affect long term functioning of the common skate population. Therefore, the overall effect to is considered to be minor and not significant.	Minor	Not significant	
	All other marine fish	Low	Low	Other marine fish species are considered to be of low sensitivity to increases in suspended sediments and turbidity within the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				being low. Many other marine fish species within the are considered to be high value receptors due to their conservation status. However, all other marine fish species have low sensitivity to increases in suspended sediments and turbidity, since any impacts are unlikely to affect long term functioning of the other marine fish species populations. Therefore, the overall effect to all other marine fish species is considered to be minor and not significant.			
	Marine shellfish	Moderate	Low	Shellfish are considered to be of moderate sensitivity to potential smothering caused by the drill cuttings piles at the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the impact magnitude is defined as being of low. Therefore, the overall effect to shellfish is considered to be minor and not significant.	Minor	Not significant	
Spawning and nursery ground habitat loss/damage	Sandeels	Moderate	Negligible	Sandeels within are considered to be high value receptors as a Scottish PMF species and of moderate sensitivity to potential habitat loss or damage at the Offshore Site. Based on localised spatial and temporal change and low frequency of construction events, the magnitude of impact is defined as being negligible.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				However, the impact to sandeels will be localised to the Offshore Site and any impacts are unlikely to affect long term functioning of the sandeel population. Therefore, the overall effect to sandeels is considered to be minor and not significant.			concluded that the impact was not significant
	Herring	Moderate	Negligible	Herring are considered to be high value receptors as a Scottish PMF species and of moderate sensitivity to potential habitat loss or damage at the Offshore Site. As the construction activities will occur intermittently, only a small area of seabed is expected to be disturbed at any one time. Therefore the magnitude of impact is defined as being negligible. The impact to herring will be localised to the Offshore Site, and any impacts are unlikely to affect long term functioning of the herring population. Therefore, the overall effect to herring is considered to be minor and not significant.	Minor	Not significant	
	Common skate	High	Negligible	Common skate are considered to be high value receptors as a critically endangered species and PMF and of high sensitivity to potential habitat loss or damage at the Offshore Site. As the construction activities will occur intermittently, only a small area of seabed is expected to be disturbed at any one time. Therefore the magnitude of impact is defined	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				as being negligible. The impact to common skate will be localised to the Offshore Site, and any impacts are unlikely to affect long term functioning of the population. Therefore, the overall effect to common skate is considered to be minor and not significant.			
	All other marine fish	Low	Negligible	Other marine fish species are considered to be of low sensitivity to potential habitat loss or damage at the Offshore Site. As the construction activities will occur intermittently, only a small area of seabed is expected to be disturbed at any one time, therefore the magnitude of impact is defined as being negligible. However, all other marine fish species have low sensitivity to habitat loss and the impact will be localised to the Project site, and any impacts are unlikely to affect long term functioning of the other marine fish species populations. Therefore, the overall effect to all other marine fish species is considered to be minor and not significant.	Minor	Not significant	
	Marine shellfish	Moderate	Negligible	Shellfish are considered to be of moderate sensitivity to potential habitat loss or damage. Based on localised spatial and temporal change and low frequency of construction events, the impact magnitude is defined as being of	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				negligible. Therefore, the overall effect is considered to be minor and not significant.			
OPERATION AND MAINTENANCE							
Habitat creation and fish aggregation effect	All marine and shellfish species fish	Moderate	Negligible	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 negligible 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.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant
Underwater noise from tidal devices operation	Sandeels	Low	Low	Sandeels are a protected species and 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. Based on localised spatial change, the magnitude of impact is defined as being low. In addition, any impacts are unlikely to affect long term functioning of the sandeel populations. Therefore, the overall effect to sandeel receptors is	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				considered to be minor and not significant.			
	Herring	Moderate	Low	Herring are highly protected and are highly sensitive to underwater noise. However, considering the Offshore Site is not located within a key spawning or nursery ground for this species and that adult herring are a mobile species that are unlikely to be exposed to noise for an extended length of time, herring have been assessed to have moderate sensitivity to underwater noise at the Offshore Site. Based on the highly localised spatial change, impacts are unlikely to affect long term functioning of the herring populations. Therefore, for herring the magnitude of impact is defined as being low and the overall effect to herring receptors is considered to be minor and not significant.	Minor	Not significant	
	All other marine and diadromous fish	Moderate	Low	All other fish species are considered have moderate sensitivity to underwater noise. Based on localised spatial change, and on the basis that all of the species considered here are pelagic spawners, the impact is defined as being of low magnitude. 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.	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
	Marine shellfish	Low	Low	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. The impact is defined as being of low magnitude. Therefore, the overall effect is minor and not significant.	Minor	Not significant	
Changes to sediment and hydrodynamic regime	Marine fish	Low	Low	Any impacts on hydrodynamics and sediment processes are considered insufficient to alter the distribution of available habitat for sandeels, herring or shellfish. Therefore, the sensitivity of receptor is considered low. Potential changes to the hydrodynamic regime was assessed to be low in Volume 1, Chapter 7: Hydrodynamic and Physical Processes, therefore the magnitude of impact is negligible. Therefore, the overall effect is negligible and not significant.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant
	Marine shellfish	Low	Negligible		Negligible	Not significant	
	Common skate	**Moderate**	**Negligible**	It is assumed that there could be the potential for common skate egg laying in the Offshore Site. Given the conservation importance of this species, as Critically Endangered on the IUCN Red List and a Scottish PMF species, the sensitivity is assigned as moderate. Potential changes to the hydrodynamic regime was assessed to be low in Volume 1, Chapter 7: Hydrodynamic and Physical Processes, therefore the magnitude of impact is	**Minor**	**Not Significant**	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				negligible. Therefore, the overall effect is minor and not significant.			
Electromagnetic Field (EMF) effects	Elasmobranchs	Moderate	Negligible	Elasmobranch species are sensitive to increases in EMF, as such have been given a moderate sensitivity rating. Based on the localised spatial change as discussed, the EMF emitted by the subsea cables is considered to be negligible, therefore, the impact is defined as being of low magnitude. Therefore, the overall effect to elasmobranch species receptors is considered to be minor and not significant.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant
	Diadromous fish	Moderate	Negligible	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. based on the localised spatial change, the impact is defined as being of low magnitude as the levels of EMF emitted will be negligible. Therefore, the overall effect to diadromous fish species receptors is considered to be minor and not significant.	Minor	Not significant	
	Marine fish	Moderate	Negligible	Marine fish are deemed not to be vulnerable to EMF. They are highly mobile and therefore exhibit the capacity to adapt and recover to any disturbance as may be generated by EMF. However, acknowledging the lack of concrete evidence on fish responses to EMF and also considering that several marine fish species are protected as PMFs, they are considered to have a	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				moderate sensitivity. EMF will be emitted throughout the life cycle of the Project, however, based on the localised spatial change, the magnitude of impact is defined as being low as the levels of EMF emitted will be negligible.			
	Marine shellfish	Moderate	Negligible	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 cables will be sufficiently protected to reduce EMFs experienced at the seabed, the impact is defined as being of negligible magnitude. Therefore, the overall effect upon shellfish receptors is considered to be minor and not significant.	Minor	Not significant	
Presence of tidal devices and associated infrastructure leading to a barrier effect	Diadromous fish	Moderate	Low	Atlantic salmon are considered to have the highest sensitivity to barrier effects with moderate sensitivity. The magnitude is low. Therefore, the overall effect to diadromous species receptors is considered to be minor and not significant.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Table 4 3 (Section 4.3) as it was concluded that the impact was not significant
	Marine fish	Low	Low	The Offshore Site is not expected to be important for herring or cod as it does not overlap with high intensity nursey or spawning grounds for	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				either species, and therefore, they are not expected to be in the area in high numbers, therefore, the sensitivity of receptor is considered low. Based on the small area the devices cover the magnitude is low. Therefore, the overall effect to marine species receptors is considered to be minor and not significant			
Collision with turbine blades leading to injury or death	Diadromous fish	Moderate	Low	Diadromous fish are more likely to aggregate around the devices, and their ability to avoid the devices at close range. Diadromous fish should be able to evade the device from between 20 and 50 m and are unlikely to get very close to a device, they have a moderate sensitivity to collision risk with the tidal devices. However, the magnitude is low, based on the results of the CRM indicating a low proportion of Atlantic salmon population being affected, and the limited potential for collision to occur, accounting for behavioural evasion. Therefore, the overall effect to diadromous fish receptors is considered to be minor and not significant.	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant
	Marine fish	Moderate	Low	All other fish species are considered have low sensitivity to collision risk at the Offshore Site. Based on localised spatial change, and given pelagic species are less inclined to aggregate around structures, the impact is defined as being of low magnitude. Therefore, the overall	Minor	Not significant	

IMPACT PATHWAY	RECEPTOR	SENSITIVITY	MAGNITUDE	RATIONALE	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	ADDITIONAL REQUIREMENT
				effect to marine fish species receptors is considered to be minor and not significant.			

13.7 Assessment of Cumulative Effects

The projects which could result in cumulative impacts are restricted to those which could generate similar impacts to the Fall of Warness tidal test site and are located within 25 km of the Offshore Site. Impacts relating to habitat disturbance are expected to be localised to the Offshore Site with a similar Zone of Influence (ZoI) to Benthic Environment (25 km) (see Volume 2, Chapter 8: Benthic Environment). A similar ZoI has been used for EMF effects and underwater noise, however, this is considered to be conservative due to the extremely localised extent of EMF emissions and a low underwater noise impact associated with construction/operational noise. Based on the minor or negligible impact significance determined for the standalone impacts associated with the Project, it is not expected that other impact mechanisms will have the potential to act cumulatively with third-party projects located more than 25 km from the Project. The projects that have the potential to cause cumulative impacts are presented below in Table 13-18 and Figure 13-12.

Based on the minor or negligible impact significance determined for the standalone impacts associated with the Project, it is not expected that other impact mechanisms will have the potential to act cumulatively with third-party projects located more than 25 km from the Project.

The following effect pathways have been assessed for potential cumulative impacts for the fish and shellfish:

Construction / decommissioning:

- Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance;
- Increased suspended sediment/turbidity (including release of drilled cuttings);
- Smothering because of drill cuttings or re-settlement of sediments; and
- Spawning and nursery ground habitat loss/ damage.

Operation:

- Habitat creation and fish aggregation effect;
- Underwater noise from tidal devices operation;
- Changes to sediment and hydrodynamic regime;
- EMF effects;
- Presence of tidal devices and associated infrastructure leading to barrier effects; and
- Collison with turbine blades leading to injury or death.

Table 13-18 List of projects considered for Fish and Shellfish Ecology cumulative impact assessment

PROJECT NAMES	STATUS	DISTANCE (KM)
RENEWABLES		
Westray Tidal Array	Pre-Application (Scoping)	0.065
European Marine Energy Centre (EMEC) Shapinsay Sound	Operational	14.01
European Marine Energy Centre (EMEC) Deer Sound	Consented	18.12
CABLES		
Eday - Westray distribution cable	Active	1.84
R100 s 2.06 telecom cable	Active	3.54

PROJECT NAMES	STATUS	DISTANCE (KM)
Eday - Sanday distribution cable	Active	3.55
Rousay - Westray distribution cable	Active	4.25
Rousay - Egilsay distribution cable	Active	5.46
R100 s 2.05 telecom cable	Active	6.52
R100 s 2.07 telecom cable	Active	6.68
Sanday - Stronsay distribution cable	Active	6.84
Shapinsay - Stronsay 2 distribution cable	Active	8.54
Shapinsay - Stronsay distribution cable	Active	8.59
Rousay - Wyre distribution cable	Active	8.74
Shapinsay - Stronsay 2 distribution cable	Active	9.20
Shapinsay - Stronsay 2 distribution cable	Active	10.51
Hie s 1.19 telecom cable	Active	10.99
R100 s 2.10 telecom cable	Active	11.22
Rousay - Orkney mainland distribution cable	Active	11.22
Orkney - Rousay distribution cable	Active	11.99
Orkney mainland - Shapinsay distribution cable	Active	13.27
R100 s 2.09 telecom cable	Active	15.48
Westray - Papa Westray distribution cable	Active	20.05
Orkney - Holm of Grimbister distribution cable	Active	20.05
Sanday – N Ronaldsay distribution cable	Active	23.77
PORTS AND HARBOURS		
Faray slipway Extension and Landing Jetty	Consented	4.09
Hatston Pier and Terminal Expansion	Application	17.03
Scapa Deep Water Quay	Application	23.36
AQUACULTURE		
Various aquaculture projects	Includes operational and proposed sites	Closest is approximately 2.5 km

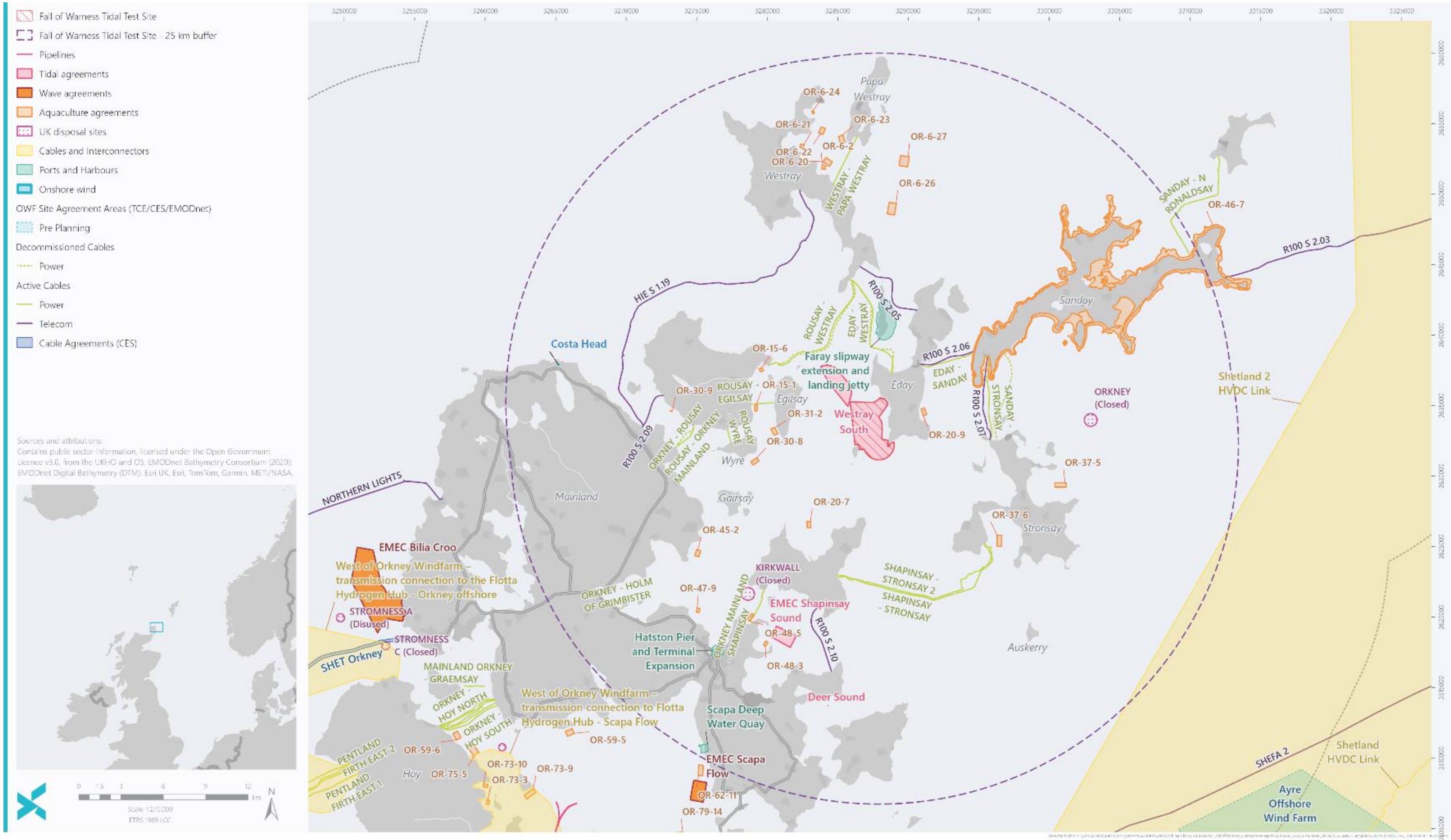

Figure 13-12 Cumulative projects

13.7.1 Cumulative Effects During Construction and Decommissioning

The construction for the Westray Tidal Array project is planned to commence in 2028, and therefore the construction and decommissioning phases may overlap with the construction and decommissioning phases of the proposed Fall of Warness Project (2026 to 2028). The Westray Tidal Array project is expected to be on a similar scale to the proposed Fall of Warness Project, therefore the magnitude of potential impacts is expected to be similar.

The EMEC Shapinsay Sound Test Site is already operational. The Shapinsay Sound Test Site currently contains a single device berth, with the potential for additional mooring system for a test support buoy (EMEC, 2020). The Marine Licence for the construction of the test support buoy is valid from 2024 to 2026, and therefore, there is the potential to overlap the Project's construction phase.

The EMEC Deer sound site comprises of a mooring system to enable certain maintenance tasks on the Orbital O2 2MW tidal turbine, deployed at the existing EMEC Fall of Warness test site, if the turbine needs to be removed (Orbital Marine Power, 2019). The turbine will not be operating when on-site at the Deer Sound. Given the highly localised footprint of the mooring system at the Deer Sound and infrequent use of this site, there is limited potential for cumulative impacts with the Project. Therefore, this project has been screened out of the cumulative impact assessment.

There are a number of active cables in the vicinity of the Offshore Site. The main pathway for cumulative effect would be from any localised EMF effects that could coalesce with those of the Project and habitat creation. Both effects are highly localised and therefore a cumulative effect would only be expected in close proximity to the Project or for cables overlapping the Offshore Site export or umbilical cables. It is anticipated that other projects will largely aim for cable burial to a sufficient depth where possible or, where burial is not possible, cable protection measures would be applied reducing the effects of EMF. Therefore, given that the closest operational or planned cable is over 1 km from the Offshore Site, the potential for cumulative effects Is limited. Therefore, operational cables have been screened out of the cumulative impact assessment.

There are a number of ports and harbours within 25 km of the Offshore Site. The Faray Slipway Extension and Landing Jetty project is expected to have a total structure footprint of up to 1,168 m^2 and require dredging of up to an additional 2,050 m^2 outside of the structure footprint (Orkney Islands Council, 2021). This project will also involve sheet piling and has the potential to introduce additional underwater noise into the marine environment. This extension will support the development of a windfarm on the island of Faray. Construction is expected to commence in 2025 and last approximately two years (Orkney Islands Council, 2021). Therefore, construction may overlap with the construction of the Project.

The EIAR for the Hatston Pier and Terminal Expansion, also referred to as the Orkney Logistics Base (Hatston), was submitted in June 2023 (Orkney Islands Council, 2023). The Haston Pier and Terminal expansion is scheduled to complete phase 1 construction in 2025, and phase 2 and 3 by 2027, and therefore, construction may overlap with the construction of the Project. The proposed development involves the extension of the existing Hatston Quay and adjacent land to create a multi-user logistics base northwest of Kirkwall. The project includes a 300 m outer quay extension, a 125 m inner berth with a fixed ramp and provision for a future link span, and a boat lift facility. Approximately 7.5 hectares of additional land will be created through seabed reclamation, and the development will support a range of sectors including offshore wind, freight, ferries, and aquaculture (Orkney Islands Council, 2023). The marine works will require dredging and piling activities (Orkney Islands Council, 2023).

The EIAR for the Scapa Deep Water Quay was submitted in July 2023 and additional information as submitted in support of the Marine Licence applications in late 2024. The construction of the Scapa Deep Water Quay Project is expected to commence in 2025 with completion of all phases by 2028 (EnviroCentre, 2024a). The proposed Scapa Deep Water Quay will comprise of a 597 m long main quayside berth with a 135 m quayside pocket, a north tug and pilot boa berth and a laydown area of approximately 22.85 hectares. A total seabed area of approximately 65,000 m^2 will be dredged to depths between -15 m and -20 m Chart Datum (CD) adjacent to the quay to provide deepwater berths. Sheet piles will be installed for the quay wall using a vibro hammering technique (EnviroCentre, 2023).

As noted in Table 13-18, there are proposed aquaculture sites within 25 km, and construction and decommissioning of some of these sites may overlap with the Project. The construction of aquaculture sites will vary depending on the species being farmed, however the majority of the structural elements will be suspended in the water column, with any foundations being relatively lightweight compared to the foundation elements for marine renewables and port and harbour developments.

13.7.1.1 Underwater Noise from Foundation/Mooring Installation Methods and Vessels Leading to Auditory Injury, Death or Disturbance

During construction, underwater noise associated with installation vessels and drilling piles may cause cumulative disturbance impacts if the construction periods overlap.

If the Westray Tidal Array project were to be installed at the same time as the Project, this could result in an increase in underwater noise emissions. Up to 70 tidal devices may be installed at the Westray Tidal Array project which will be moored to the seabed via anchors, with the potential for drilling activity (Orbital Marine Power, 2023). However, similar to the Project, any underwater sound will be temporary and highly localised.

Faray Slipway Extension and Landing Jetty, the Hatston Pier and Terminal expansion, the Scapa Deep Water Quay and the Flotta Ultra Deep-Water Quay may involve piling of sheet piles over a short duration of time (Orkney Islands Council, 2021; Orkney Islands Council, 2023; EnviroCentre, 2024a; 2024b). Although piling may result in elevations in underwater sound, possibly resulting in disturbance to seals, this will be over a short period, and with the implementation of standard mitigation, the impact remains as temporary, localised and reversible. Furthermore, construction and installation noise of Scapa Flow Deep Water Quay or the Hatston Pier and Terminal Expansion are unlikely to spatially overlap with that of the Project, given the distances of these developments from the Offshore Site (23.36 km and 17.03 km, respectively).

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **low magnitude** for all receptors. The cumulative impact is therefore expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant.**

13.7.1.2 Increased Suspended Sediment/Turbidity (Including Release of Drilled Cuttings)

Construction works at the Westray Tidal Array project may result in sediment disturbance, or the production of drill cuttings, in a similar manner to the Project, as described in Section 13.6.2.2. It is possible that suspended sediment produced from construction works could combine with sediments from the Project. Furthermore, the release of fish effluent at aquaculture sites could also act cumulatively with smothering during the construction of the Project as well as any sediments disturbed during dredging works at nearby ports and harbours. The Faray Slipway Extension project is closest to the Offshore Site and will require the dredging of up to 3,000 m^3 of sediment (almost exclusively sand with very little fine material), which would be disposed of in a licensed site. Dredging is expected to take one to two weeks. It is estimated that 5% (150 m^3) of the dredged material will escape and become entrained in the water column, and that this will almost all settle out within 150 m of the dredging area (Orkney Islands Council, 2021). There is limited potential for the suspended sediment from the dredging at the Scapa Flow Deep Water Quay and the Hatston Pier and Terminal Expansion project to act cumulatively with the Project. The Scapa Flow is cut off from its natural eastern drainage by the Churchill Barriers, and the tide must flow into the Pentland Firth to the south and the Atlantic to the west. The sediment plume generated by dredging operations at the Hatston Pier and Terminal Expansion project is anticipated to be localised within the Kirkwall Bay area, with limited connectivity to the Project due to hydrodynamic separation and prevailing tidal flows. Overall, given the short duration of the potential impact and the small area affected, it is considered unlikely that the sediment plumes from other developments would interact with any sediment disturbed from the Offshore Site.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **low magnitude** for all species. The cumulative impact is expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant.**

13.7.1.3 Smothering Because of Drill Cuttings or Re-Settlement of Sediments

As noted above, there is the potential for sediment disturbance from other projects, which will result in the release of suspended sediments could also result in smothering of Fish and Shellfish Ecology receptors due to the settlement of suspended sediment. However, as noted above, there is very limited potential for a cumulative impact from increased suspended sediments and the same applies for smothering due to the re-settlement of sediments.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **low magnitude** for all species. The cumulative impact is expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant**

13.7.1.4 Spawning and Nursery Ground Habitat Loss / Damage

There is currently no information available to calculate the Westray Tidal Array project seabed footprint, which is in close proximity to the Project. However, this site could involve the construction of up to 70 tidal turbine devices, and associated infrastructure, and therefore a similar seabed footprint to the Project could be assumed (Orbital Marine Power, 2023). Although the construction of the Westray Tidal Array project will increase the cumulative seabed disturbance footprint, as spawning and nursery ground habitat availability for sensitive species, even those with strong habitat preferences, is not restricted to the Offshore Site, any loss/ damage of spawning and nursery grounds is unlikely to impact species significantly beyond which is already been assessed for the Project. The function and value of the receptors are not expected to be affected.

The Faray slipway Extension and Landing Jetty, Scapa Flow Deep Water Quay, and Hatston Pier and Terminal Expansion works will include dredging and construction which have the potential to cause loss/damage to fish spawning and nursey grounds. However, given the distance of the projects (4.09 km, 23.36 km and 17.03 km, respectively), the localised impact associated with the Offshore Site and the wide spread availability of spawning and nursery grounds, the construction of these ports and harbours is not anticipated to significantly increase the impact magnitude.

Receptor sensitivity is considered as **high** as a worst-case for all species. The impact remains as being **negligible magnitude** for all receptors. As such, any cumulative impact with the Offshore Site is expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant**.

13.7.2 Cumulative Effects During Operation and Maintenance

As a worst case it is assumed that all the third-party projects listed in Table 13-18 will be operating simultaneously with the Project. Impact pathways that could lead to cumulative impacts on the Fish and Shellfish Ecology are discussed below.

13.7.2.1 Habitat Creation and Fish Aggregation Effect

All the third-party projects described in Table 13-18 are expected to introduce new hard substrate to the seabed. Third-party projects could introduce further hard substrate, such as cable protection and tidal turbines (e.g. at the Westray Tidal Array project).

The introduction of up to 70 tidal turbines and associated infrastructure at the Westray Tidal Array project will increase the hard substrate in the region, resulting in further novel habitat creation and potential fish aggregation effects (Orbital Marine Power, 2023). However, it is expected that the impact will remain as being spatially limited and is not expected to substantially increase the magnitude of impact compared to the Project alone.

The EMEC Shapinsay Sound Test Site has already been installed and has the potential for fish to aggregate around the underwater resulting cumulative noise impacts during operation. However, as discussed in Section 13.6.3.1, fish are less likely to aggregate around moving underwater turbines and will be deterred due to noise and potential collision risk. Given the localised impact of habitat creation and fish aggregation and the distance of the projects to the Offshore Site, cumulative impacts are unlikely to occur.

The various aquaculture sites are generally located in slightly more sheltered locations, and the seabed in these locations tends towards coarse sediment rather than rock. Further hard substrate may be introduced at port and harbour developments (e.g. Scapa Deep Water Quay). However, once again, these areas will be highly localised.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **negligible magnitude** for all receptors. The cumulative impact is expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant.**

13.7.2.2 Underwater Noise from Tidal Devices Operation

The presence of operational turbines in the Westray Tidal Array project, once constructed, could act cumulatively with the operational noise of the Project. However, as per the Project, the underwater noise will be highly localised and is not considered likely to result in wide-scale behavioural effects. The EMEC Shapinsay Sound Test Site has already been installed and also has the potential to cause cumulative noise impacts during operation. However, given the localised impact of operational noise and the distance of this project to the Offshore Site, cumulative noise impacts are unlikely to occur.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **low magnitude** for all receptors. The cumulative impact is expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant.**

13.7.2.3 Changes to Sediment and Hydrodynamic Regime

Changes to the hydrodynamic regime caused by the presence of the Westray Tidal Array project and the EMEC Shapinsay Sound Tidal Test Site are expected to be as described for the Project in Section 13.6.3.3, although at varying scales. The installations are expected to extract a very small proportion of the available energy from the tidal stream, with commensurately small magnitude impacts on the receptors of interest.

Nearby harbour walls and the proposed Faray slipway Extension and Landing Jetty, Scapa Deep Water Quay and Hatston Pier and Terminal Expansion will block wave action and obstruct the natural flow of water in the immediate vicinity. This is likely to create areas of scour near the ends of the structures. Conversely, it is likely that reduced current speed in the sheltered lee of the structures will result in the settlement of finer sediment in the vicinity than would have been present prior to their introduction. The Faray Slipway Extension project is located in a relatively sheltered area on the southeast side of Faray where it is protected from storm conditions (Orkney Island Council, 2021). The existing slipway (due to be replaced) was once longer than the existing structure, which itself has been in place for many years with no discernible effect on erosion in the local area. As such Orkney Islands Council (2021) predicted negligible impact on coastal processes.

Scour produced by these third-party projects is likely to be detectable at the local level if the natural seabed comprises sediment as opposed to bare rock. However, the magnitude of the impact is expected to be low in the context of natural variation in the hydrodynamic and sediment regime. The cumulative impact of changes to the hydrodynamic and sediment regime due to the presence of the Project and other developments is not expected to affect the value and function of any of the receptors of interest.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **negligible magnitude** for all receptors The cumulative impact on the fish and shellfish receptors is expected to be of **minor impact significance**. The **significance of effect** on all receptors is therefore considered **not significant**.

13.7.2.4 EMF Effects

Nearby cables may increase EMF intensities in the region; however, this will be highly localised. Given the low, localised levels of EMF levels anticipated by the Project cables, cumulative impacts are unlikely to occur.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **negligible magnitude** for all receptors. The cumulative impact is expected to be of **minor impact significance** to all receptors and the **significance of effect** is therefore considered **not significant**.

13.7.2.5 Presence of Tidal Devices and Associated Infrastructure Leading to Barrier Effects

There are no cumulative impacts associated with barrier effects with proposed and existing cables, beyond potential avoidance associated with EMFs, which will be highly localised and therefore is not expected to substantially increase the magnitude of impact from the Project alone.

For physical barrier effects, the Westray Tidal Array project is likely to represent the project with the greatest potential to result in a cumulative impact. The presence of the tidal turbines at the Westray Tidal Array project will act similarly to the Project to result in potential barrier effects. However, most species present within the Offshore Site have very large geographical coverage, extending around the north coast of Scotland into the North Sea and Atlantic Ocean.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **low magnitude** for all receptors. The cumulative impact on the fish and shellfish receptors is expected to be of **minor impact significance**. The **significance of effect** on all receptors is therefore considered **not significant**.

13.7.2.6 Collison with Turbine Blades Leading to Injury or Death

As described above for barrier effects, for collision risk, the Westray Tidal Array project likely represents the project with the greatest potential to act cumulatively with the Project. However, as described above, most species present within the Offshore Site have very large geographical coverage, extending around the north coast of Scotland into the North Sea and Atlantic Ocean. There is no recorded incident of collision between fish and tidal turbine.

Receptor sensitivity is considered as **moderate** as a worst-case for all species. The impact remains as being **low magnitude** for all receptors. The cumulative impact on the fish and shellfish receptors is expected to be of **minor impact significance**. The **significance of effect** on all receptors is therefore considered **not significant**.

13.8 Conclusions and Residual Effects

A summary of all the impacts assessed as part of the Project are included in Table 13-19.

Table 13-19 Summary of residual effects for Fish and Shellfish Ecology

IMPACT PATHWAY	RECEPTOR	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	MITIGATION / MONITORING / RESEARCH IDENTIFIED	SIGNIFICANCE OF RESIDUAL EFFECT
CONSTRUCTION AND DECOMMISSIONING					
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance: Mortality, potential mortal injury and recoverable injury	Sandeels	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Herring	Minor	Not significant		
	All other marine fish and diadromous fish	Minor	Not significant		
	Marine shellfish	Minor	Not significant		
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance: TTS, masking and behavioural disturbance	Sandeels	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Herring	Minor	Not significant		Not significant
	All other marine fish and diadromous fish	Minor	Not significant		Not significant
	Marine shellfish	Minor	Not significant		Not significant
Increased suspended sediment/turbidity (including release of drilled cuttings)	Sandeels	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Herring	Minor	Not significant		
	Common skate	Minor	Not significant		
	All other marine fish and diadromous fish	Minor	Not significant		
	Marine shellfish	Minor	Not significant		
Smothering because of drill cuttings or re-settlement of sediments	Sandeels	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Herring	Minor	Not significant		
	Common skate	Minor	Not significant		
	All other marine fish and diadromous fish	Minor	Not significant		

IMPACT PATHWAY	RECEPTOR	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	MITIGATION / MONITORING / RESEARCH IDENTIFIED	SIGNIFICANCE OF RESIDUAL EFFECT
	Marine shellfish	Minor	Not significant		
Spawning and nursery ground habitat loss/ damage	Sandeels	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Herring	Minor	Not significant		
	Common skate	Minor	Not significant		
	All other marine fish and diadromous fish	Minor	Not significant		
	Marine shellfish	Minor	Not significant		
OPERATION AND MAINTENANCE					
Habitat creation and fish aggregation effect	All marine fish and shellfish receptors	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
Underwater noise from tidal devices operation	Sandeels	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Herring	Minor	Not significant		
	All other marine and diadromous fish	Minor	Not significant		
	Marine shellfish	Minor	Not significant		
Changes to sediment and hydrodynamic regime	Marine fish	Negligible	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Marine shellfish	Negligible	Not significant		
	Common skate	Minor	Not significant		Not significant
EMF effects	Diadromous fish	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for	Not significant
	Elasmobranch fish	Minor	Not significant		

IMPACT PATHWAY	RECEPTOR	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	MITIGATION / MONITORING / RESEARCH IDENTIFIED	SIGNIFICANCE OF RESIDUAL EFFECT
	Marine fish	Minor	Not significant	this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	
	Marine shellfish	Minor	Not significant		
Presence of tidal devices and associated infrastructure leading to barrier effects	Diadromous fish	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Marine fish	Minor	Not significant		
Collison with turbine blades leading to injury or death	Diadromous fish	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
	Marine fish	Minor	Not significant		
CUMULATIVE					
CONSTRUCTION AND DECOMMISSIONING					
Underwater noise from foundation/mooring installation methods and vessels leading to auditory injury, death or disturbance	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
Increased suspended sediment/turbidity (including release of drilled cuttings)	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant

IMPACT PATHWAY	RECEPTOR	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	MITIGATION / MONITORING / RESEARCH IDENTIFIED	SIGNIFICANCE OF RESIDUAL EFFECT
Smothering because of drill cuttings or re-settlement of sediments	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
Spawning and nursery ground habitat loss/ damage	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
OPERATION AND MAINTENANCE					
Habitat creation and fish aggregation effect	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
Underwater noise from tidal devices operation	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
Changes to sediment and hydrodynamic regime	All fish and shellfish species	Negligible	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant

IMPACT PATHWAY	RECEPTOR	IMPACT SIGNIFICANCE	SIGNIFICANCE OF EFFECT	MITIGATION / MONITORING / RESEARCH IDENTIFIED	SIGNIFICANCE OF RESIDUAL EFFECT
EMF effects	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant
Collison with turbine blades leading to injury or death	All fish and shellfish species	Minor	Not significant	No additional mitigation, monitoring or research requirements have been identified for this impact above and beyond the measures presented in Volume 1, Chapter 4: Project Description as it was concluded that the impact was not significant	Not significant

13.9 Topic Specific References

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13.10 Topic Specific Acronyms and Abbreviations

ACRONYM	DEFINITION
AC	Alternating Currents
BRUV	Baited Remote Underwater Video
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
DC	Direct Currents
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMEC	European Marine Energy Centre
EMF	Electromagnetic Field
FAD	Fish Aggregation Device
HVDC	High Voltage Direct Current
Hz	Hertz
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IHLS	The International Herring Larvae Surveys
IUCN	International Union for Conservation of Nature
LAT	Lowest Astronomical Tide
MHWS	Mean High Water Spring
MPA	Marine Protected Area
MD-LOT	Marine Directorate - Licensing Operations Team
MS-LOT	Marine Scotland - Licensing Operations Team
MD-SEDD	Marine Scotland – Science, Evidence, Data and Digital
MSS	Marine Scotland Science
mT	milli Tesla
NBN	National Biodiversity Network
NCMPA	Nature Conservation Marine Protected Areas
OSPAR	Convention for the Protection of the Marine Environment of the North East Atlantic
OSW	One Sea Winter
PMF	Priority Marine Features
PrePARED	Predators and Prey Around Renewable Energy Developments
PTS	Permanent Threshold Shift
rms	Root mean square
SAC	Special Area of Conservation
SEL	Sound Exposure Level
SPA	Special Protection Area
TTS	Temporary Threshold Shift
UK	United Kingdom
UKBAP	UK Biodiversity Action

ACRONYM	DEFINITION
μT	micro Tesla
μV	Microvolts
ZOI	Zone of Influence

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