Chapter 9: Fish and Shellfish Ecology

Array EIA Report

2024

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CONTENTS

TABLES

FIGURES

9. FISH AND SHELLFISH ECOLOGY

9.1. INTRODUCTION

1. This chapter of the Array Environmental Impact Assessment (EIA) Report presents the assessment of the likely significant effects (LSE[1]) (as per the EIA Regulations) on fish and shellfish ecology as a result of the Ossian Array which is the subject of this application (hereafter referred to as "the Array"). Specifically, this chapter assesses the LSE[1] of the Array on fish and shellfish ecology during the construction, operation and maintenance, and decommissioning phases.

2. In this Array EIA Report, LSE[1] refers to the term used in the EIA Regulations. The accompanying Report to Inform Appropriate Assessment (RIAA) for the Array uses the term as defined by the Habitats Regulations Appraisal (HRA) Regulations.

3. The following technical chapters and appendices also inform the assessment presented in this chapter:

- volume 2, chapter 7: Physical Processes;
- volume 3, appendix 7.1: Physical Processes Technical Report;
- volume 2, chapter 8: Benthic Subtidal Ecology;
- volume 3, appendix 8.1: Benthic Subtidal Ecology Technical Report;
- volume 3, appendix 9.1: Fish and Shellfish Ecology Technical Report;
- volume 2, chapter 10: Marine Mammals;
- volume 3, appendix 10.1: Underwater Noise Technical Report;
- volume 2, chapter 11: Offshore Ornithology; and
- volume 3, appendix 12.1: Commercial Fisheries Technical Report;

4. This chapter summarises information contained within volume 3, appendix 9.1.

9.2. PURPOSE OF THE CHAPTER

5. The Array EIA Report provides the Scottish Ministers, statutory and non-statutory stakeholders with adequate information to determine the LSE[1] of the Array on the receiving environment. This is further outlined in volume 1, chapter 1.

6. The purpose of this fish and shellfish Array EIA Report chapter is to:

- present the existing environmental baseline established from desk studies, site-specific surveys, numerical modelling studies consultation with stakeholders;
- identify any assumptions and limitations encountered in compiling the environmental information;
- present the environmental impacts on fish and shellfish ecology arising from the Array and reach a conclusion on the LSE[1] on fish and shellfish ecology, based on the information gathered and the analysis and assessments undertaken; and
- highlight any necessary monitoring and/or mitigation measures which are recommended to prevent, minimise, reduce or offset the likely significant adverse environmental effects of the Array on fish and shellfish ecology.

9.3. STUDY AREA

7. As fish and shellfish are spatially and temporally variable, a broad fish and shellfish ecology study area has been defined for the purposes of baseline characterisation.

8. The fish and shellfish ecology study area has been reduced compared to the fish and shellfish ecology study area presented in the Array EIA Scoping Report (Ossian OWFL, 2023). Consultation feedback received from Marine Directorate - Licensing Operations Team (MD-LOT) in 2023 advised that though they were "*…broadly content with the proposed fish and shellfish ecology study area*" presented in the Array EIA Scoping Report, "*identifying a smaller study area using the recommended methods detailed in the NatureScot representation*" was recommended. NatureScot advised in their Array EIA Scoping Report response in relation to the fish and shellfish study area that "*…this is a very large area. The Applicant may wish to consider a smaller study area based on either International Council for the Exploration of the Sea (ICES) rectangles or modelled subsea noise and/or Suspended Sediment Concentrations (SSC) data, whichever extend furthest from the site*" (MD-LOT, 2023).

9. Although the fish and shellfish ecology study area presented in the Array EIA Scoping Report was significantly more precautionary, this has been reduced to the current fish and shellfish study area following MD-LOT (2023) advice. Therefore, the revised fish and shellfish ecology study area presented in this chapter (Figure 9.1) extends over both Scottish and English waters and is based on a precautionary Zone of Influence (ZoI) of underwater noise (100 km), including the Firth of Forth.

10. This has taken account of potential direct and indirect impacts on fish species, including disturbance or injury resulting from underwater noise from piling, temporary habitat loss and increased SSC and associated deposition. The use of 100 km as a precautionary ZoI for underwater noise aligns with both the noise modelling conducted for the Array (volume 2, chapter 10), and that of other offshore wind projects (such as Berwick Bank Offshore Wind Farm (SSER, 2022a) which found highly localised injurious effects for fish, but behavioural impacts out to the range of the low tens of kilometres. Furthermore, this ZoI accounts for fish mobility and their spawning/nursery grounds, along with capturing coastal waters to accommodate diadromous fish and their movements.

11. The fish and shellfish ecology study area provides a wide context for the spatially and temporally variable species and populations, including diadromous fish, which are known to occur within and in the vicinity of the site boundary. This fish and shellfish ecology study area will facilitate the characterisation of all fish and shellfish ecology receptors within the area and is therefore sufficiently precautionary to consider direct (e.g. habitat loss/disturbance within the site boundary) and indirect impacts (e.g. underwater noise over a wider area) associated with the Array on identified receptors.

12. Figure 9.1 illustrates the fish and shellfish ecology study area for the Array, which encompasses:

- the Array (i.e. the wind turbines and associated infrastructure which will be located within the site boundary); and
- the seabed and water column that could be subject to indirect impacts from underwater noise or increased SSCs resulting from activities associated with the Array and has the potential to extend beyond the Array site boundary, based on the outputs of relevant modelling (e.g. noise and physical processes modelling) as set out above.

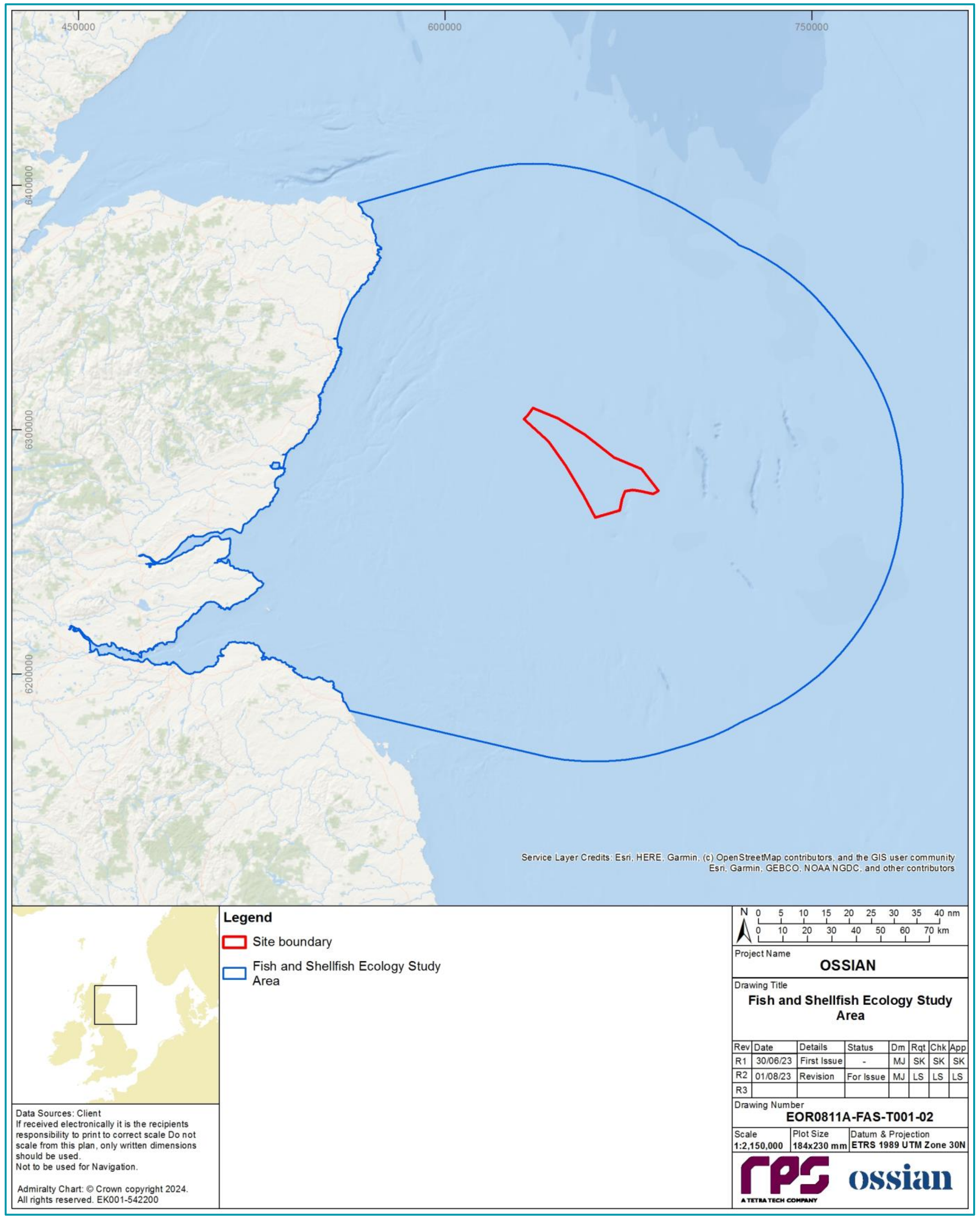

Figure 9.1: Fish and Shellfish Ecology Study Area

9.4. POLICY AND LEGISLATIVE CONTEXT

13. Volume 1, chapter 2 of the Array EIA Report presents the policy and legislation of relevance to renewable energy infrastructure. Policy specifically in relation to fish and shellfish ecology is contained in the the Marine and Coastal Access Act (MCAA) 2009, the Habitats Regulations, Scotland's National Marine Plan, the Sectoral Marine Plan (SMP) and the United Kingdom (UK) Marine Policy Statement (MPS). A summary of the legislative provisions relevant to fish and shellfish ecology are provided in Table 9.1 to Table 9.6. Further detail is presented in volume 1, chapter 2.

Table 9.1: Summary of Marine and Coastal Access Act 2009 Relevant to Fish and Shellfish Ecology

Summary of Relevant Policy	How and Where Considered in the Array EIA Report
MPAs/Marine Conservation Zones (MCZs)	
MPAs existing beyond the 12 nm limit in Scottish Waters and MCZs in English waters are designated under the MCAA 2009. These sites are areas that have been designated for the purpose of conserving – marine flora and fauna; marine habitat or types of marine habitat; or features of geological or geomorphological interest (section 117).	All relevant MPAs in Scottish offshore waters (beyond 12 nm) are listed in section 9.7.2, and further described in volume 3, appendix 9.1 and potential effects on these are considered in section 9.11. No MCZs in English waters designated for fish and shellfish features were identified in the fish and shellfish ecology study area.

Table 9.2: Summary of the Habitats Regulations Relevant to Fish and Shellfish Ecology

Summary of Relevant Legislation	How and Where Considered in the Array EIA Report
Designated Sites	
Before deciding to undertake, or give any consent, permission or other authorisation for, a plan or project which is likely to have a significant effect on a European offshore marine site or a European site (either alone or in combination with other plans or projects), and is not directly connected with or necessary to the management of the site, a competent authority must make an appropriate assessment of the implications of the plan or project for that site in view of that site's conservation objectives.	All relevant designated sites are listed in section 9.7.2, along with their proximity to the Array and potential effects on these are considered in section 9.11. Section 9.12 also considers impacts on designated sites from other plans and projects cumulatively with the Array. European sites are further assessed in line accordance with the Habitats Regulations in the RIAA (Ossian OWFL, 2024).
Species Protection	
A person is guilty of an offence if they: deliberately capture, injure, deliberately disturb or kill any wild animal of a European Protected Species (EPS).	All the relevant protected species have been identified in section 9.7.3 and the environmental assessments in section 9.11 considers the conservation status of fish and shellfish ecology receptors in coming to a conclusion regarding the significance of effect and proposing mitigation where the impacts are found to be unacceptable. There may also a need for EPS Licences for specific species where relevant, although none of the receptors are identified as EPS.

Table 9.3: Summary of Scotland's National Marine Plan Relevant to Fish and Shellfish Ecology (Scottish Government, 2015)

Summary of Relevant Policy	How and Where Considered in the Array EIA Report
General Policies	
GEN9 Natural Heritage: Development and use of the marine environment must: comply with legal requirements for protected areas and protected species; not result in significant impact on the national status of Priority Marine Features (PMFs); and protect and, where appropriate, enhance the health of the marine area.	Protected species and PMFs are identified in Table 9.12. Section 9.11 presents an assessment of the significance of the effects of the Array on fish and shellfish ecology receptors as well as mitigation measures where appropriate.

Summary of Relevant Policy	How and Where Considered in the Array EIA Report
Paragraph 4.47: The Marine Acts place a duty on all regulators to ensure that there is no significant risk of hindering the achievement of the conservation objectives of an MPA before giving consent to an activity. Where an ongoing activity presents a significant risk of hindering the achievement of the conservation objectives of an MPA there will be a management intervention. This intervention will be practical and proportionate, utilising the most appropriate statutory mechanism to reduce the risk.	Section 9.11 presents assessments of the significance of the effects of the development on fish and shellfish ecology receptors, including on the features of the relevant designated sites such as MPAs.
GEN5 Climate Change: Marine planners and decision makers must act in the way best calculated to mitigate, and adapt to, climate change.	The impact of climate change on the baseline environment and how this may influence the assessment of effects is considered as part of the future baseline in section 9.7.4 and also in greater detail in volume 2, chapter 17.
WILD FISH 1: The impact of development and use of the marine environment on diadromous fish species should be considered in marine planning and decision making processes. Where evidence of impacts on salmon and other diadromous species is inconclusive, mitigation should be adopted where possible and information on impacts on diadromous species from monitoring of developments should be used to inform subsequent marine decision making.	Section 9.11 presents assessments of the significance of the effects of the Array on diadromous fish species separately from marine species.

Table 9.4: Summary of Priority Marine Features in Scotland's Seas Relevant to Fish and Shellfish (NatureScot, 2020)

Summary of Relevant Policy	How and Where Considered in the Array EIA Report
Fish and Shellfish Species	
PMFs are habitats and species that NatureScot consider to be marine nature conservation priorities in Scottish waters. These include 39 species of fish and shellfish, including elasmobranch species and 1 decapod crustacean.	Relevant PMFs are identified in Table 9.12. Section 9.11 assesses the significance of the effect of the Array on all fish and shellfish ecology receptors, including PMFs within the fish and shellfish ecology study area, where an impact pathway exists.

Table 9.5: Summary of The Sectoral Marine Plan (SMP) for Offshore Wind Energy Relevant to Fish and Shellfish Ecology (Scottish Government, 2020)

Summary of Relevant Policy	How and Where Considered in the Array EIA Report
General Policies	
Reduce the potential adverse effects on other marine users, economic sectors and the environment resulting from further commercial scale offshore wind development.	The potential for adverse effects on the identified environmental (i.e. fish and shellfish) receptors are considered fully in section 9.11, with consequent effects on other environmental receptors (e.g. marine mammals and offshore ornithology) and commercial fisheries considered in volume 2, chapters 10, 11 and 12, respectively. The cumulative effects of the Array alongside others in the region are assessed in section 9.12.
Offshore Wind and Marine Renewable Energy Policies	
Regional cumulative effects include the potential for negative effects on bird populations, benthic habitats, cetaceans, navigational safety, seascape/landscape and commercial fisheries. The Sectoral Marine Plan includes measures to mitigate potential impacts at various scales.	The cumulative effects of the Array alongside others in the region are assessed in section 9.12.

Table 9.6: Summary of the UK Marine Policy Statement (MPS) Relevant to Fish and Shellfish Ecology (HM Government, 2011)

Summary of Relevant Policy	How and Where Considered in the Array EIA Report
General and Offshore Wind and Marine Renewable Energy Policies	
Ensure a sustainable marine environment which promotes healthy, functioning marine ecosystems and protects marine habitats, species and our heritage assets.	The magnitude of impacts and the sensitivity of fish and shellfish ecology receptors are analysed in section 9.11 to determine if the relevant impacts represent a significant effect on the relevant fish and shellfish ecology receptors.
The marine environment plays an important role in mitigating climate change.	The impact of climate change on the baseline environment and how this will influence the predictions made in the effects assessment is considered as part of the future baseline in section 9.7.4 and also in greater detail in volume 2, chapter 17.
Biodiversity is protected, conserved and where appropriate recovered and loss has been halted.	The significance of effects on fish and shellfish ecology receptors is considered, as well as mitigation measures where appropriate, in section 9.11.
Marine businesses are acting in a way which respects environmental limits and is socially responsible.	Section 9.11 presents assessments of the significance of the effects of the development on fish and shellfish ecology receptors, with mitigation presented, as necessary, to reduce effects to an acceptable level.

9.5. CONSULTATION

14. Table 9.7 presents a summary of the key issues raised during consultation activities undertaken to date specific to fish and shellfish ecology for the Array and in the Ossian Array Scoping Opinion (MD-LOT, 2023) along with how these have these have been considered in the development of this fish and shellfish ecology Array EIA Report chapter. Further detail is presented within volume 1, chapter 5.

Table 9.7: Summary of Issues Raised During Consultation and Scoping Opinion Representations Relevant to Fish and Shellfish Ecology

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
Scoping Opinion			
June 2023	MD-LOT	*"The EIA Report must provide the estimate of expected residues and emissions, for example drill cuttings where considered in the design envelope. Specific reference should be made to water, air, soil and subsoil pollution, noise, vibration, light, heat, radiation and quantities and types of waste produced during the construction and operation phases, where relevant. This information should be provided in a clear and consistent fashion and may be integrated into the relevant aspect assessments."*	All options from the Project Description (volume 1, chapter 3) are carried into the assessment under the Maximum Design Scenario (MDS) and are fully assessed within this chapter, including assumptions regarding relevant emissions/residues, such as deposition of any drill cuttings, underwater noise, EMF and pollutants. The MDS is fully assessed within section 9.8.1, drawing on modelling and assessments undertaken for other topics, including physical processes, as relevant. Directly or indirectly, these factors have been considered throughout the assessments within section 9.11.
		"*The Scottish Ministers direct the Developer to the NatureScot representation on the need to understand potential impacts holistically at a wider ecosystem scale, rather than just as discrete individual receptor assessments. The Scottish Ministers therefore advise that potential impacts should be given consideration across key trophic levels, particularly in relation to the availability of prey species. Detailed advice on assessment of across trophic levels is provided in the receptor chapters in section 5 of the Scoping Opinion."*	Consideration has been given across key trophic levels when assessing impacts. Outputs from relevant receptor topics are considered where appropriate to support this, in section 9.11, and in section 9.15 for inter-related effects and ecosystem assessment (volume 3, chapter 20).
		"Wet storage is also a potentially significant impact pathway in respect of the Proposed Development identified by NatureScot in its representation. The Scottish Ministers advise that, if there is potential for wet storage of floating WTGs (whether fully assembled or in component parts), this must be detailed and consideration of impacts on receptors must be addressed within the EIA Report and HRA."	The location of the final integration and marshalling port is currently unknown. Ossian OWFL (hereafter referred to as 'the Applicant') are currently developing a fabrication, delivery and integration strategy and engaging with a number of port and harbour operators to identify an optimised approach. In the absence of an integration and marshalling yard it is not possible, at this stage, to consider the potential site-specific impacts on relevant receptors. Enabling works, including integration, and marshalling activities, required within the final integration port to cover turbine pre-commissioning, testing and storage (if required) will be covered by the consenting requirements applying to them (including any requirements for environmental assessment) and will be managed by the port or harbour authority with support where appropriate from the Applicant. The Ossian construction programme will be managed to reduce the requirement for storage of integrated pre-commissioned turbines within port. A stock of floating foundations will be accumulated, and mooring lines and cables would be installed within the array in advance of turbine integration. The Applicant aims to minimise any wet storage requirements by towing integrated turbines to their final location within the array as soon as they are ready, subject to suitable weather conditions for transfer. Temporary offshore wet storage has been included in the MDS for applicable impacts (Table 9.13) and assessed, such as in paragraph 65.
		"The Scottish Ministers are broadly content with the proposed study areas, however advise the Developer to consider identifying a smaller study area using the recommended methods detailed in the NatureScot representation."	The study areas are reviewed and reduced in extent where appropriate, as detailed in section 9.3 and Figure 9.1.
		"In regards to baseline environment as detailed by the Developer in Section 6.2.3 and Appendix 8 of the Scoping Report the Scottish Ministers advise that the NatureScot advice in relation to fish assemblage and shellfish assemblage must be fully implemented in the EIA Report. "	NatureScot guidance has been reviewed and applied where appropriate throughout the assessments (section 9.11).
		"…the Scottish Ministers recommend [environmental Deoxyribonucleic Acid] *eDNA surveys are carried out to gain information on PMF species and prey fish present at the site of the Proposed Development. This view is supported by the NatureScot representation."*	Site-specific environmental Deoxyribonucleic Acid (eDNA) sampling will be conducted for the Proposed interconnector cable corridor(s) and will be used to inform its baseline. However, eDNA sampling will not be undertaken for the Array, as agreed upon with NatureScot (email received on 24 January 2024) through consultation on a detailed eDNA Proposed Approach Note (volume 3, appendix 5.1, annex A). PMFs are considered within this EIA in Table 9.12, based on desk-based studies.
		"The Scottish Ministers are content that the majority of relevant data sources have been identified to characterise the baseline however advise the Developer to include the additional data sources highlighted in the NatureScot representation, and to consider the data source in relation to salmon and sea trout smolt tracking highlighted in the Dee DSFB representation."	The additional data sources recommended are applied to support baseline characterisation (see section 9.7.1). The recommended data do not provide certainty over the range of sea trout smolts, but they are considered as present within the study area and have thus been given consideration in volume 3, appendix 10.1 and within this chapter.

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		"*In Table 6.9 of the Scoping Report the Developer summarises the impact pathways to be scoped in for fish and shellfish ecology for each phase of the Proposed Development. The Scottish Ministers largely support the proposed approach however advise that subsea noise should be scoped in during the operation and maintenance phase in line with the NatureScot and SFF representations, and that habitat loss and disturbance should be scoped in for pre-construction preparation works. Additionally, the Scottish Ministers highlight NatureScot's representation on sediment related impacts and advise that these should be scoped in, particularly in relation to smothering of herring spawning grounds. The SFF representation considers further impacts should be scoped in and advises on the importance of spawning grounds in the area which the Scottish Minister advise must be fully considered by the Developer in the EIA Report.*"	The evidence base has been reviewed with regards to underwater noise during the operation and maintenance phase (volume 3, appendix 10.1). The potential impact associated with underwater noise during the operation and maintenance phase has been addressed in section 9.11).The potential for habitat loss and disturbance has been assessed for seabed preparation activities during the construction phase (section 9.11). The potential for impacts arising from sediment effects including smothering of herring eggs have been examined in the increases in the volume of suspended sediment concentration and associated deposition impact (section 9.11).
		"*The Scottish Ministers support scoping in of EMF and the colonisation of hard structures, however, in line with the NatureScot representation, advise that consideration of Invasive Non-Native Species (INNS) and how this will be monitored and recorded should be detailed in the EIA Report with clear links to fish and shellfish identified in the benthic ecology INNS assessment to be presented in the Fish and Shellfish chapter. The NatureScot representation regarding EMF levels in relation to cable burial must also be fully addressed within the EIA Report.*"	The evidence base for INNS impacting fish and shellfish ecology receptors has been reviewed in line with outputs from the benthic ecology EIA chapter (volume 2, chapter 8), and is described as part of the colonisation of hard structures impact (section 9.11). The potential impact of EMFs surrounding buried and unburied cables has also been addressed (section 9.11).
		"*Clear links between the marine mammal and offshore ornithology assessments in relation to prey availability should be made to the fish and shellfish assessment within the EIA Report. The advice and data sources provided in the NatureScot representation in relation to prey species and impacts to spawning and nursery grounds should be fully considered and addressed by the Developer in the EIA Report.*"	Consideration has been given across key trophic levels when assessing impacts. Outputs from relevant receptor topics are considered where appropriate to support this, in section 9.11, and in section 9.15 for inter-related effects and ecosystem assessment (volume 3, chapter 20).
		"*With regards to the approach to assessment set out in section 6.2.8, the Scottish Ministers are largely content, however advise that assessment should quantify where possible the likely impacts to key PMFs and consider whether this could lead to a significant impact on the national status of the PMFs under consideration, and that the additional guidance identified by NatureScot should be included*."	Potential impacts to PMFs are fully considered within the assessment (section 9.11). Any PMFs identified with relevance to the Array are included as Important Ecological Features (IEFs) and are specifically addressed during assessment under relevant impacts (section 9.11).
		"*The Scottish Ministers are broadly content with the designed in mitigation measures described in section 6.2.5 of the Scoping Report and advise that the full range of mitigation measures and published guidance are considered in the EIA Report. Information on proposed fish and shellfish monitoring should be outlined in the EIA Report. This is a view supported by NatureScot.*"	Following assessment, the Array EIA Report includes details of any proposed mitigation and/or monitoring for any potentially significant adverse effects, along with any justification for the recommendation, based upon the efficacy of the measure, and how the information will be used (section 9.10).
		"*The Scottish Ministers agree that subsea noise should be scoped into the cumulative assessment, however, advise that further cumulative impacts should not be discounted at this stage. In particular the Scottish Ministers highlight that consideration should be given to displaced fishing activity for habitat loss/change as outlined in the NatureScot representation.*"	The potential impact of habitat loss/disturbance is considered in section 9.11. Effects of displacement of commercial fishing activity associated with the project are considered in volume 2, chapter 12.
June 2023	MD-LOT	"*With regards to the HRA Screening Report, the Scottish Ministers agree with the advice within the NatureScot representation that migratory fish should currently be assessed through the EIA process and not through the HRA process. However, the Developer should engage with the Scottish Ministers and NatureScot in regards to any change in how diadromous fish should be assessed through EIA and HRA as a result of ongoing research in this area.*"	We acknowledge the advice provided by NatureScot and MD-LOT, however, the Applicant propose that diadromous fish should be screened in for assessment within the RIAA on a precautionary basis and the integrity test should be dealt with at a high level in the RIAA. This is because there is uncertainty in relation to impacts on diadromous fish and the available information through the ongoing research could change. Effects on diadromous fish are also considered throughout the EIA in section 9.11.
June 2023	NatureScot Scoping Representation (May 2023)	"*We recommend early consideration of potential Positive Effects for Biodiversity as well as nature inclusive design aspects at an early stage and following through into the EIA Report. We acknowledge that, whilst not policy, these aspects form part of our ability to address both the climate and biodiversity crises and as such we encourage developers to consider this as part of their application.*"	This has been reviewed through assessment of the potential for colonisation of hard substrates (section 9.11).
		"*We note that several SACs for migratory fish are included in this list of designated sites. As previously advised to Marine Directorate, we cannot advise on these species under the HRA process. Due to uncertainty on where migratory fish (Atlantic salmon, sea and river lamprey) go within marine waters and any connectivity back to natal rivers, we consider these species should be assessed through EIA only and not through HRA.*"	Diadromous fish are considered throughout the EIA in section 9.11. It should be noted that river lamprey are an estuarine species, and have therefore have no potential for interaction with the Array and has not been scoped in as a target species for assessment (see Table 9.12). Further the diadromous species: sparling/European smelt *Osmerus eperlanus*, has also been scoped out of assessment using the same justification as river lamprey (see Table 9.12).

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		"We note that cable burial is listed as a designed in measure that will reduce exposure to EMF. Research by Hutchison et al. (2020) considers that cable burial may actually generate a response from sensitive species, as it reduces EMF levels to the 'normal' range that species use to hunt prey or navigate, and as such is unlikely to fully mitigate potential effects."	Effects to fish and shellfish ecology due to EMFs from subsea electrical cabling is assessed fully in section 9.11, and considers the conclusions detailed in Hutchison *et al*. (2020) alongside other published research on the topic.
		"…we do not support the scoping out of increased SSCs and associated deposition."	Increased SSCs and associated deposition have been considered and assessed for the construction and operation and maintenance and decommissioning phases in section 9.11.
		"We welcome the identification of 'Designed In Measures' described in each of the relevant sections of the EIA Scoping Report (for example Section 2.7) and summarised in Appendix 2. The EIA Report must clearly articulate those mitigation measures that are informed by the EIA (or HRA) and are necessary to avoid or reduce predicted significant adverse environmental effects of the proposed development. We advise that the full range of mitigation and monitoring measures, and published guidance, are considered and discussed in the EIA Report."	Designed in measures are outlined in section 9.10 in relation to each applicable impact, providing details surrounding their perceived benefits. Mitigation measures and monitoring are recommended following assessment of each impact for each receptor, where required, such as, where a moderate adverse significant effect is considered a potential outcome. Mitigation measures and monitoring, where proposed, are provided with full justification.
		"We advise that this is a very large area. The applicant may wish to consider a smaller study area based on either ICES rectangles (as shown in Appendix figure 8.5) or modelled subsea noise and/ or suspended sediment concentration (SSC) data, whichever extends furthest from the site."	The study areas are reviewed and reduced in extent where appropriate, as detailed in section 9.3 and Figure 9.1.
		"We recommend the use of eDNA surveys within the offshore windfarm array area (and export cable corridor route) to help provide information on PMFs and prey fish species. See our advice above, within the benthic subtidal ecology appendix."	Site-specific eDNA sampling will be conducted for the Proposed interconnector cable corridor(s) and will be used to inform its baseline. However, eDNA sampling will not be undertaken for the Array, as agreed upon with NatureScot on 24 January 2024 through consultation on a detailed eDNA Proposed Approach Note (volume 3, appendix 5.3, annex A). PMFs are considered within this EIA in Table 9.12, based on desk-based studies.
		"With regard to data sources on fish and EMF, we recommend that a recent MSc paper by Lucie Hervé "An evaluation of current practice and recommendations for environmental impact assessment of electromagnetic fields from offshore renewables on marine invertebrates and fish" is included as a data source in Apx Table 8.1. We can supply a copy of this paper on request.	The additional data sources recommended are applied to support baseline characterisation (see section 9.7.1). The recommended data do not provide certainty over the range of sea trout smolts, but they are considered as present within the study area and have thus been given consideration in volume 3, appendix 10.1 and within this chapter. The Applicant will seek to engage with other offshore wind developers and strategically, through initiatives such as ScotMER to address evidence gaps in understanding for key areas of uncertainty in relation to floating offshore wind.
		"Appendix 8, Apx Table 8.1 captures most of the relevant baseline datasets, but we recommend inclusion of "Essential Fish Habitat Maps for Fish and Shellfish Species in Scotland" developed by the Scottish Marine Energy Research (ScotMER) programme, which is due for publication shortly. We also recommend inclusion of the Feature Activity Sensitivity Tool (FeAST), which is also due to be updated shortly with fish and shellfish information."	FeAST has been monitored for updates on sensitivity information to ensure inclusion of essential fish habitat maps (section 9.11). The essential fish habitat habitat maps report (cited as Fanco *et al.*, 2022) has been monitored for updates and has been used to support evidence such as in paragraph 73.
		"We advise that the fish assemblage grouping should be based around PMF and prey species. Of particular interest are those species with lifecycle connections with the seabed, this would include: • *sandeel throughout their whole lifecycle (not just spawning) and their specific, often patchy, habitat requirements;* • *herring during spawning only, and protection of the very specific gravely habitat suitable for herring spawning;* • *cod during spawning only; and* • *elasmobranch species present and impacts of EMF."*	This has been considered in the definition of IEFs and in the impact assessments (section 9.11).

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		"Subsea noise during the operation and maintenance phase is proposed to be scoped out. We advise that this should be scoped in. The effects arising from floating wind turbine generators, their anchoring systems and cabling are not well understood at present. This will require further discussion and agreement. We welcome the inclusion of both sound pressure and particle motion in the proposed approach to assessment. Sensitive fish species have not been specified but we would expect to see sandeel, cod and herring eggs if appropriate to the study area."	Evidence has been reviewed with regards to underwater noise during the operation and maintenance phase (volume 3, appendix 10.1), which summarised that underwater noise from operational wind turbines could only cause a possible behavioural reaction within metres from the wind turbine. The potential impact associated with underwater noise during the operation and maintenance phase has been addressed in section 9.11). Effects upon sandeel, cod, and eggs of herring are given consideration within other assessments which may be impactful, such as increased SSCs and associated deposition (section 9.11).
		"Habitat loss and disturbance (temporary and long term) is a key impact pathway identified for the construction, operation and maintenance, and decommissioning stages. All appropriate preconstruction seabed preparation works should also be included."	Relating to habitat loss and disturbance, evidence has been reviewed and impacts are scoped in for full consideration within the impact assessment (section 9.11).
		"We recommend inclusion of the NatureScot Commissioned Report 791 "Understanding the potential for marine megafauna entanglement risk from renewable marine energy developments". Other relevant guidance that should be included is: JNCC guidance on underwater noise, unexploded ordnance clearance – joint interim position statement and the Scottish Marine Wildlife Watching Code. We also note that section 5.2.7 correctly identifies the most relevant technical guidance on subsea noise and fish receptors."	Joint Nature Conservation Committee (JNCC) guidance has been considered within the impact assessments (section 9.11). The NatureScot Commissioned Report 791 on marine megafauna entanglement is covered within the impact of entanglement on marine mammals in volume 2, chapter 10, with entanglement also having a potential impact on basking shark, which have been identified as an IEF for this assessment. The measures set out to minimise entanglement risk committed to in the marine mammal assessment (volume 2, chapter 10) will also ensure entanglement risk to basking shark and other megafauna is reduced. With these in place and considering the low abundances of basking shark in the North Sea, there is no potential for LSE[1] and this impact has been scoped out of further assessment within this EIA report.
		"*We recommend that the assessment should quantify, where possible, the likely impacts to key fish and shellfish PMFs. It should assess whether these could lead to a significant impact on the national status of the PMFs being considered."*	Quantification of impacts to any relevant PMFs (identified as IEFs) are provided throughout section 9.11.
		"*We advise that the EIA Report should provide details on how INNS will be considered, monitored and recorded. We note that INNS are incorporated into the Benthic Subtidal Ecology assessment and recommend that any relevant links to fish and shellfish receptors are made clear in the Fish and Shellfish assessment."*	INNS have been considered, along with associated monitoring, in Table 9.18. Also, consideration has been given in relation to the benthic subtidal ecology assessment (volume 2, chapter 8), through, for example, the assessment on colonisation of hard structures (section 9.11).
		"*We recognise that changes to prey availability is an impact pathway scoped into both marine mammal and offshore ornithology assessments. Clear links should be made between those assessments and the fish and shellfish assessment. Most EIA Reports concentrate on receptor specific impacts, however we increasingly need to understand impacts at the ecosystem scale. Therefore, consideration across key trophic levels will enable better understanding of the consequences (positive or negative) of any potential changes in prey distribution and abundance on marine mammal (and other top predator) interests and how this may influence population level impacts."*	Consideration has been given across key trophic levels when assessing impacts. Outputs from relevant receptor topics are considered where appropriate to support this, in section 9.11, and in section 9.15 for inter-related effects and ecosystem assessment (volume 2, chapter 20).
		"*Consideration of how this loss and or disturbance may affect the recruitment of key prey (fish) species through impacts to important spawning or nursery ground habitats should also be assessed. In addition, the PrePARED (Predators and Prey Around Renewable Energy Developments) project will also assist in the understanding of predator-prey relationships in and around fixed offshore wind farms which started in 2022 and will run for five years."*	Consideration has been given across key trophic levels when assessing impacts. Outputs from relevant receptor topics are considered where appropriate to support this, in section 9.11, and in section 9.15 for inter-related effects and ecosystem assessment (volume 2, chapter 20).

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		"*Sediment-related impacts are proposed to be scoped out on the basis that sediment will be deposited locally and none of the species within the site are sensitive to smothering, which we support. However, modelling outputs from other wind farms show that sand wave clearance could disperse suspended sediments further than the boundaries of the site, depending on the location where the activity takes place. It therefore has the potential to smother herring eggs and other receptors which are sensitive to burial, and there may be herring spawning grounds in the area around the proposal (see Coull et al, 1998). We therefore advise that this impact is scoped into assessment.*"	The effects of smothering upon receptors such as herring eggs are given consideration within the assessment for increased SSCs and associated deposition (section 9.11). Based on the results of the site-specific geophysical surveys, significant sand waves and bedforms were not recorded within the site boundary. It is expected that dredging will not be required as part of seabed preparation and so is not considered further within this chapter.
		"*Given the scale of ScotWind and the number of proposed developments, it may be too premature to discount cumulative impacts. In addition to the impacts associated within the windfarm array consideration should also be given to displaced fishing activity for habitat loss/change to key forage species*."	The impact of habitat loss/disturbance is considered in section 9.11. Effects of displacement of commercial fishing activity associated with the project are considered in volume 2, chapter 12. Changes to key forage species has not been scoped in as it is generally something not considered within fish and shellfish EIAs. Cumulative effects on fish and shellfish receptors are fully considered in section 9.12.
		"*We welcome the designed in measures described in section 6.2.5. We advise that the full range of mitigation measures, published guidance, and any proposed monitoring are considered and discussed in the EIA Report.*"	Designed in mitigation measures, published guidance and proposed monitoring are considered and discussed within sections 9.10 and 9.13, respectively.
		"*No specific monitoring for fish and shellfish is mentioned in the Mitigation and Monitoring Commitments Register in the EIA Scoping Report (Appendix 2). Further information on proposed fish and shellfish monitoring should be discussed in the EIA Report.*"	Based on assessments being considered not significant in EIA terms, site-specific monitoring and secondary mitigation are not specifically recommended.
June 2023	Scottish Fishermen's Federation (SFF) Scoping Representation (April 2023)	"*Page 14, Site Selection Methodology, para 135, states that, according to the SMP, the key concerns within the E1 PO Area included minor socio-economic impacts to commercial fishing. The fact that the area is fish spawning grounds for herring Clupea harengus, cod Gadus morhua, whiting Merlangius merlangus, plaice and sandeel Ammodytes spp. (Scottish Government, 2020a) therefore the impacts on them should be scoped in.*"	Impacts to spawning grounds are assessed within section 9.11. Impacts to commercial fisheries is discussed within volume 2, chapter 12.
		"*The document highlights that the significance of the effects on fish and shellfish ecology may result in the requirement for additional mitigation. This will be consulted upon with the statutory consultees throughout the EIA and consultation processes. It is possible that particular mitigation may be required for species such as herring, which are particularly sensitive to subsea noise. This will be discussed via the EIA and consultation processes.*" "*SFF believe that since the impacts of the development on the fishing is obvious, the developer should scope in effective types of mitigation to offset the negative impacts.*"	Mitigation measures are considered during the assessment of underwater noise from piling and Unexploded Ordinance (UXO) clearance impacts on fish and shellfish communities in section 9.10. Impacts to commercial fisheries and any proposed mitigation is discussed within volume 2, chapter 12.
		"*A currently unpublished report (Putland et al., In prep), was described to the stakeholders to support the proposal to scope out impacts to fish and shellfish due to operational noise. Data sources to inform scoping and assessment were presented to stakeholders, and additional literature sources were recommended by MSS*". *SFF believe that scoping out the noise effects on fish and shellfish ecology based on one unpublished study is not sufficient. Since there are other studies that do not agree with the findings of Putland, noise impacts must be scoped in.*"	Evidence has been reviewed with regards to underwater noise during the operation and maintenance phase (volume 3, appendix 10.1), summarising that underwater noise from operational wind turbines would only cause a possible behavioural reaction within metres from the wind turbine. The potential impact associated with underwater noise during the operation and maintenance phase has been addressed in section 9.11.
		"*Further consideration needs to be given to the EMF, noise, wake effects, boulder movements and seabed disturbance of the project on the fish and shellfish ecology receptors.*"	The evidence base has been reviewed to seek specific areas where these factors can be considered within the existing impacts (such as habitat loss), and where additional impacts may be required to be scoped in to address. These are assessed in section 9.11. Regarding wake effects, sufficient spacing between turbines (at least 1 km) is sufficient to avoid wake effects and as such this impact was not included in the physical processes assessment (volume 2, chapter 7), nor in this chapter.
		"*SFF believe that the "Effects to fish and shellfish ecology due to accidental release of pollutants" and "Subsea noise from wind turbine operation impacting fish and shellfish receptors" during operation and maintenance should be scoped in and monitored.*" In addition, the "Temporary habitat loss and disturbance" during operation and maintenance should also be scoped in since there is no sufficient evidence in the application to back it up.	Accidental pollution is effectively managed by implementation of a Marine Pollution Contingency Plan (MPCP) and an Environmental Management Plan (EMP) (volume 4, appendix 21), with all vessels operating on site required to adhere to the provisions. This has been scoped out of assessment. Underwater noise effects are assessed in section 9.11. Temporary habitat loss during operation and maintenance is assessed in section 9.11.

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
		"As illustrated in paragraph 492 et seq., commercial fishing activity is relatively low within ICES rectangle 42E9, and a decrease in landings has been observed from 2011 to 2021 (Table 7.1). As a result, the density of commercial fishing vessel traffic through the commercial fisheries study area is low compared to other areas within the North Sea, as illustrated in Appendix 10, Apx Figure 10.6". Page 3 82, para 502, confirms the importance of E1 for spawning ground but the study area is considered low fishing activity area. It may not be currently fully fished but still the area is important spawning ground; therefore, fisheries ecology would be negatively impacted if the spawning ground is disturbed. Therefore, proper care should be taken during construction, and it should be ensured that no disruptive activity interferes with spawning season."	Impacts to fish and shellfish spawning are assessed in section 9.11
June 2023	Dee District Salmon Fishery Board Scoping Representation (March 2023)	*"We welcome the interrogation of the datasets and scientific literature available as identified in Appendix 8 (table 8.2). We would suggest that the scientific information relating to salmon and sea trout smolt tracking from the Aberdeen Offshore Windfarm* [European Offshore Wind Deployment Centre] *(EOWDC) research also be considered. An interim report is available on the website here: https://group.vattenfall.com/uk/what-we-do/ourprojects/european-offshore-wind-deployment-centre."*	The report has been reviewed and incorporated into the baseline characterisation of volume 3, appendix 10.1, and impact assessments (section 9.11).
		"Furthermore, we note that throughout the scoping report there is no reference to the ScotMER Diadromous Fish Specialist Receptor Group. We would therefore suggest that further consultation takes place with Marine Scotland Science and Fisheries Management Scotland with reference to broadening our understanding of any potential impact upon diadromous fish because of this proposed development."	Annual ScotMER symposia (including 2024) are attended by relevant people working on this EIA chapter, to remain up to date on diadromous fish research and implications for offshore wind development. Where relevant, information from ScotMER has been considered within the current assessment.
June 2023	East Lothian Council Scoping Representation (March 2023)	*"The Scoping Report does not say if there is any potential for contaminants from the windfarm to enter the human food chain."*	Contaminant release from the project (such as resuspension of contaminated sediments or accidental release of pollutants) has been considered. However, these have been scoped out due to low levels of contaminants in sediments and management of accidental pollution events by the project. As such, and with the implementation of measures to be set out in the EMP and MPCP as outlined in section 9.10, the risk for effects on the human food chain is negligible (refer to volume 4, appendix 21).
Post-Scoping Consultation			
January 2024	NatureScot (email communication)	*"We advise:* • *since the [eDNA] Technical Note was written, further papers have been published on the use of eDNA, including specifically Natural Power (2023);* • *in our view, this paper supports the use of eDNA in establishing a site-specific baseline for fish & shellfish ecology, when compared to traditional trawl sampling or historic fisheries data and as such we welcome and promote use of eDNA sampling for baseline characterisation efforts; however; in this instance, we accept the existing methods used to characterise the array area, and welcome consideration of eDNA sampling to help inform characterisation of the export cable corridor route."*	Site-specific eDNA sampling will be considered for the proposed offshore export cable corridor(s) and will be used to inform its baseline if appropriate. However, eDNA sampling will not be undertaken for the Array, as agreed upon with NatureScot on 24 January 2024 through consultation on a detailed eDNA Proposed Approach Note (volume 3, appendix 5.1, annex A).

9.6. METHODOLOGY TO INFORM BASELINE

15. A desktop review has been undertaken to inform the baseline for fish and shellfish ecology, including review of several peer-reviewed publications and reports from surveys undertaken to inform other project assessments. These provide information on the fish and shellfish assemblages within the fish and shellfish ecology study area. In addition, the benthic subtidal ecology site-specific survey undertaken within the site boundary in July 2022 (volume 3, appendix 8.1, annex A) has also been used to inform the baseline characterisation for fish and shellfish ecology. This survey is described in detail in volume 3 appendix 9.1.

16. The fish and shellfish ecology baseline has also been informed by the commercial fisheries baseline characterisation (volume 3, appendix 12.1), as well as consultation with relevant stakeholders (section 9.5).

9.6.1. DESKTOP STUDY

17. Information on fish and shellfish within the fish and shellfish ecology study area was collected through a detailed desktop review of existing studies and datasets which are summarised in Table 9.8.

18. Both the literature review of the reports and data mapping using the datasets were used to characterise the baseline. The fish and shellfish Technical Report (volume 3, appendix 9.1) includes full details of the analysis undertaken to develop the fish and shellfish ecology baseline.

Table 9.8: Summary of Key Desktop Reports

Title	Source	Extent	Year	Author
The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species	IUCN	2023	2023	IUCN
The Marine Life Information Network (MarLIN)	Marine Biological Association	2023	2023	MarLIN
The Marine Scotland National Marine Plan National Marine Plan Interactive (NMPi) maps	Marine Scotland Science (MSS)	Not Applicable (N/A)	2023	Marine Scotland
North East Scotland Salmon and Sea Trout Tracking Array	River Dee Trust and MSS	2016-2021	2023	Main *et al.*
International Bottom Trawl Surveys (IBTS)	ICES	2019–2023	2022a	ICES
International Herring Larvae Surveys (IHLS)	ICES	2007–2016	2022b	ICES
Atlantic salmon *Salmo salar* and Sea trout *Salmo trutta* Fishery Statistics	MSS	2021	2022a	Marine Scotland
Sea trout fishery statistics- 2021 Season	MSS	2021	2022b	Marine Scotland
Scottish Sea Fisheries Statistics – Fishing Effort and Quantity and Value of Landings by ICES Rectangles	MSS	2021	2022c	Marine Scotland
ICES Statistical Rectangles and Areas.	MSS	2022	2022d	Marine Scotland
Berwick Bank Wind Farm Offshore EIA Report – Fish and Shellfish Ecology	SSER – volume 2, chapter 9 of the Offshore EIA Report.	2022	2022a	SSER
Developing Essential Fish Habitat maps for fish and shellfish species in Scotland	The Scottish Government	2022	2023	Franco *et al.*
MPA Mapper	JNCC	2020	2023	JNCC
National Biodiversity Network (NBN) Atlas	NBN Atlas Partnership	2021	2021	NBN Atlas
European Marine Observation and Data Network (EMODnet) broad-scale seabed habitat map for Europe (EUSeaMap)	EMODnet – Seabed Habitats	2021	2021	EMODnet
A verified distribution model for the lesser sandeel *Ammodytes marinus*[*]	Marine Ecology Progress Series	2019	2021	Langton *et al.*
OneBenthic Portal	Centre for Environment Fisheries and Aquaculture Science (Cefas) Open Science	N/A	2019	Cefas
Seagreen Phase 1 (Seagreen Alpha and Seagreen Bravo): Natural Fish and Shellfish Resource Environmental Statement chapter for the optimised project[1]	Seagreen Wind Energy Ltd. – Chapter 9, Seagreen Environmental Statement volume 1	2019	2019	Seagreen Wind Energy Ltd

[*] *Ammodytes marinus* described herein as Raitt's sandeel.

[1] Hereafter in this chapter, Seagreen Alpha and Seagreen Bravo are referred to as Seagreen 1 Offshore Wind Farm and Seagreen 1A Project, respectively.

Title	Source	Extent	Year	Author
Sectoral Marine Plan for Offshore Wind Energy. Strategic HRA: Screening and Appropriate Assessment Information Report – Final. Appendix I: Fish Literature Review.	ABPmer for the Scottish Government	2019	2019	ABPmer
Impacts on fish from piling at offshore wind sites: collating population information, gap analysis and appraisal of mitigation options	Offshore Renewables Joint Industry Programme (ORJIP)	1998–2017	2018	Boyle and New
Crab and Lobster Fisheries in Scotland: Results of Stock Assessments 2013-2015	MSS	2013–2015	2017	Mesquita, *et al.*
A review of the geographic distribution, status, and conservation of Scotland's lampreys	Glasgow Naturalist	1758–2017	2017	Hume
Crab and Lobster Fisheries in Scotland: Results of Stock Assessments 2009-2012	MSS	2009–2012	2016	Mesquita, *et al.*
Spatio-Temporal Variability in Scottish Smolt Emigration Times and Sizes	MSS	2014	2015	Malcolm, *et al.*
Updating Fisheries Sensitivity Maps in British Waters	MSS	1987–2012	2014	Aires, *et al.*
Fish and Shellfish Stocks 2013 Edition	MSS	2011–2012	2013	Marine Scotland
Spawning and nursery grounds of selected fish species in UK waters	Cefas	1982–2011	2012	Ellis *et al.*
Natural Fish and Shellfish Resource Environmental Statement section for the original project	Seagreen Wind Energy Ltd. – Environmental Impact Assessment Report: volume 1, chapter 12	2012	2012	Seagreen Wind Energy Ltd.
Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables	MSS	1911–2010	2010	Malcolm, *et al.*
Fisheries sensitivity maps in British Waters	Cefas	1991–1996	1998	Coull, *et al.*

9.6.2. IDENTIFICATION OF DESIGNATED SITES

19. A three-step process was used to identify all designated sites within the fish and shellfish ecology study area and qualifying interest features that could be affected by the construction, operation and maintenance, and decommissioning phases of the Array. This process is described below:

- step 1: All designated sites of international, national, and local importance within the fish and shellfish ecology study area were identified using several sources. These sources included JNCC, MPA mapper, and the Marine Scotland NMPi maps.
- step 2: Information was compiled on the relevant features for each of these sites (e.g. species listed as features of the relevant designated sites, information on habitat usage, migration information etc.).
- step 3: Using the above information and expert judgement, sites were included for further consideration if:
  - a designated site directly overlaps with the site boundary and therefore has the potential to be directly affected by the Array;
  - sites and associated features were located within the potential ZoI for impacts associated with the Array; and
  - sites which are designated to protect mobile features (e.g. diadromous fish) and where the range of those features has the potential to overlap with either the Array and/or the ZoI of impacts associated with the Array (e.g. fish migrating through or close to the Array at particular life history stages).

9.6.3. SITE-SPECIFIC SURVEYS

20. Considering the studies and datasets available covering the fish and shellfish ecology study area to characterise the baseline for fish and shellfish ecology, no site-specific fish and shellfish ecology surveys have been carried out to inform the impact assessment for fish and shellfish specifically. However, a site-specific benthic subtidal ecology survey was completed for the Array as outlined in Table 9.9.

Table 9.9: Summary of Site-Specific Survey Data

Title	Extent of Survey	Overview of Survey	Survey Contractor	Date	Reference to Further Information
Benthic subtidal ecology survey	Site boundary	Benthic subtidal ecology survey to characterise the benthic environment within the site boundary encompassing Drop Down Video (DDV), grab sampling and epibenthic trawling	Ocean Infinity	2022	Volume 3, appendix 8.1, annex A

9.7. BASELINE ENVIRONMENT

9.7.1. OVERVIEW OF BASELINE ENVIRONMENT

Marine fish and shellfish species

21. The following sections provide a summary of the fish and shellfish ecology baseline environment. The fish and shellfish Technical Report (volume 3, appendix 9.1) includes full details of the analysis undertaken to develop the fish and shellfish ecology baseline characterisation, including results of site-specific surveys. The fish and shellfish ecology receptors that could be potentially impacted by the Array have been determined by the desktop review of available data and information as detailed in Table 9.8, and through site-specific surveys, as detailed in Table 9.9 (see volume 3, appendix 9.1 for further detail regarding baseline data collection and site-specific surveys). The baseline environment was described for the fish and shellfish ecology study area, which encompasses the Firth of Forth (see Figure 9.1). Baseline data sources cover a broad spatial and temporal scale, making use of data collected using a range of methods. The baseline presented is therefore considered to represent a comprehensive and robust description of likely fish and shellfish species that could be present within the vicinity of the site boundary and fish and shellfish study area.

22. The following species were identified as those key fish and shellfish receptors likely to be found within the fish and shellfish ecology study area, representing the most commonly found species in the area. Based on the baseline information a subset of ecologically and commercially important species have been carried forward as IEFs for the purposes of EIA (see section 9.7.3):

- **demersal species** – cod *Gadus morhua*, haddock *Melanogrammus aeglefinus,* whiting *Merlangius merlangus*, plaice *Pleuronectes platessa*, lemon sole *Microstomus kitt*, ling *Molva molva*, saithe *Pollachius virens* and sandeel *Ammodytes* spp;
- **pelagic species** – herring *Clupea harengus*, mackerel *Scomber scombrus* and sprat *Sprattus sprattus*;
- **elasmobranch species** – spotted ray *Raja montagui*, thornback ray *Raja clavata*, tope shark *Galeorhinus galeus*, small-spotted catshark *Scyliorhinus canicula*, spurdog *Squalus acanthias*, thorny skate *Amblyraja radiata* and cuckoo ray *Leucoraja naevus*, among others, have been observed in the fish and shellfish ecology study area (Coull *et al.,* 1998; Daan *et al.,* 2005; Baxter *et al.,* 2011; Ellis *et al.,* 2012).
- **diadromous species** – Atlantic salmon, sea trout, river lamprey *Lampetra fluviatilis* (inshore areas only), sea lamprey *Petromyzon marinus*, European eel *Anguilla anguilla,* allis shad *Alosa alosa*, twaite shad *Allosa fallax*, and freshwater pearl mussel *Margaritifera margaritifera* (included here due to reliance on Atlantic salmon and sea trout at specific life stages); and
- **shellfish species** – pink shrimp *Pandalus borealis*, *Nephrops*, edible crab *Cancer pagurus*, king scallop *Pecten maximus*, European lobster *Homarus gammarus*, brown shrimp *Crangon crangon*, velvet swimming crab *Necora puber*, queen scallop *Aequipecten opercularis*, cockle *Cerastoderma edule*, blue mussel *Mytilus edulis*, common whelk *Buccinum undatum* (referred to as whelk hereafter), and squid (*Loliginidae* spp. and *Ommastrephidae* spp.).

23. The spawning and nursery habitats present within the site boundary are summarised in Table 9.10 based on Ellis *et al*. (2012) and Coull *et al*. (1998). Nursery and spawning habitats were categorised by Ellis *et al.* (2012) as either high or low intensity dependent on the level of spawning activity or abundance of juveniles recorded. Spawning grounds identified by Coull *et al.* (1998) are classified as low, high or undetermined, again based on the level of spawning activity. Intensity of nursery grounds were not specified by Coull *et al.* (1998). Further detail on nursery and spawning grounds is presented in volume 3, appendix 9.1.

Table 9.10: Key Species with Spawning and Nursery Grounds which Overlap with the Site Boundary

Common Name	Scientific Name	Spawning	Spawning Intensity	Nursery	Nursery Intensity
Teleost fish					
Anglerfish	*Lophius piscatorius*	-	-	✓	Low
Blue whiting	*Micromesistius poutassou*	-	-	✓	Low
Cod	*Gadus morhua*	✓	Low	✓	Low
European hake	*Merluccius merluccius*	-	-	✓	Low
Haddock	*Melanogrammus aeglefinus*	-	-	✓	-
Herring	*Clupea harengus*	Adjacent	-	✓	Low
Ling	*Molva molva*	-	-	✓	Low
Lemon sole	*Microstomus kitt*	✓	-	✓	-
Mackerel	*Scomber scombrus*	-	-	✓	Low
Norway pout	*Trisopterus esmarkii*	✓	Low	✓	-
Plaice	*Pleuronectes platessa*	✓	Low	✓	High
Sandeel	*Ammodytidae* spp.	✓	Low	✓	High
Sprat	*Sprattus sprattus*	✓	-	✓	-
Whiting	*Merlangius merlangus*	✓	Low	✓	High
Elasmobranchs					
Common skate	*Dipturus batis*	-	-	Adjacent	Low
Spotted ray	*Raja montagui*	-	-	✓	Low
Spurdog	*Squalus acanthias*	-	-	✓	Low
Tope shark	*Galeorhinus galeus*	-	-	Adjacent	Low

Herring

24. Herring utilise specific benthic habitats during spawning, which increases their vulnerability to activities impacting the seabed. Further, as a hearing specialist (Popper *et al.,* 2022), herring are vulnerable to impacts arising from underwater noise. Figure 9.2 illustrates site-specific survey data alongside EMODnet seabed substrate data. This figure shows the site boundary as characterised unsuitable habitat for herring to spawn. Preferred habitats are located directly north of the site boundary, in line with spawning grounds from Coull *et al.* (1998).

25. As displayed by Figure 9.2 the spawning ground adjacent to the north-west of the site boundary identified by Coull *et al.* (1998) has recorded persistently high levels of spawning activity with relatively little variation from 2007 to 2016. The spawning area identified to the south-west of the site boundary has had variable spawning levels from 2007 to 2016. Due to lack of IHLS survey data between 2017 and 2018, and a change in reporting strategy from IHLS, since 2019, more recent herring larvae data were not available for analysis. However, an ICES scientific report (ICES, 2021) noted that IHLS data for 2019

to 2020 in the Buchan area (where an autumn spawning stock exists off the north-east coast of Scotland) was in the same order of magnitude as previous years (Boyle and New, 2018), therefore, it can be assumed that there are no significant changes from the results presented for 2007 to 2016 outside of normal annual variations. The highest concentrations of herring larval abundances are localised off the coast of Peterhead, which do not extend throughout the undetermined intensity spawning grounds of Coull *et al.* (1998) (see Figure 9.2). This is supported by the habitat suitability data from both site-specific sampling effort and broadscale EMODnet seabed substrates (following classifications in Reach *et al.*, 2013), as shown in Figure 9.2.

Sandeel

26. Raitt's sandeel *Ammodytes marinus* and lesser sandeel *Ammodytes tobianus* are Scottish PMFs. Sandeel behaviour limits the habitat that sandeel can occupy to areas of very specific sediment particle sizes, where penetration into the sediment is possible. Figure 9.4 presents the results of site-specific PSA survey data alongside EMODnet seabed substrate data which can be used to assess habitat suitability for sandeel.

27. For the purposes of considering sandeel habitat, suitability across the fish and shellfish ecology study area and surrounding areas, 'gravelly sand', '(gravelly) sand', and 'sand' in the EMODnet data were classified as preferred habitat and 'sandy gravel' as marginal habitat (see volume 3, appendix 9.1 for further details on these classifications). The EMODnet data suggests that the whole site boundary is covered by slightly gravelly sand, which is a preferred habitat for sandeel (Figure 9.4). However, the site-specific survey data show the north-west portion as preferred and marginal habitat and south-east as a mosaic of unsuitable and marginal habitat. These data highlight a degree of fine-scale variation that is not possible to resolve when working with broadscale data alone and highlights the patchy nature of sandeel habitat within the site boundary.

28. The north-west section of the site boundary is mostly characterised by marginal and preferred habitats, while the south-east is covered by patches of unsuitable and marginal habitat, according to Latto *et al.* (2013) criteria (Figure 9.4). Abundance data from grab sampling and epibenthic trawls within the site boundary also indicated higher abundances of sandeel in the north-west section of the site boundary which aligns with the composition of the sediments (see volume 3, appendix 9.1 for further detail).

29. Figure 9.4 presents the outputs of predicted distribution modelling by Langton *et al.* (2021) within the site boundary and shows that the whole site boundary has extremely low probability of sandeel presence, with areas where predicted density is high closer to the coasts or towards the Firth of Forth.

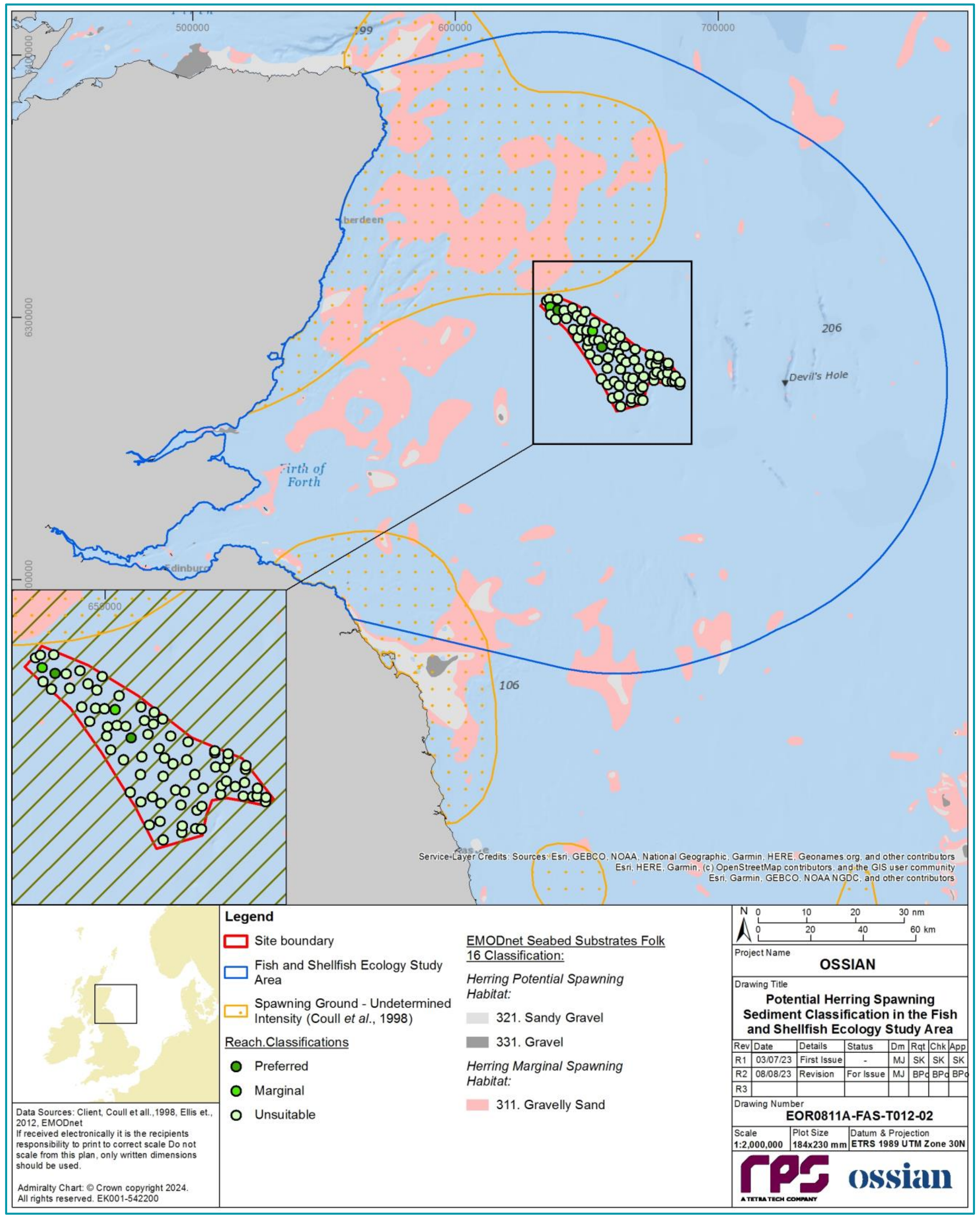

Figure 9.2: Herring Spawning Habitat Preference Classifications from EMODnet and Site-specific Survey Data

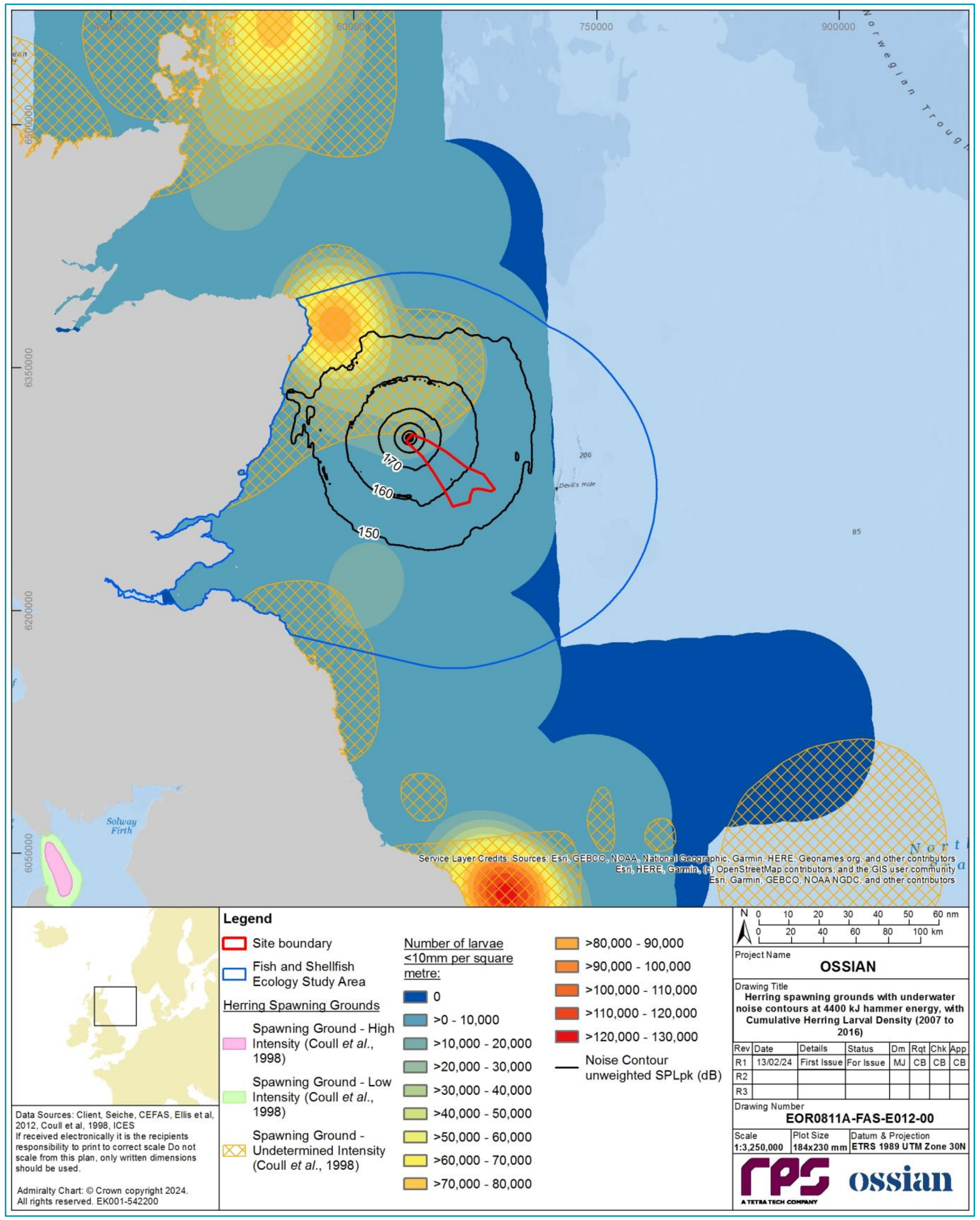

Figure 9.3: Herring Cumulative Larval Density from IHLS Data Sets from 2007 to 2016

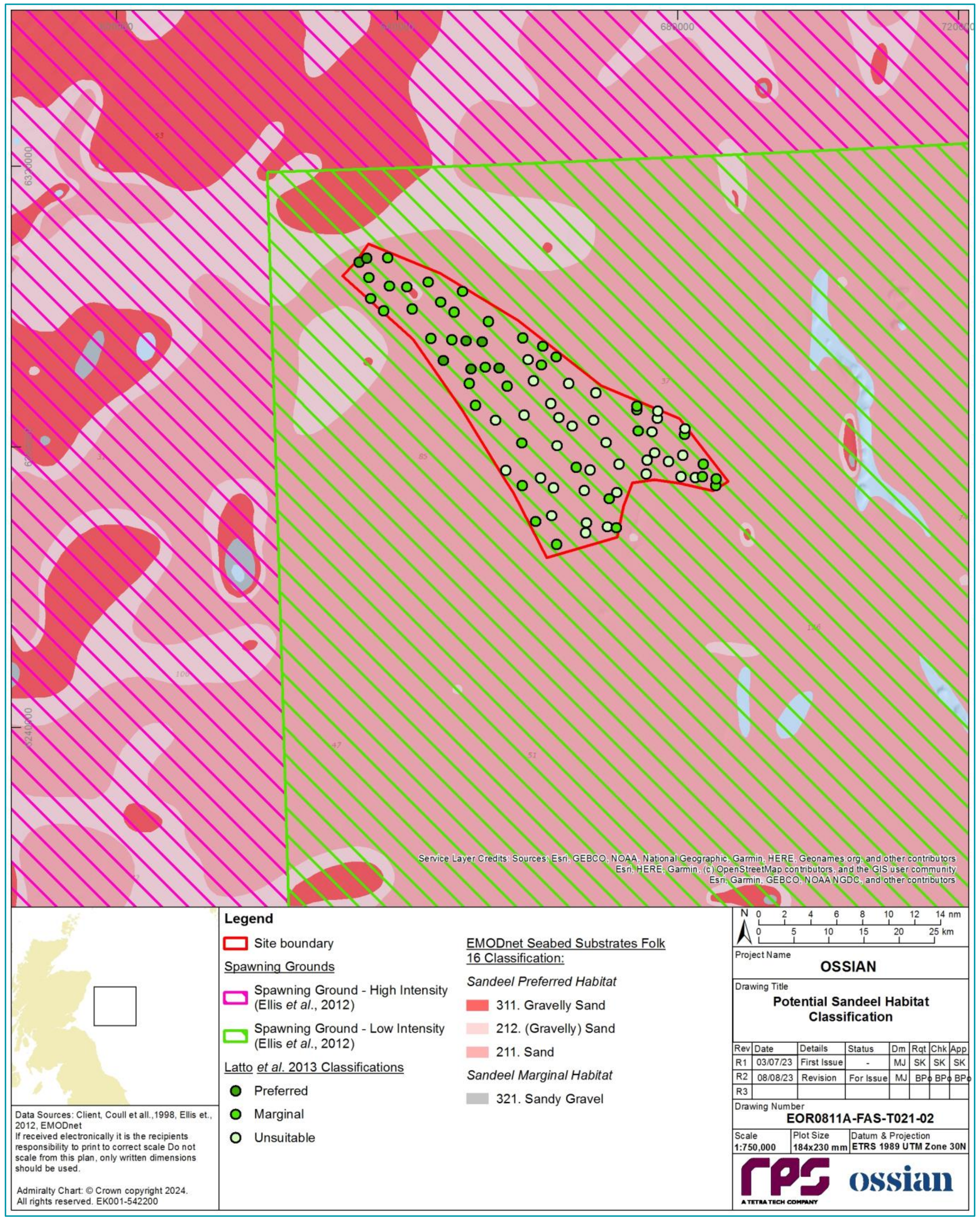

Figure 9.4: Sandeel Habitat Classification from EMODnet, Latto *et al.* (2013), and Site-specific Survey Data

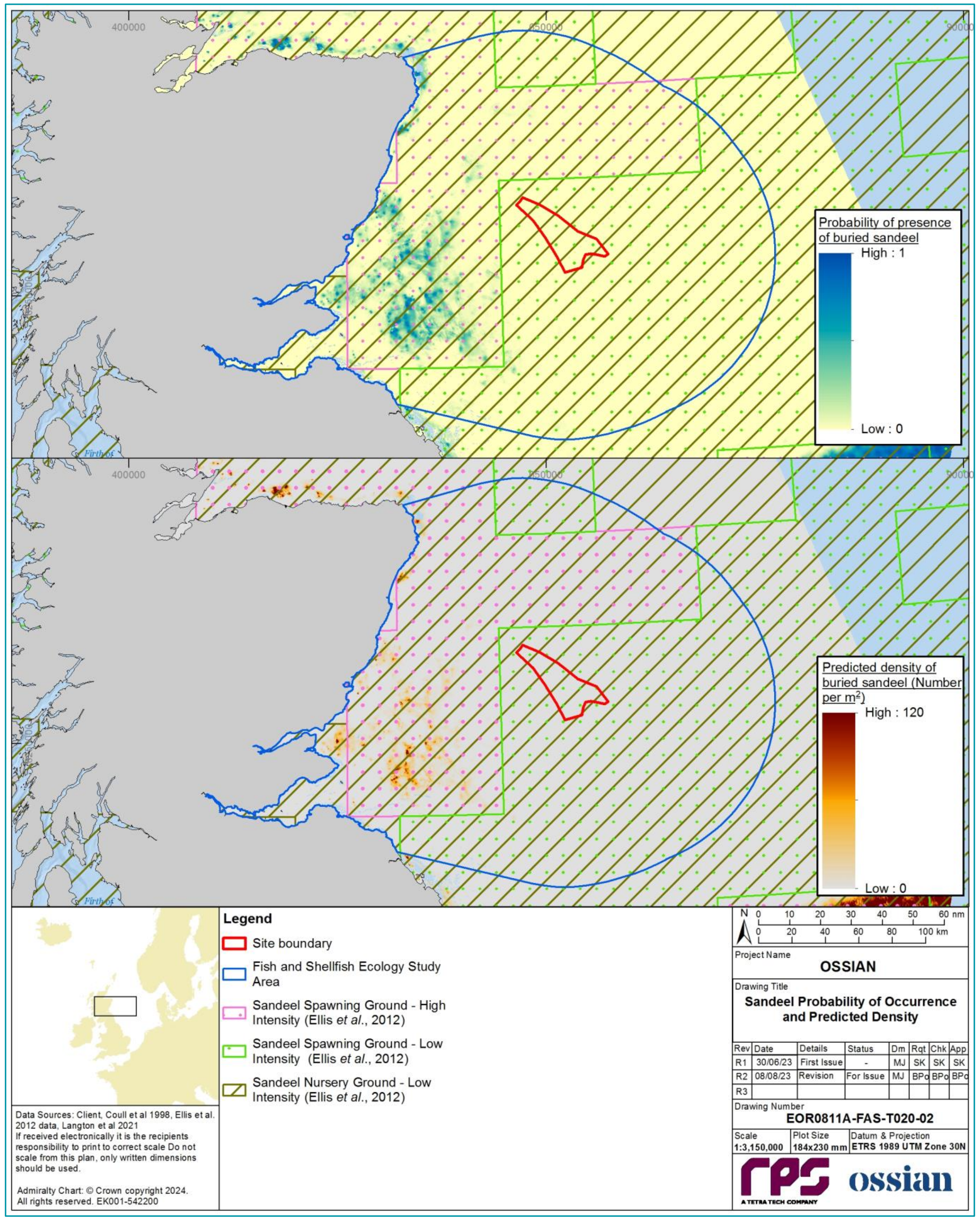

Figure 9.5: Model Derived Predictions of Density and Probability of Presence of Sandeel within the Site Boundary (Derived from Langton *et al.* 2021)

9.7.2. DESIGNATED SITES

30. Designated sites and relevant qualifying interest features identified for the fish and shellfish ecology Array EIA Report chapter are described in Table 9.11 and presented in Figure 9.6.

Table 9.11: Designated Sites and Relevant Qualifying Interest Features for the Fish and Shellfish Ecology Array EIA Report Chapter

Designated Site	Closest Distance to Array (km)	Relevant Qualifying Interest Feature(s)
Turbot Bank Nature Conservation MPA	48.75	• Sandeels (Raitt's sandeel and lesser sandeel)
River Dee Special Area of Conservation (SAC)	80.83	• Atlantic salmon • Freshwater pearl mussel
River South Esk SAC	106.85	• Atlantic salmon • Freshwater pearl mussel
Tweed Estuary SAC	128.58	• River lamprey • Sea lamprey
River Tweed SAC and Site of Special Scientific Interest (SSSI)	132.43	• River lamprey • Sea lamprey • Atlantic salmon
River Tay SAC	182.68	• River lamprey • Sea lamprey • Atlantic salmon
River Teith SAC	227.51	• River lamprey • Sea lamprey • Atlantic salmon

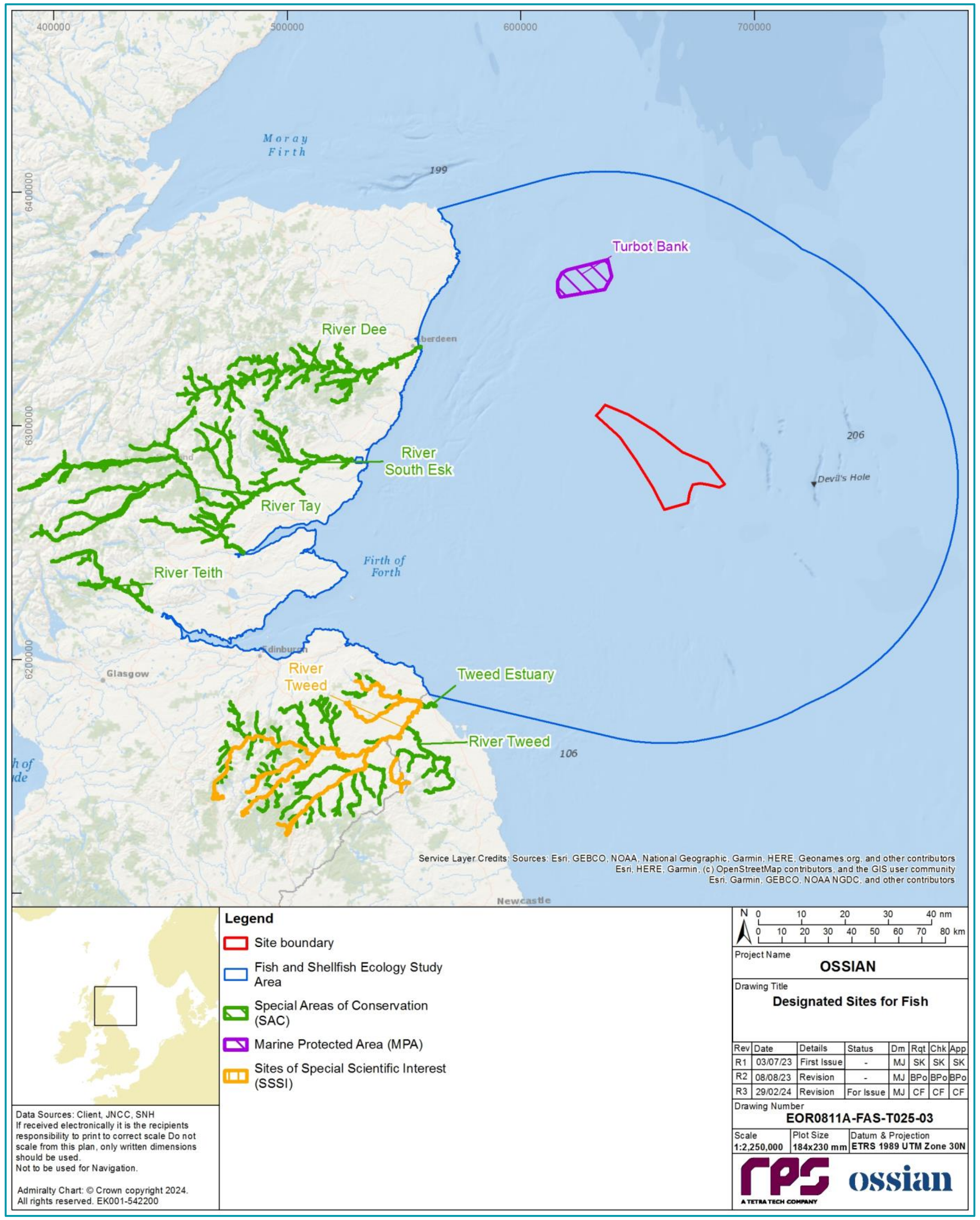

Figure 9.6: Fish and Shellfish Ecology Relevant Designated Sites

9.7.3. IMPORANT ECOLOGICAL FEATURES

31. For the purposes of the fish and shellfish ecology Array EIA chapter IEFs have been identified using good practice guidelines (Chartered Institute of Ecology and Environmental Management (CIEEM), 2019). The potential impacts of the Array which have been scoped into the assessment (see section 9.8) have been assessed against the IEFs to determine whether or not they are likely to be significant, therefore, the IEFs assessed are those that are considered to be important and potentially impacted by the Array. Importance may be assigned due to quality or extent of habitats, habitat or species rarity or the extent to which they are threatened (CIEEM, 2019). For a species or habitat to be considered an IEF, they must have a specific biodiversity importance recognised through international or national legislation or through local, regional, or national conservation plans (e.g. Annex I habitats under the Habitats Directive, Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), National Biodiversity Plan or the Marine Strategy Framework Directive, Scottish PMFs and the Scottish Biodiversity list). In addition, the commercial importance of fish and shellfish receptors is considered when assigning importance of IEFs within the fish and shellfish ecology study area, drawing on information presented in commercial fisheries baseline characterisation (volume 3, appendix 12.1).

32. As requested by NatureScot (Table 9.7), IEFs have been identified based on a range of factors, including their importance as PMFs, their ecological importance (e.g. as prey species) and the importance of the fish and shellfish study area at particular life history stages (e.g. spawning, nursery and migration).

33. Table 9.12 lists all the IEFs within the fish and shellfish ecology study area, by applying the defining criteria summarised in paragraph 31 (see volume 3, appendix 9.1 for further detail).

Table 9.12: IEFs within the Fish and Shellfish Ecology Study Area

IEF	Scientific Name	Description and Justification	Importance within the Fish and Shellfish Ecology Study Area
Marine Fish IEF Species			
Plaice	*Pleuronectes platessa*	Low intensity nursery and spawning grounds identified throughout the fish and shellfish ecology study area. It is an important commercial species, but not targeted within the fish and shellfish ecology study area. Listed as Priority Species under the UK Post-2010 Biodiversity Framework.	Regional
Lemon sole	*Microstomus kitt*	Undefined intensity nursery and spawning grounds throughout the fish and shellfish ecology study area. It is an important commercial species, but not targeted within the study area.	Regional
Other flatfish species	*Limanda limanda* *Hippoglossoides platessoides*	Other flatfish species including common dab and long rough dab are likely to occur within the fish and shellfish ecology study area. These species either have no known spawning or nursery grounds or low intensity/undetermined nursery and spawning grounds within the fish and shellfish ecology study area.	Local
Blue whiting	*Micromesistius poutassou*	Low intensity nursery grounds are present throughout the fish and shellfish ecology study area. Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework.	Regional
Cod	*Gadus morhua*	Listed as a PMF. Listed by OSPAR as threatened and/or declining and listed as Vulnerable on the IUCN Red List. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. Low intensity nursery grounds and low intensity spawning grounds are present throughout the fish and shellfish ecology study area. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Haddock	*Melanogrammus aeglefinus*	Nursery ground of unspecified intensity overlaps the fish and shellfish ecology study area. Listed as Vulnerable on the IUCN Red List. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Whiting	*Merlangius merlangus*	High intensity nursery grounds and low intensity spawning grounds identified throughout the fish and shellfish ecology study area. Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Saithe	*Pollachius virens*	Unspecified nursery grounds. intensity nursery grounds in proximity to the fish and shellfish ecology study area. Listed as a PMF. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Other PMF species	*Lophius piscatorius* *Molva molva*	Species listed as PMFs and listed as Priority Species under the UK Post-2010 Biodiversity Framework include anglerfish and ling. Both species may be present within site boundary as there are low intensity nursery grounds throughout the fish and shellfish ecology study area. However, there are no spawning grounds present.	Regional
Other demersal species	*Merluccius merluccius*	Demersal species including European hake are common throughout Scottish waters and are likely to be present within the fish and shellfish ecology study area. They are important commercial species, but not targeted within the fish and shellfish ecology study area.	Local

IEF	Scientific Name	Description and Justification	Importance within the Fish and Shellfish Ecology Study Area
Sandeel species	Ammodytidae	There are five species of sandeel found in Scottish waters lesser sandeel and greater sandeel being the most found species, particularly in the vicinity of the fish and shellfish ecology study area. Low intensity spawning grounds and low intensity nursery grounds present throughout the site boundary. Also identified as likely to be present in the fish and shellfish ecology study area based on historic data and habitat preference (see paragraphs 24 to 25). Lesser sandeel and Raitt's sandeel are listed as PMFs and listed as protected features within the Turbot Bank Nature Conservation MPA, which occurs within the fish and shellfish ecology study area. Listed as Priority Species under the UK Post-2010 Biodiversity Framework.	National
Herring	*Clupea harengus*	Important prey species for larger fish, birds, and marine mammals. Low intensity nursery grounds within the site boundary. Known to have spawning grounds in the vicinity of the site boundary, with core spawning habitats to the north and south of the fish and shellfish ecology study area. The closest spawning habitat was identified 0.62 km north-west of the site boundary (Coull *et al*., 1998). However, there was low spawning habitat suitability identified within the site boundary (see paragraphs 24 to 25). Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Mackerel	*Scomber scombrus*	Important prey species for larger fish, birds, and marine mammals. Low intensity nursery grounds throughout the site boundary. No spawning grounds in the vicinity of the fish and shellfish ecology study area. Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Norway pout	*Trisopterus esmarkii*	Non-specified intensity nursery grounds and low intensity spawning grounds are present over most of the fish and shellfish ecology study area. Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework.	Regional
Sprat	*Sprattus sprattus*	Important prey species for larger fish, birds and marine mammals. Unspecified intensity spawning and nursery grounds over the majority of the fish and shellfish ecology study area. It is an important commercial species, but not targeted within the fish and shellfish ecology study area.	Regional
Elasmobranchs			
Basking shark	*Cetorhinus maximus*	The North East Atlantic population are classed as Endangered on the IUCN Red List. They are listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II and classified as a Priority Species under the UK Post-2010 Biodiversity Framework. Protected in the UK under the Wildlife and Countryside Act. Listed as a PMF, however only likely to be present in low abundances if present at all in the fish and shellfish ecology study area.	National

IEF	Scientific Name	Description and Justification	Importance within the Fish and Shellfish Ecology Study Area
Tope shark	*Galeorhinus galeus*	Listed as Vulnerable by the IUCN Red List and is a Priority Species under the UK Post-2010 Biodiversity Framework. Low intensity nursery grounds in proximity to the fish and shellfish ecology study area.	Regional
Spurdog	*Squalus acanthias*	Listed as Vulnerable by the IUCN Red List and is a Priority Species under the UK Post-2010 Biodiversity Framework. Listed as a PMF. Low intensity nursery grounds within the fish and shellfish ecology study area.	Regional
Common skate	*Dipturus batis*	Listed as Critically Endangered on the IUCN Red List. Listed as a PMF. It is a Priority Species under the UK Post-2010 Biodiversity Framework. Low intensity nursery grounds in proximity to the fish and shellfish ecology study area (10.31 km away).	Regional
Rays	*Raja montagui* *Raja clavata*	Ray species including spotted ray and thornback ray. These species either have low intensity nursery grounds or no known nursery grounds overlapping the site boundary.	Regional
Shellfish IEF Species			
Edible crab	*Cancer pagurus*	Commercially important species, but not targeted within the fish and shellfish ecology study area. Identified as being likely to be present within the fish and shellfish ecology study area.	Regional
Norway lobster	*Nephrops norvegicus*	Commercially important species, but not targeted within the fish and shellfish ecology study area. Identified as unlikely to be present in the site boundary based on habitat preference. Spawning and nursery grounds present throughout the majority of fish and shellfish ecology study area.	Regional
European lobster	*Homarus gammarus*	Commercially important species, but not targeted within the fish and shellfish ecology study area. Identified as being likely to be present within the fish and shellfish ecology study area.	Regional
King scallop	*Pecten maximus*	Commercially important species, but not targeted within the fish and shellfish ecology study area. Identified as being likely to be present within the fish and shellfish ecology study area.	Regional
Velvet swimming crab	*Necora puber*	Commercially important species, but not targeted within the fish and shellfish ecology study area. Identified as being likely to be present within the fish and shellfish ecology study area.	Regional
Other crustaceans	Various	Other shellfish including shrimps, queen scallop, whelk, razor clams, and cephalopods have been identified as being likely to occur within the fish and shellfish ecology study area. Within the fish and shellfish ecology study area, these species are of relatively low commercial importance when compared to species such as *Nephrops*.	Local
Diadromous Fish IEF Species			
Atlantic salmon	*Salmo salar*	Likely to migrate through the fish and shellfish ecology study area. Annex II species and listed as qualifying features of a number of SACs in the fish and shellfish ecology study area. Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. Listed as Vulnerable by the IUCN Red List and listed by OSPAR as threatened or declining.	International

IEF	Scientific Name	Description and Justification	Importance within the Fish and Shellfish Ecology Study Area
Sea trout	*Salmo trutta*	Likely to migrate through the site boundary. Listed as a PMF. Listed as OSPAR threatened/declining species. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. Not a feature of any designated sites in the vicinity of the fish and shellfish ecology study area.	National
European eel	*Anguilla anguilla*	Likely to migrate through the site boundary. Listed as an OSPAR threatened/declining species and listed as Critically Endangered on the IUCN Red List. Listed as a PMF. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. Not a feature of any designated sites in the vicinity of the fish and shellfish ecology study area.	National
Sea lamprey	*Petromyzon marinus*	Listed as a PMF. Annex II species and listed as qualifying features of a number of SACs in the fish and shellfish ecology study area but not in the vicinity of the site boundary	National
River lamprey	*Lampetra fluviatilis*	Listed as a PMF. Annex II species and listed as qualifying features of a number of SACs in the fish and shellfish ecology study area but not in the vicinity of the site boundary. **Scoped out**: As noted during Scoping, this is an estuarine species and is therefore unlikely to have any interaction with the Array. As such, this species is not considered further in the assessment.	National
Twaite shad	*Alosa fallax*	Potential to migrate through the site boundary. Annex II species although not listed as qualifying features of any SACs in the vicinity of the site boundary. Listed as Priority Species under the UK Post-2010 Biodiversity Framework. Protected in the UK under the Wildlife and Countryside Act.	National
Allis shad	*Alosa alosa*	Potential to migrate through the site boundary. Annex II species although not listed as qualifying features of any SACs in the vicinity of the site boundary. Listed as Priority Species under the UK Post-2010 Biodiversity Framework and listed by OSPAR as threatened or declining. Protected in the UK under the Wildlife and Countryside Act.	National
Sparling/European smelt	*Osmerus eperlanus*	Listed as a PMF. **Scoped out**: As noted during Scoping, this is an estuarine species and are is therefore unlikely to have any interaction with the Array. As such, these this species is not considered further in the assessment.	N/A

IEF	Scientific Name	Description and Justification	Importance within the Fish and Shellfish Ecology Study Area
Freshwater pearl mussel	*Margaritifera margaritifera*	Listed in Annexes II and V of the EU Habitats and Species Directive and Appendix III of the Bern Convention. Listed as Endangered on the IUCN Red List. Annex II species and listed as qualifying features of several SACs in the vicinity of the site boundary. Freshwater pearl mussel are included due to their dependency on Atlantic salmon and sea trout.	International

9.7.4. FUTURE BASELINE SCENARIO

34. The EIA Regulations require that "*a description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the project, as far as natural changes from the baseline scenario can be assessed with reasonable effort, on the basis of the availability of environmental information and scientific knowledge*" is included within the Array EIA Report.

35. If the Array does not come forward, a description of the 'without development' future baseline conditions has also been carried out and is described within this section.

36. The baseline environment is not static and will exhibit some degree of natural change over time, even if the Array does not come forward, due to naturally occurring cycles and processes and additionally any potential changes resulting from climate change (refer to volume 2, chapter 17 for further detail). Therefore, when undertaking assessments of LSE[1], it will be necessary to place any potential impacts into the context of the envelope of change that might occur over the timescale of the Array.

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

38. Scottish and UK waters are facing an increase in sea surface temperature. The rate of increases is varied geographically, but between 1985 and 2009, the average rate of increase in Scottish waters has been greater than 0.2°C per decade, with the south-east of Scotland having a higher rate of 0.5°C per decade (Marine Scotland, 2011). A study completed over a longer period showed Scottish waters (coastal and oceanic) have warmed by between 0.05 and 0.07°C per decade, calculated across the period 1870 to 2016 (Hughes *et al*., 2018). Changes in temperature will have an effect on fish and shellfish at all biological levels (cellular, individual, population, species, community and ecosystem) both directly and indirectly. As sea temperatures rise, species adapted to cold water (e.g. cod and herring) will begin to disappear while warm water adapted species will become more established. It is also predicted that due to changes in weather patterns, for example increased numbers of spring storms, changes in stratification of water columns and plankton production may occur (Morison *et al*., 2019). This may cause knock on impacts on fish and shellfish species due to changes in food availability for prey species. Climate change presents many uncertainties as to how the marine environment will change in the future.

39. Furthermore, fisheries management measures, may also affect fish and shellfish species, communities and habitats in the fish and shellfish ecology study area. This includes the recent closure of sandeel fisheries in Scottish waters (i.e. The Sandeel (Prohibition of Fishing) (Scotland) Order 2024) which will see a ban on the fishing for sandeel from March 2024 within the Scottish zone. It is anticipated that this closure will provide wider potential benefits to the marine ecosystem including direct benefits to sandeel populations (through reduction of pressures from fishing) and indirect benefits to a wide range of fish, seabird and marine mammal species, as sandeel is an important prey species for a wide range of species in the marine ecosystem.

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

9.7.5. DATA LIMITATIONS AND ASSUMPTIONS

41. The data sources used in this chapter are detailed in Table 9.8 and volume 3, appendix 9.1. The desktop data used are the most up to date publicly available information which can be obtained from the applicable data sources as cited. Data that has been collected is based on existing literature, consultation with stakeholders, identification of habitats and site-specific survey data. This has been used to inform likely fish and shellfish species and communities and their associated habitats within the fish and shellfish ecology study area.

42. Site-specific surveys, including grab sampling and epibenthic trawls, were carried out to characterise the benthic subtidal ecology within the site boundary (volume 2, chapter 8), and did not specifically target fish and shellfish species. As a result, some species may have been missed. However, commercial fisheries information has been incorporated into the baseline characterisation, which itself was informed by consultation with the fishing industry, as presented in volume 2, chapter 12. As such, this additional information will have filled any gaps missed through site-specific surveys. These surveys provided opportunistic additional fish and shellfish data which have been incorporated into the assessment. However, given the detailed desktop study completed, covering a long time series and a wide variety of information sources (e.g. including scientific literature, grey literature, commercial fisheries information) and the conservative approach adopted, it is unlikely that key species have been omitted from the assessment.

9.8. KEY PARAMETERS FOR ASSESSMENT

9.8.1. MAXIMUM DESIGN SCENARIO

43. The MDSs identified in Table 9.13 are those expected to have the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in volume 1, chapter 3 of the Array EIA Report. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the Project Description (volume 1, chapter 3) (e.g. different infrastructure layout), to that assessed here, be taken forward in the final design scheme.

Table 9.13: Maximum Design Scenario Considered for Each Potential Impact as Part of the Assessment of LSE[1] on Fish and Shellfish

Potential Impact	Phase[2] C	O	D	Maximum Design Scenario	Justification
Temporary habitat loss and disturbance	✓	✓	✓	**Site Preparation and Construction Phases** A total of up to 49,948,548 m² (49.95 km²) of temporary habitat loss and/or disturbance due to: • a footprint area of 14,723,348 m² due to boulder and sand wave clearance; • a footprint area of 9,540,000 m² due to disturbance due to Drag Embedment Anchor (DEA) installation; • a footprint area of 25,392,000 m² due to disturbance caused by the installation of inter-array and interconnector cables; • a footprint area of up to 250,000 m² for temporary offshore wet storage; and • a footprint area of 43,200 m² due to jack up vessel use for Offshore Substation Platform (OSP) installation. This represents 5.82% of the total site boundary. In addition, up to 5,190 m² of temporary habitat loss could occur due to crater formation from the clearance of UXO. This value has not been included in the total of 49,948,548 m² as it has not been derived from the Project Description (volume 1, chapter 3). Instead, it has been calculated based on appropriate crater sizes from other projects, and applied to the 15 potential UXOs that may require clearance during the construction of the Array (Ordtek, 2018, Royal Haskoning DHV, 2022). **Operation and Maintenance Phase** A total of up to 51,411,500 m² (51.41 km²) of temporary habitat loss and/or disturbance over the 35 year lifecycle of the Array due to: • a footprint area of 367,500 m² due to jack up vessel usage for operation and maintenance activities (10,500 m² per year over the 35 year lifecycle); and • a footprint area of 51,044,000 m² due to disturbance caused by reburial of inter-array and interconnector cables (1,222,400 m² and 236,000 m², respectively per year). This represents 5.99% of the total site boundary. **Decommissioning Phase** A total of up to 43,200 m² of temporary habitat loss and/or disturbance due to the footprint area of jack up vessel use for decommissioning activities. This represents 0.01% of the total site boundary.	The MDS for this impact considers the maximum seabed footprint of temporary habitat loss and/or disturbance during the construction, operation and maintenance and decommissioning phases of the Array.

[2] C = Construction, O = Operation and maintenance, D = Decommissioning

Potential Impact	Phase[2] C	O	D	Maximum Design Scenario	Justification
Long term habitat loss and disturbance	✓	✓	✓	**Construction and Operation and Maintenance Phases** Up to 19,270,958 m^2 (19.27 km^2) of long term subtidal habitat loss due to infrastructure installed in the construction phase, which will persist into the operation and maintenance phase. This is due to: • a total footprint area of 12,416,305 m^2 due to mooring lines on the seabed. Mooring lines on the seabed will cover a maximum total footprint of 46,854 m^2 per foundation (n = 265) using catenary moorings. Some of these mooring cables will be buried and therefore not associated with long term habitat loss or disturbance, although the proportion that will be buried cannot be confirmed at this time and therefore a conservative approach has been taken, assuming all mooring lines will not be buried a total footprint area of 25,288 m^2 due to anchors on the seabed (265 foundations with an anchor footprint of 95 m^2 each); • a footprint area of 632,196 m^2 due to scour protection for moorings and anchors; • a footprint area of 2,163 m^2 due to OSP jacket foundations (3 large OSPs with an area of 382 m^2 each and 12 small OSPs at 85 m^2 each); • a footprint area of 94,814 m^2 due to scour protection for all small OSP jacket foundations; • 10% of piles will require drilling, with a volume of 636 m^3 from drill arisings per pile; • a footprint area of 4,889,600 m^2 due to all inter-array cable protection and 944,000 m^2 of interconnector cable protection; • a footprint area of 24,000 m^2 due to all inter-array and interconnector cable crossing protection; • a total footprint area of 41,040 m^2 due to inter-array junction boxes (228 boxes with a footprint area of 180 m^2 each); and • a footprint area of 201,552 m^2 due to scour protection for all inter-array junction boxes. This represents 2.25% of the total site boundary. In addition, up to 778,464 m^2 of long term seabed disturbance may occur due to movement of mooring lines and dynamic cables, which is subject to intermittent movement (therefore, repeated seabed disturbance). This value has been derived from a maximum disturbance footprint of 2,937.6 m^2 from mooring lines for each foundation (n=265 total). This footprint of repeated disturbance equates to 0.09% of the total area of the site boundary. **Decommissioning Phase** Up to 6,786,162 m^2 (6.79 km^2) of long term subtidal habitat loss due to infrastructure left *in situ* during the decommissioning of the Array (all scour protection and cable protection). This is comprised of: • a total footprint area of 4,901,600 m^2 due to all inter-array cable protection (4,889,600 m^2) and cable crossing protection (12,000 m^2); • a total footprint area of 956,000 m^2 due to all interconnector cable protection (944,000 m^2) and cable crossing protection (12,000 m^2); • a total footprint area of 928,562 m^2 due to scour protection for moorings and anchors (632,196 m^2), inter-array junction boxes (201,552 m^2), and large OSP jackets (94,814 m^2). This represents 0.79% of the site boundary.	The MDS for this impact accounts for the maximum seabed footprint of infrastructure installed during the construction phase which will result in the greatest extent of long term subtidal habitat loss in the operation and maintenance phase. In the decommissioning phase, the MDS accounts for the maximum seabed footprint of infrastructure that will remain *in situ*. It should be noted that the decommissioning strategy is not yet fully defined and is being assessed on an individual impact basis. The MDS for removal of infrastructure differs between impacts (e.g. increased SSCs and associated deposition). Currently, it is proposed that all scour protection and cable protection are to be left *in situ.* All inter-array and interconnector cables are also proposed to be left in situ; however, these will be buried to a minimum target burial depth of 0.4 m (subject to a Cable Burial Risk Assessment (CBRA)) and therefore do not represent a source of long term subtidal habitat loss.

Potential Impact	Phase[2] C	O	D	Maximum Design Scenario	Justification
Colonisation of hard structures	×	✓	×	**Operation and Maintenance Phase** Up to 19,270,958 m^2 (19.27 km^2) of hard structures will be installed in the construction phase (see 'Long term subtidal habitat loss' above) which could be colonised by benthic species in the operation and maintenance phase. As stated above, this represents up to 2.25% of the total site boundary. In addition, the floating wind turbine foundations, dynamic cables, and anchor mooring lines represent hard substrate introduced into the water column. Given the uncertainties surrounding calculating a footprint of impact within the water column, as opposed to the seabed, a value has not been calculated for the hard structures present within the water column. The available space for colonisation on the floating wind turbine foundations, dynamic cables, and anchor mooring lines will be affected by the final design. Further, marine growth will be periodically removed from the floating wind turbine foundations, as it could inhibit buoyancy, so this impact is more precautionary than that of the infrastructure installed on the seabed. Finally, up to 116 km of inter-array cables will be present within the water column, which could potentially be colonised. Therefore, the MDS for this impact is represented by up to 19.27 km^2 of hard substrate installed on the seabed and an unquantified area installed in the water column from dynamic cabling, mooring lines and the floating foundations.	Whilst hard structures are introduced during the construction phase, colonisation occurs later, during the operation and maintenance phase. As such, this impact assessment is considered only for the operation and maintenance phase. The MDS for this impact considers the maximum footprint area of hard substrate that will be installed in the construction phase, comprising of mooring lines, cable protection, cable crossing protection, and scour protection.

Potential Impact	Phase[2]			Maximum Design Scenario	Justification
	C	O	D		
Underwater noise from piling and UXO clearance impacting fish and shellfish receptors	✓	×	×	**Site Preparation and Construction Phases** Piling: *Wind turbines:* • up to 265 semi-submersible floating wind turbine foundations with up to 6 anchors per foundation and one 4.5 m diameter pile per anchor (1,590 piles); • absolute maximum scenario is for 100% of piles to be driven piles; • maximum hammer energy of up to 3,000 kJ; • up to 2 vessels piling concurrently at floating wind turbine anchors; • minimum 950 m and maximum 30 km distance between concurrent piling events; • up to 8 hours maximum piling per pile, therefore 3 piles installed over 24 hours; and • total duration of piling of 12,720 hours/530 days; and • total piling phase at floating wind turbine anchors of 63 months (assuming no piling during Q1 due to high likelihood of unsuitable offshore conditions) over a period of 7 years (within the 8 years construction phase). *OSPs:* • up to 3 large and 12 small jacket foundations with up to 12 and 6 legs per foundation, respectively; 24 x 4.5 m (large jacket) and 12 x 3.0 m (small jacket) diameter piles per leg (216 piles); • maximum hammer energy of up to 4,400 kJ; • only 1 vessel piling at any one time at large OSP locations, although there may be concurrent piling with a wind turbine anchor; • up to 8 hours maximum piling per pile, therefore 3 piles installed over 24 hours; • total duration of piling of 1,728 hours/72 days; and • total piling phase at large OSP foundations of 72 months over a period of 8 years assuming reduced piling during the winder period due to greater risk of inclement weather) over a period of 8 years. There is a potential for 2 vessels piling concurrently at either 2 wind turbine anchor locations or 1 wind turbine anchor and 1 large OSP foundation. Number of days when piling may occur within piling phase at floating wind turbine anchors and large OSPs = 602 days. Unexploded Ordnance (UXO) clearance: • clearance of 15 UXOs within the site boundary; • maximum UXO size of up to 698 kg Net Explosive Quantity (NEQ), realistic worst case 227 kg NEQ; • UXO clearance campaign will involve the use of up to 2 vessels on site at any one time with up to 4 return trips; • intention for clearance of all UXOs using low order techniques (subsonic combustion) with a single donor charge of up to 0.25 kg NEQ for each clearance event; • up to 0.5 kg NEQ clearance shot for neutralisation of residual explosive material at each location; • up to 2 detonations within 24 hours; • total duration of UXO clearance campaign 8 days excluding any time lost due to weather conditions; and • clearance during daylight hours only.	The MDS for this impact considers all activities with the potential to create underwater noise which may impact fish and shellfish ecology. The parameters considered in the MDS for this impact represent the design parameters with the potential to generate the highest underwater noise levels. For example, up to nine anchor piles may be required for the 130 turbine scenario (1,170 piles in total), however up to six anchor piles may be required for the 265 turbine scenario (1,590 piles in total). This impact is only being considered in the construction phase, as piling and UXO clearance activities will not occur during the operation and maintenance phase and decommissioning phase.

Potential Impact	Phase[2] C	O	D	Maximum Design Scenario	Justification
Underwater noise from the operation of floating wind turbines and anchor mooring lines impacting fish and shellfish receptors	×	✓	×	**Operation and Maintenance Phase** Up to 265 semi-submersible floating wind turbine foundations with up to 224 m hub height, placed 25 m deep in the water column with up to 100 m excursion limit. There is the potential for generation of underwater noise occurring at a very low frequency and low sound pressure level. Anchor mooring lines: • up to 1,590 catenary mooring lines; • maximum line length of up to 750 m (measured from the connection at the sea surface to the anchor located at the deepest water depth); • maximum mooring radius of up to 700 m (measured from the anchor to the floating foundation when located at a neutral central point within the excursion limit); • 200 m per mooring line will be dynamic in water column during the operation and maintenance phase with potential increases to 700 m during storms; and • the mooring line attachment to the foundation will be at a point below the splash zone, nominally set at 5 m below the sea surface. Operation and maintenance phase of up to 35 years.	The maximum scale of the Array (based upon the maximum number of turbines) as well as the type and dimensions of the floating wind turbines and anchor mooring lines represent the maximum potential for impacts associated with underwater noise during the operational of floating wind turbines and anchor mooring lines.

Potential Impact	Phase[2]			Maximum Design Scenario	Justification
	C	O	D		
Increased SSCs and associated deposition	✓	✓	✓	**Site Preparation and Construction Phases** There is potential for increased SSCs and associated deposition to occur because of the following activities: • boulder clearance, wherein a clearance width of up to 24 m will be used for an estimated 25% of inter-array cables (315.25 km) and interconnector cables (59 km); • sand waves may be cleared to a width of 24 m along inter-array cables, interconnector cables, and scour protection for OSP foundations. The maximum volume of cleared material is 5,867,520 m^3 at inter-array cables, 1,133 m^3 at interconnector cables, and 104,295 m^3 at OSP foundations (total 11,841,602 m^3 of cleared material); • installation of up to 1,590 DEAs, which may be dragged up to 60 m each along the seabed; and • installation of 1,261 km of inter-array cables and 236 km of interconnector cables. **Operation and Maintenance Phase** Project lifetime of 35 years. The mooring line chain thickness is 185 mm, and the horizontal diameter is 620 mm. There are two potential MDSs associated with this impact for fish and shellfish ecology, 130 turbines with up to 9 catenary mooring lines each, or 265 turbines with up to 6 catenary mooring lines each. Justification for the inclusion of both is provided in the next column. <u>130 turbine MDS:</u> Mooring lines – movement around touchdown points on the seabed of up to 9 catenary mooring lines per semi-submersible foundation, of which there are up to 130, at a minimum spacing of 1.4 km. The maximum length of each mooring line in contact with the seabed during operation is: • 680 m: which amounts to 6,120 m per foundation and up to a total of 795,600 m of mooring line with the potential to be in contact with the seabed. <u>265 turbine MDS:</u> Mooring lines – movement around touchdown points on the seabed of up to 6 catenary mooring lines per semi-submersible foundation, of which there are up to 265, at a minimum spacing of 1 km. The maximum length of each mooring line in contact with the seabed during operation is: • 680 m: which amounts to 4,080 m per foundation and up to a total of 1,081,200 m of mooring line with the potential to be in contact with the seabed. **Decommissioning Phase** • Up to 19,270,958 m^2 (19.27 km^2) of hard substrate on the seabed will be removed in the decommissioning of the Array. SSC levels are expected to be similar or of a lower extent to the construction phase (given the absence of site preparation activities in the decommissioning phase).	In the construction phase, the MDS for this impact is associated with the activities that may result in increased SSCs and associated deposition. As this impact was not scoped in for assessment for this phase in the physical processes chapter (volume 2, chapter 7), these are assessed highly qualitatively in section 9.11. Where available in the Project Description (volume 1, chapter 3), volumes of cleared material and/or arisings are presented (e.g. for sand wave clearance and drilling). Inter-array and interconnector cable burial methodology will be identified at the final design stage (post-consent), however cable plough, jet trencher, mass flow excavator, and mechanical cutter are potential options (volume 1, chapter 3). During the operation and maintenance phase, the potential of an increase in SSCs may arise as a result of mooring lines or cables making contact with and moving on the seabed, disturbing seabed materials and causing scouring and increased SSCs within the water column. This may lead to associated deposition of these materials,. There is the potential impact to fish and shellfish ecology from the increase in SSCs. The greatest potential for the increase in SSCs is from catenary moorings which have the greatest proportion of mooring line that could move on the seabed. Taut and semi-taut systems will be designed so there is little or no sections of mooring rope or chain in contact with the seabed. For catenary systems during normal operations mooring chains are expected to have limited movement on the seabed. During more extreme weather conditions mooring lines on the windward side of the turbine will lift from the seabed, whilst mooring lines on the leeward side will drop onto the seabed. The MDS is considered to be the foundations with the greatest length of mooring line in contact with the seabed per foundation, rather than over the site as a whole, as the effects are considered to be very localised. This is in line with the approach taken in the physical processes assessment. Dynamic inter-array cables at turbines will have a section of cable between the touchdown point and where they become static that may move during operation. Buoyancy modules and tether anchors may be used to reduce movement. Increased SSC may occur around the touchdown points. All other inter-array cables and interconnector cables will be static and will be buried where practicable subject to the outputs of a Cable Burial Risk Assessment (CBRA). Where target burial depth is not achieved, cable protection will be used in the form of rock protection, concrete mattresses or similar. Two MDSs are provided to assess this impact for fish and shellfish ecology. The first considers the MDS to be 130 turbines with up to 9 catenary mooring lines each. This is in line with the MDS presented in the physical processes assessment (volume 2, chapter 7). The 130 turbine MDS considers the number of foundations with the greatest length of mooring line on the seabed per foundation, rather than over the site boundary as a whole, as the effects are considered to be very localised. The greatest length of mooring line per foundation represents the maximum potential increase in SSCs at each turbine. Any increase in SSCs will be limited to the vicinity of each foundation for a short period of time and will not be exacerbated by interaction between adjacent foundations for all spacings considered within the Project Description (volume 1, chapter 3). This MDS therefore represents the highest impact to the fish and shellfish species in the immediate vicinity of each turbine.

Potential Impact	Phase[2] C	O	D	Maximum Design Scenario	Justification
Effects to fish and shellfish receptors due to Electromagnetic Fields (EMFs) from subsea electrical cabling	×	✓	×	**Operation and Maintenance Phase** Presence of inter-array and interconnector cables: • up to 1,261 km of 66 kV or 132 kV inter-array cables with maximum 116 km in the water column, with the rest buried to a minimum target depth of 0.4 m (subject to CBRA); • up to 236 km of 275 kV Alternating Current (AC) or 525 kV Direct Current (DC) interconnector cables with a minimum target burial depth of 0.4 m (subject to CBRA), or protected where target burial depth is not achieved); • up to 20% of inter-array and interconnector cables may require cable protection; • cables will also require cable protection at asset crossings (up to 12 crossings for inter-array cables and up to 12 crossings for interconnector cables); and • up to 228 junction boxes will be required for inter-array cables. The operation and maintenance phase will be up to 35 years.	The MDS for this impact is based on the greatest cable length proposed, both in the water column and buried in the seabed.

9.8.2. IMPACTS SCOPED OUT OF THE ASSESSMENT

44. The fish and shellfish ecology pre-Scoping workshop (see Table 9.7) was used to facilitate stakeholder engagement on topics to be scoped out of the assessment.

45. On the basis of the baseline environment and the Project Description outlined in volume 1, chapter 3 of the Array EIA Report, a number of impacts have been agreed to be scoped out of the assessment for fish and shellfish ecology. This was either agreed with key stakeholders through consultation as discussed in volume 1, chapter 5, or otherwise, the impact was proposed to be scoped out in the Array EIA Scoping Report (Ossian OWFL, 2023), and no concerns were raised by key consultees within the Scoping Opinion.

46. These impacts are outlined, together with a justification for scoping them out, in Table 9.14.

Table 9.14: Impact Scoped Out of the Assessment for Fish and Shellfish Ecology (Tick Confirms the Impact is Scoped Out)

Potential Impact	Phase[3]			Justification
	C	O	D	
Effects to fish and shellfish ecology due to accidental release of pollutants	✓	✓	✓	Pollution could be accidentally released from vessels, equipment, and machinery associated within the construction phase. However, the potential risk of accidental release of pollutants is reduced by designed in mitigation measures, such as the development of, and adherence to, an EMP which includes a MPCP. These designed in mitigation measures include planning for accidental spills, discuss all potential contaminants, and provide key emergency contact details. They will also adhere to good industry practice and relevant guidelines, such as the OSPAR, International Marine Organisation (IMO), and the International Convention for the Prevention of Pollution from Ships (MARPOL) guidelines for preventing pollution at sea. An accidental spill is, therefore, very unlikely, and even if it occurs, the magnitude will be reduced through measures outlined in the designed in measures for this impact (such the MPCP). Based on this information, as agreed in consultation with regulators, advisory bodies and Statutory Nature Conservation Bodies (SNCBs), this impact has been scoped out of further consideration within the EIA for fish and shellfish ecology.
Underwater noise from vessels impacting fish and shellfish receptors	✓	✓	✓	There are no designed in measures necessary as underwater noise generated by operational vessels is likely to be low and potential impacts to fish and shellfish ecology receptors are only likely to occur if individuals remained within their immediate vicinity (i.e. within metres) for several hours/days. This is highly unlikely to occur. Therefore, levels of noise generated by vessels are not considered to have LSE[1] on fish and shellfish ecology receptors, and it is proposed to scope this impact out of further consideration within the EIA for fish and shellfish ecology. The agreement to scope this impact out of the assessment for fish and shellfish ecology is in line with that of similar projects (e.g. Inch Cape Offshore Wind Farm, Seagreen 1 Offshore Wind Farm; Seagreen, 2012, Berwick Bank; SSER, 2022a).
Entanglement	×	✓	×	Joint Nature Conservation Committee (JNCC) guidance has been considered within the impact assessments (section 9.11). The NatureScot Commissioned Report 791 on marine megafauna entanglement is covered within the impact of entanglement on marine mammals in volume 2, chapter 10, with entanglement also having a potential impact on basking shark, which have been identified as an IEF for this assessment. The measures set out to minimise entanglement risk committed to in the marine mammal assessment (volume 2, chapter 10) will also ensure entanglement risk to basking shark and other megafauna is reduced. With these in place and considering the low abundances of basking shark in the North Sea, there are no significant effects predicted, and this impact is scoped out of assessment.

[3] C = Construction, O = Operation and maintenance, D = Decommissioning

9.9. METHODOLOGY FOR ASSESSMENT OF EFFECTS

9.9.1. OVERVIEW

47. The fish and shellfish ecology assessment of effects has followed the methodology set out in volume 1, chapter 6 of the Array EIA Report. Specific to the fish and shellfish ecology EIA, the following guidance documents have also been considered:

- guidelines for Ecological Impact Assessment (EcIA) in the UK and Ireland. Terrestrial, Freshwater and Coastal (CIEEM, 2019);
- guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008); and
- guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Judd, 2012).

9.9.2. CRITERIA FOR ASSESSMENT OF EFFECTS

48. When determining the significance of effects, a two-stage process that involves defining the magnitude of the potential impacts and the sensitivity of the receptors. This section describes the criteria applied in this chapter to assign values to the magnitude of potential impacts and the sensitivity of the receptors. The terms used to define magnitude and sensitivity are based on those which are described in further detail in volume 1, chapter 6 of the Array EIA Report.

49. The criteria for defining magnitude in this chapter are outlined in Table 9.15. Each assessment considered the spatial extent, duration, frequency and reversibility of impact and these are outlined within the magnitude section of each assessment of effect (e.g. a duration of hours or days would be considered for most receptors to be of short term duration, which is likely to result in a low magnitude of impact).

Table 9.15: Definition of Terms Relating to the Magnitude of an Impact

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

50. The criteria for defining sensitivity in this chapter are outlined in Table 9.16.

51. The definitions of sensitivities of fish and shellfish IEFs have been informed by the Marine Evidence based Sensitivity Assessment (MarESA) (MarLIN, 2021) and FeAST (NatureScot, 2021). The MarESA defines sensitivity as a product of the likelihood of damage (resistance) due to a pressure and the rate of recovery (recoverability) once the pressure has been removed. Recoverability is the ability of a habitat to return to the state of the habitat that existed before the activity or event which caused change. Full recovery does not necessarily mean that every component species has returned to its prior condition, abundance, or extent but that the relevant functional components are present, and the habitat is structurally and functionally recognisable as the initial habitat of interest. The FeAST is another web based application which allows users to investigate the sensitivity of marine features in Scotland's seas, to pressures arising from human activities (noting that this has been developed for features of low/limited mobility, so may not be relevant to fish and shellfish ecology). The FeAST sensitivity assessment considers feature tolerance (ability to absorb or resist change or disturbance) to a pressure and its ability to recover once the pressure stops. Both the MarESA and the FeAST define pressures by a benchmark which describes the extent and duration of the pressure but does not consider the intensity, frequency of pressures or any cumulative impacts. The FeAST tool has been utilised to identify pressures where possible, however, it is only available for a small number of fish and shellfish species at the time of writing.

52. Information on sensitivity of the fish and shellfish ecology IEFs are discussed within the impact assessment according to the broad groupings set out in section 9.7.3, as in many cases sensitivities for fish and shellfish receptors to particular impacts are similar across species groupings. Where further detail on species specific sensitivities are required (e.g. for species known to be sensitive to particular impacts and/or of particular importance), these are discussed and evidenced as appropriate. For example sensitivity to habitat loss impacts may be discussed for marine fish and shellfish species in general, with further evidence presented for sandeel, which are known to be particularly sensitive to seabed impacts. For each impact, where a species is particularly sensitive to that impact this species is considered individually under its own heading. Sensitivities for other marine fish and shellfish species are presented separately to diadromous fish species. This approach has been agreed with stakeholders through the Scoping process.

Table 9.16: Definition of Terms Relating to the Sensitivity of the Receptor

Sensitivity of the Receptor	Description
Very High	Very high importance and rarity, international receptor with no potential or very limited potential for recovery.
High	High importance and rarity, international and/or national receptor and limited potential for recovery.
Medium	High or medium importance and rarity, regional receptor, and potential for recovery.
Low	Low or medium importance and rarity, local receptor and high potential for recovery.
Negligible	Very low importance and rarity, local receptor and very high potential for recovery.

53. The magnitude of the impact and the sensitivity of the receptor are combined when determining the significance of the effect upon fish and shellfish ecology. The particular method employed for this assessment is presented in Table 9.17.

54. Where a range is suggested for the significance of effect, for example, minor to moderate, it is possible that this may span the significance threshold. The technical specialist's professional judgement was applied to determine which outcome defines the most likely effect, which took in to account the sensitivity of the receptor and the magnitude of impact. Where professional judgement was applied to quantify final significance from a range, the assessment has set out the factors that result in the final assessment of significance. These factors may include the likelihood that an effect will occur, data certainty and relevant information about the wider environmental context.

55. For the purposes of this assessment:

- a level of residual effect of moderate or more will be considered a 'significant' effect in terms of the EIA Regulations; and
- a level of residual effect of minor or less will be considered 'not significant' in terms of the EIA Regulations.

56. Effects of moderate significance or above are therefore considered important in the decision-making process, whilst effects of minor significance or less warrant little, if any, weight in the decision-making process.

Table 9.17: Matrix Used for the Assessment of the Significance of the Effect

Sensitivity of Receptor	Magnitude of Impact			
	Negligible	**Low**	**Medium**	**High**
Negligible	Negligible	Negligible to Minor	Negligible to Minor	Minor
Low	Negligible to Minor	Negligible to Minor	Minor	Minor to Moderate
Medium	Negligible to Minor	Minor	Moderate	Moderate to Major
High	Minor	Minor to Moderate	Moderate to Major	Major
Very High	Minor	Moderate to Major	Major	Major

9.9.3. DESIGNATED SITES

57. This fish and shellfish ecology EIA chapter assesses the LSE[1] in EIA terms on the qualifying interest feature(s) of Natura 2000 sites (i.e. nature conservation sites in Europe designated under the Habitats or Birds Directives[4]) and/or sites in the UK that comprise the National Site Network (collectively termed 'European sites') as described within section 9.7.2 of this chapter. The RIAA for the Array includes the assessment of the potential impacts on the site itself. A summary of the outcomes reported in the RIAA is provided in (Ossian OWFL, 2024).

58. Where locally designated sites and national designations (other than European sites) fall within the boundaries of a European site and where qualifying interest features are the same, only the assessment on the European site is presented. Potential impacts on the integrity and conservation status of the locally or nationally designated site on the relevant qualifying interest features would be synonymous with the assessment of the European site so a separate assessment for the local or national site is not presented.

59. However, assessment of the LSE[1] on a local or nationally designated site which falls outside the boundaries of a European site, but within the fish and shellfish ecology study area, has been undertaken within this chapter using the EIA methodology.

9.10. MEASURES ADOPTED AS PART OF THE ARRAY

60. As part of the Array design process, several designed in measures have been proposed to reduce the potential for impacts on fish and shellfish ecology (see Table 9.18). They are considered inherently part of the design of the Array and, as there is a commitment to implementing these measures, these have been considered in the assessment presented in section 9.11 (i.e. the determination of magnitude and therefore significance assumes implementation of these measures). These designed in measures are considered standard industry practice for this type of development.

[4] Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

Table 9.18: Designed In Measures Adopted as Part of the Array

Designed In Measures Adopted as Part of the Array	Justification
The development of, and adherence to a Piling Strategy (PS) (or equivalent) which will set out the following measures: Implementation of initiation stage and soft start during piling. This will involve the use of a low hammer energy with a low number of strikes used initially, followed by lower hammer energies at a higher strike rate at the beginning of the piling sequence before energy input is 'ramped up' (increased) over time to required higher levels.	These measures will reduce the likelihood of injury from elevated underwater noise to marine life in the immediate vicinity of piling operations as far as practicable, allowing individuals to move away from the area before sound levels reach a level at which injury may occur. The assessments of significance are presented in section 9.11.
Undertake Unexploded Ordnance (UXO) clearance using low order disposal techniques where technically feasible.	Low order techniques will be adopted wherever practicable (e.g. deflagration and clearance shots) as mitigation to reduce noise levels and thereby injury and disturbance to fish and shellfish ecology receptors. However, as noted in paragraph 181, there is a small risk that low order disposal could unintentionally arise in a high order detonation and therefore this scenario has also been considered in the assessment of LSE[1].
Implementation of soft start measures for UXO clearance using a sequence of small explosive charges detonated over set time intervals.	These measures will reduce the likelihood of injury from elevated underwater noise to fish and shellfish receptors in the immediate vicinity of piling/UXO clearance operations as far as practicable, allowing individuals to move away from the area before sound levels reach a level at which injury may occur. This is in line with the most up to date guidance for piling/UXO clearance operations (Joint Nature Conservation Committee (JNCC), 2010a; JNCC, 2010b) and, in most cases, compliance with this guidance reduce the likelihood of injury to fish and shellfish receptors to negligible levels.
Development of, and adherence to an EMP.	To ensure adequate environmental controls are in place across the project to manage and mitigate any potential risk to the environment. Measures will cover all aspects of environmental management including environmental awareness training, auditing, environmental reporting and waste management. It is anticipated that the MPCP and INNSMP will be appendices to the overarching EMP (volume 4, appendix 21).
Development of, and adherence to a MPCP (volume 4, appendix 21, annex A).	To reduce the potential for release of pollutants from construction, operation and maintenance and decommissioning plant is reduced so far as reasonably practicable. These will likely include designated areas for refuelling where spillages can be easily contained, storage of chemicals in secure designated areas in line with appropriate regulations and guidelines, double skinning of pipes containing hazardous substances, and storage of these substances in impenetrable bunds. All vessels associated with the Array will be required to comply with the standards set out by MARPOL.
Development of, and adherence to an Invasive Non-Native Species Management Plan (INNSMP) (volume 4, appendix 21, annex B).	To reduce the risk of introduction and spread of INNS during all phase of the Array as far as reasonably possible.
Development of, and adherence to a CBRA.	The CBRA will determine the risks arising from cable burial, such as scour, erosion, and dropped objects, and any measures to address them, in order to limit disturbance to the seabed as far as reasonably practicable.
Development of, and adherence to, a Decommissioning Programme (DP[2]).	The aim of this plan is to adhere to the existing UK and international legislation and guidance, with decommissioning industry practice applied. Overall, this will reduce the amount of long term disturbance to the environment as far as reasonably practicable. While this measure has been committed to as part of the Array, the MDS for the decommissioning phase has been considered in each of the assessments of effects presented in section 9.11.

9.11. ASSESSMENT OF SIGNIFICANCE

61. Table 9.13 summarises the potential impacts arising from the construction, operation and maintenance and decommissioning phases of the Array, as well as the MDS against which each impact has been assessed. An assessment of the likely significance of the effects of the Array on the fish and shellfish ecology receptors caused by each identified impact is given below.

TEMPORARY HABITAT LOSS AND DISTURBANCE

62. Direct temporary habitat loss/disturbance of subtidal seabed habitats within the Array during the construction, operation and maintenance, and decommissioning phases will occur as a result of a range of activities (as set out in Table 9.13) including boulder and sand wave clearance and UXO clearance, disturbance from inter-array and interconnector cables, installation of DEAs, temporary wet storage, and use of jack up vessels for the OSP installation. Disturbance to these habitats has the potential to affect identified fish and shellfish IEFs directly (e.g. removal or injury of individuals) and indirectly (e.g. loss of important fish and shellfish habitats, such as spawning grounds).

Construction phase

Magnitude of impact

63. The MDS accounts for up to a total of 40.41 km^2 of temporary habitat loss and disturbance during the construction phase (Table 9.13). The represents 4.71% of the total Array fish and shellfish ecology study area. The MDS has been based on the total temporary habitat loss and disturbance as a result of the following activities in the site preparation and construction phases:

- sandwave and boulder clearance/relocation;
- installation of inter-array and interconnector cables;
- footprint of temporary offshore wet storage;
- footprint of jack up vessels used for OSP installation; and
- installation of DEAs

64. Jack-up footprints associated with installation of OSPs will result in compression of seabed sediments beneath spud cans where these are placed on the seabed. These will infill over time, although may remain on the seabed for several years, as demonstrated by monitoring studies of UK offshore wind farms (BOWind, 2008; EGS, 2011). Monitoring at Lynn and Inner Dowsing offshore wind farm showed some infilling of the footprints, although the depressions (of the order of tens of centimetres) were still visible a two years post construction (EGS, 2011). In areas where mobile sands and coarse sediments are present such as in the majority of the fish and shellfish ecology study area (refer to volume 2, chapter 8), jack-up depressions are likely to be temporary features which will only persist for a period of months to a small number of years. In less dynamic areas, jack-up depressions may be more persistent, though will not affect fish and shellfish use of relevant habitats due to these shallow depressions usually being comprised of the same sediment types.

65. With respect to cable installation, following seabed clearance (e.g. boulder and sand wave clearance) cables will be installed beneath surface sediments using one of the cable burial methods set out in Project Description (refer to volume 1, chapter 3) (e.g. ploughing, jetting, trenching etc.). A report (RPS, 2019) commissioned by The Crown Estate reviewed the effects of cable installation on subtidal sediments and habitats, drawing on monitoring reports from over 20 UK offshore wind farms. Following cable installation, sandy sediments were shown to recover quickly, with little to no evidence of disturbance in the years following cable installation (RPS, 2019). Although there was some evidence that remnant cable trenches in coarse and mixed sediments were conspicuous for several years after installation, these shallow depressions were of limited depth (i.e. tens of centimetres) relative to the surrounding seabed, and spread over a horizontal distance of several metres and therefore did not represent a large shift from the baseline environment (RPS, 2019). In muddy and muddy sand seabed habitats, remnant trenches were observed years following cable installation, although these were relatively shallow (i.e. a few tens of centimetres) (RPS, 2019). Given that the seabed sediments within the fish and shellfish ecology study area are dominated by sands and sandy gravels, as set out in volume 2, chapter 8, the results of the RPS (2019) study suggest that disturbance to these sediments is likely to be reversible.

66. The maximum footprint of temporary wet storage is up to 250,000 m^2 (Table 9.13). Wet storage may be used to optimise delivery schedules during construction. Anchors or mooring chains may be placed on the seabed in the vicinity of their final installation location so the deliver vessel can return to port. The installation vessel will then move the equipment into their final position and install. Anchors, mooring lines and any ancillary weights may also be stored in the final turbine locations ready for the integrated turbines to be towed to site and installed within their final location. Temporary wet storage would occur within the site boundary. Impacts resulting from wet storage would be temporary in nature, and the seabed is expected to recover in the same manner as described in paragraph 65).

67. Finally, if DEAs are selected as an anchoring method for floating foundations (see Anchoring Option 2 and 3 in the Project Description, volume 1, chapter 3), it is assumed that these will be lifted from the installation vessel using a crane and positioned on the seabed. The DEAs will then be pulled using a heavy lift vessel or similar, in order to embed the anchor in the seabed. It is estimated that the anchor would be pulled between 30 and 60 m during the installation process subject to further ground investigations and anchor design. This process will be undertaken in a controlled manner to ensure that DEAs are installed at the correct position and to appropriate depth. There will be up to 1,590 DEAs installed in this manner in total (Table 9.13).

68. Activities resulting in the temporary subtidal habitat loss/disturbance will occur intermittently throughout the construction phase. The offshore construction phase which includes activities resulting in temporary habitat loss/disturbance will occur over a period of up to eight years. Once construction in a local area has been completed, this area will not be disturbed further during the construction phase. This area will start to recover immediately following cessation of construction activities in the vicinity allowing mobile species, such as sandeel and other fish and shellfish species, to repopulate the areas of previous disturbance.

69. The impact is predicted to be of local spatial extent, medium term duration, intermittent and high reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

Marine fish and shellfish species

70. The fish and shellfish species within the fish and shellfish ecology study area likely to be most sensitive to temporary habitat loss are those which spawn on or near the seabed sediment (e.g. herring, sandeel and elasmobranchs). Other fish species identified as IEFs in Table 9.12 (particularly adults) are considered less vulnerable to temporary habitat loss as they can move away from impacted areas and recolonise quickly once construction operations have ceased in the relevant area of seabed, compared to species and life history stages (e.g. juveniles) which are less mobile.

71. As shellfish (with the exceptions of some squids) tend to be less mobile than finfish, they are usually more vulnerable to habitat loss and disturbance. For example, a mark and recapture study on berried European lobster in Norway which showed that 84% of berried female specimens remained within 500 m of their release site (Agnalt *et al*., 2007). However, evidence seems inconsistent; research on other stocks around the world reveal limited movement for some stocks and long-distance migrations for other stocks (e.g. Campbell and Stasko, 1985; Comeau and Savoie, 2002).

72. Several commercially important shellfish species such as edible crab, European lobster, *Nephrops,* scallop and velvet swimming crab inhabit the fish and shellfish ecology study area. Habitat loss in this area will represent only a small temporary disturbance to shellfish habitats (e.g. during cable laying and seabed preparation), with relatively rapid recovery of sediments (RPS, 2019), and, following this, recovery of associated communities. A recent study of the Westermost Rough Offshore wind farm (north-east coast of England), within a European lobster fishing ground, found that the size and abundance of European lobster individuals increased following temporary closure of the area for the wind farm's construction (Roach *et al.,* 2018). This study implies wind farm construction activities (including wind turbine and cable installation) did not impact on resident European lobster populations and instead allowed some relief from fishing activities for a short time period before reopening for wind farm operation (Roach *et al*., 2018). Substrate type dictates the recoverability and rate of recovery of an area after large scale seabed disturbance (e.g. dredging or trawling activities) (Newell *et al*., 1998; Desprez, 2000); mud or sand habitats, for example, return to baseline species abundance after approximately one to two years (Newell *et al*., 1998; Desprez, 2000). In comparison, harder gravely and rocky substrate takes longer to re-establish; up to ten years for boulder coastlines (Newell *et al*., 1998).

73. *Nephrops* spawning and nursery habitats overlap with the construction operations (including cable installation) within the fish and shellfish ecology study area (Coull *et al*., 1998; volume 3, appendix 9.1), though habitat type within the Array is unsuitable for *Nephrops* (Franco *et al.,* 2022).

74. King scallop and queen scallop have been identified as being likely to be present within the site boundary (see Table 9.12). Scallop, whilst predominantly sessile, can swim as an escape mechanism, over limited (up to 30 m) distances (Marshall and Wilson, 2008). This was observed by Howell and Fraser (1984) during a tag and release study. This response may allow improved resilience to temporary habitat loss/disturbance than other sessile organisms, by being able to avoid areas of disturbance and relocate to areas nearby. Scallop tend to aggregate as hydrographic features dictate their larval distributions (Brand, 1991). Therefore, it can be assumed that scallop populations can spawn outside the fish and shellfish ecology study area, and within unimpacted areas of the Array, as well as within suitable habitat. It is likely that scallop will continue to be recruited into the fish and shellfish ecology study area and will recover well from any disturbance due to short term temporary habitat loss.

75. Fish and shellfish species may also be indirectly affected through feeding habitat and prey items. For example, crabs and other crustaceans and small benthic fish species (as well as other benthic species; see volume 2, chapter 8) are considered important prey species for larger fish. However, since this impact is predicted to affect only a small proportion of seabed habitats in the fish and shellfish ecology study area at any one time, with similar habitats (and prey species) occurring throughout the fish and shellfish ecology study area, these impacts are likely to be limited and highly reversible. Also, habitat disturbance during the construction phase will also expose benthic infaunal species from the sediment (see volume 2, chapter 8), potentially offering foraging opportunities to opportunistic scavengers immediately after completion of works. The implications of changes in fish and shellfish prey species are also discussed for higher trophic level receptors (i.e. marine mammals and birds) in volume 2, chapter 10 and chapter 11.

76. Most fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore, considered to be low.

Sandeel

77. Physical disturbance to sandeel habitats could lead to sandeel mortality if individuals cannot colonise viable sandy habitats in the immediate vicinity, or where habitats may be at carrying capacity (Wright *et al.,* 2000), beyond which, intraspecific competition would lead to less dominant specimens being excluded from the habitat. The FeAST tool shows sandeel as having a high sensitivity to 'sub-surface abrasion/penetration' (Wright *et al.,* 2000) and sandeel may also be particularly vulnerable during their winter hibernation period when they are less mobile, buried in the seabed substrates. The largest component for habitat loss and disturbance during the construction phase is through the installation of inter-array and interconnector cables (25,392,000 m^2 of the total 40,408,548 m^2 associated with the overall construction phase). The fish and shellfish ecology study area is located over low intensity spawning and low intensity nursery grounds for sandeel (Figure 9.4 and Figure 9.5) and a mix of preferred, marginal and unsuitable habitat type, with the preferred habitat types in the north-west of the fish and shellfish ecology study area. Further, only a small proportion of this maximum footprint of habitat loss/disturbance will be occurring at any one time during the construction phase, with recovery of sediments, and sandeel populations into them.

78. Short and long term monitoring studies at the Horns Rev offshore wind farm in the Baltic Sea, Denmark, have shown that offshore wind farm construction (Jensen *et al*., 2004) and operation (van Deurs *et al*., 2012) has not led to significant adverse effects on sandeel populations. Further, recovery of sandeel occurred quickly following construction operations, so recovery of sandeel populations in the fish and shellfish ecology study area would be expected following construction operations, with the rate of recovery dependent on the recovery of sediments to a condition suitable for sandeel recolonisation. Specifically, Jensen *et al.,* (2010) found that sandeel populations mix within fishing grounds to distances of up to 28 km; therefore, some recovery of adult populations is likely following construction operations, with adults recolonising suitable sandy substrates from adjacent un-impacted habitats. Recovery may also occur through larval recolonisation of suitable sandy sediments with sandeel larvae likely to be distributed throughout the fish and shellfish ecology study area during spring months following spawning in winter/spring (Ellis *et al*., 2012).

79. Results from a post-construction monitoring study at the Beatrice Offshore Wind Farm showed that sandeel abundance either increased or remained at similar levels when comparing abundance from 2014 to 2020, with offshore construction of Beatrice Offshore wind farm commencing in April 2017 (BOWL, 2021). This report found no evidence that construction resulted in adverse impacts on the local sandeel population and builds on previous work by Stenberg *et al*. (2011) which also concluded that the construction of the Horns Rev 1 Offshore Wind Farm neither threatened nor directly benefitted sandeel over a seven year period.

80. Sandeel (and other less mobile prey species) would be impacted by temporary habitat loss, although recovery of this species is expected to occur quickly as the sediments recover following installation of infrastructure when adults can return and also via larval colonisation of the sandy sediments.

81. Sandeel are deemed to be of high vulnerability, high recoverability and of national importance. The sensitivity of sandeel is therefore considered to be medium.

Herring

82. Based on site-specific survey data the habitats present within the site boundary are unsuitable for herring spawning (Figure 9.2), Spawning grounds have been recorded outside the site boundary in the wider fish and shellfish ecology study area based on IHLS data (Figure 9.2 and Figure 9.3). There is, however, a small overlap with the herring spawning habitat and the fish and shellfish ecology study area. However, the area of herring spawning grounds affected by this impact is expected to be very limited (being limited to the stie boundary only), in the context of available favourable sediments habitat outside and across the fish and shellfish ecology study area (see section 9.7.1).

83. Herring are deemed to be of high vulnerability, medium recoverability and of regional importance. However, the sensitivity of herring to this impact is considered to be low, given the limited suitability of herring spawning habitat within the site boundary (where temporary habitat loss/disturbance effects will occur; see section 9.7.1).

Diadromous species

84. As diadromous fish species are highly mobile, they are usually able to avoid areas subject to temporary habitat loss and are only likely to encounter the fish and shellfish ecology study area during migrations to and from natal rivers on the east coast of Scotland. Habitats within the fish and shellfish ecology study area itself are not likely to be important for diadromous fish species, so any habitat loss during the construction phase is not likely to cause any direct impact upon diadromous fish species, and is not likely to affect their migrations.

85. As with fish and shellfish, indirect impacts might exist for diadromous fish, due to impacts on prey species. For example, adult sea lamprey are parasitic and known to prey on a wide range of fish species and some cetacean species (Silva *et al.,* 2014) and sea trout on sandeel. Like marine fish, most large species would be able to avoid habitat loss effects due to their greater mobility but would recover into the areas affected following cessation of construction.

86. Diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore considered to be low.

Significance of the effect

Marine fish and shellfish species

87. Overall, the magnitude of the impact for marine fish and shellfish species is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

88. For sandeel, the magnitude of the impact is deemed to be low and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms. This is largely due to the area of unsuitable habitat for sandeel, that sandeel spawning grounds within the fish and shellfish ecology area is of low intensity and because modelling shows the abundance of buried sandeel to be very low.

For herring, the magnitude of the impact is deemed to be low and the sensitivity is considered to be low. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

90. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

Operation and maintenance phase

Magnitude of impact

91. Operation and maintenance activities within the fish and shellfish ecology study area may lead to temporary subtidal habitat loss/disturbance. The MDS is for up to 51,411,500 m^2 of temporary habitat loss/disturbance during the operation and maintenance phase (Table 9.13). This equates to 5.99% of the total site boundary and therefore this represents a relatively small proportion of the fish and shellfish ecology study area. It should also be noted that only a small proportion of the total habitat loss/disturbance is likely to be occurring at any one time over the 35-year operation phase of the Array.

92. Temporary habitat loss will occur as a result of the use of jack-up usage for operation and maintenance activities (10,500 m^2 per year over the 35-year lifecycle), and also due to disturbance caused by reburial of inter-array and interconnector cables (1,222,400 m^2 and 236,000 m^2 per year, respectively).

93. The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

94. The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the construction phase assessment (see paragraph 70 *et seq.*), ranging from low to medium sensitivity.

Significance of the effect

Marine fish and shellfish species

95. Overall, the magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

96. For sandeel, the magnitude of the impact is deemed to be negligible and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

98. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

99. Decommissioning activities within the fish and shellfish ecology study area may lead to temporary subtidal habitat loss/disturbance. The decommissioning activities include the use of jack up vessels, and inter-array and interconnector cable removal, which could give up to a total of 25,435,200 m^2 of habitat loss/disturbance, representing 2.9% of the total site boundary. However, the removal of cables is likely to reverse the construction phase impacts in the longer term; that is, the seabed may return to its pre-construction state.

100. The impact is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

101. The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the construction phase assessment (see paragraph 70 *et seq.*), ranging from low to medium sensitivity.

Significance of the effect

Marine fish and shellfish species

102. Overall, the magnitude of the impact is deemed to be negligible and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

103. For sandeel, the magnitude of the impact is deemed to be negligible and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

105. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

LONG TERM HABITAT LOSS AND DISTURBANCE

106. Long term habitat loss and disturbance may arise due to the installation and operation of the wind turbines and associated anchors and mooring systems, OSP foundations, subsea junction boxes, and the placement and presence of scour and cable protection. This impact is relevant to the construction, operation and maintenance, and decommissioning phases of the Array and may cause indirect impacts to receptors. While this assessment considers long term habitat loss, in reality the impact will be represented not by a loss of habitat, but rather a change in a sedimentary habitat and replacement with hard artificial substrates (i.e. physical change to another seabed type, as defined by MarESA). The assessment also considers where impacts to the seabed may occur over a long period of time, for example, at the touchdown point of mooring lines and dynamic cables. At these locations the results of repeated disturbance are considered to be similar to habitat loss in that it may result in an area of seabed being unavailable to benthic species. however this does not represent a change in sedimentary habitat and replacement with artificial substrates (see paragraph 109).

107. The MDS comprises the following infrastructure, as detailed in Table 9.13.

- mooring lines and anchors on the seabed, and associated scour protection;
- scour protection for all small OSP jacket foundations;
- inter-array and interconnector cable protection;
- inter-array and interconnector cable crossing protection;
- Inter-array junction boxes; and
- movement of the mooring lines.

Construction, operation and maintenance phases

Magnitude of impact

108. The presence of infrastructure associated with the Array within the fish and shellfish ecology study area will result in long term habitat loss. The MDS is for up to 19,270,958 m^2 of long term habitat loss representing 2.25% of the total site boundary. A total area of up to 12,416,305 m^2 will be lost due to mooring lines on the seabed (46,854 m^2 per foundation). It is noted that some sections of these mooring lines or cables will be buried (e.g. mooring lines/chains associated with DEAs), which would not contribute to long term habitat loss or disturbance, though the proportion to be buried cannot be quantified at this stage. As such, the approach taken is considered to be precautionary, with the assessment based on the maximum possible habitat loss presented in the MDS. Anchors on the seabed will have a total footprint area of 25,288 m^2 (based on 265 wind turbine foundations of 95 m^2 each). Large OSP jacket foundations will have a footprint area of 2,163 m^2 (based on three large OSPs with an area of up to 382 m^2 each and 12 small OSPs at up to 85 m^2 each), and a footprint area of 94,814 m^2 will occur due to small OSP jacket foundation scour protection. The inter-array cable protection will have a footprint area of 4,889,600 m^2 due to all inter-array cable protection and 944,000 m^2 for the interconnector cable protection. Up to 20% of inter-array cables and up to 30% of interconnector cables are expected to require protection, causing a potential long term habitat loss of up to 977,920 m^2 for inter-array cables and up to 283,200 m^2 for interconnector cables (see Table 9.13). A footprint area of up to 24,000 m^2 will exist due to up to 24 inter-array and interconnector cable crossings requiring protection and the inter-array junction boxes will have a total footprint area of up to 41,040 m^2, based on 228 boxes with up to 180 m^2 footprint area each. For the inter-array junction box scour protection, a footprint area of up to 201,552 m^2 is assumed.

109. Additionally, up to 778,464 m^2 of long term seabed disturbance may exist due to the movement of foundation mooring lines, which is subject to movement and, as such, seabed disturbance. This disturbance has a maximum footprint of 2,937.6 m^2 from mooring lines for each foundation (265 in total). This footprint of repeated disturbance assumed within the MDS equates to up to 0.09% of the total site boundary. Finally, the MDS includes drilling at up to 10% of piles, with up to 636 m^3 of drill arisings associated with each.

110. The long term loss of subtidal habitat involves a change of sediment composition in affected areas (e.g. surrounding foundations and along sections of the Array) from soft sediment habitats (sands, gravels and muds) to hard structures (foundations, cable protection and scour protection). These areas of habitat loss will be discrete, either in the immediate vicinity of foundations (i.e. foundations, mooring lines, and scour protection), or for cable protection will be relatively small isolated stretches of cable within large areas of sediment which characterise the baseline environment (i.e. soft sediments). This translates into the loss of one type of habitat and the increase of a new habitat. The implications of this are discussed in the sensitivity section (paragraph 112 *et seq.*) and the potential colonisation of these new substrates is presented and discussed in later assessments of LSE[1] presented in this chapter (paragraph 126 *et seq.*). Long term subtidal habitat loss impacts will occur during the construction phase and will be continuous throughout the 35-year operation and maintenance phase.

111. The impact is predicted to be of local spatial extent, long term duration, continuous and low reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

Marine fish and shellfish species

112. The marine fish and shellfish species within the fish and shellfish ecology study area likely to be most sensitive to long term habitat loss and disturbance are those that are reliant upon the presence of suitable sediment/habitat for their survival, with specific focus given to sensitive sandeel and herring alongside the other marine fish and shellfish species identified as IEFs. Their sensitivity to this impact will depend on the availability of habitat within the wider geographical region. The seabed habitats removed or altered by the installation of infrastructure within the site boundary will reduce the amount of suitable habitat and available food resources for fish and shellfish species and communities associated with the baseline sediments. However, this area represents a low percentage compared with the extensive nature of fish and shellfish habitats (e.g. for spawning, nursery, feeding or overwintering) located within the fish and shellfish ecology study area.

113. As confirmed by desk based data sources, the fish and shellfish ecology study area coincides with fish spawning and nursery habitats including plaice, lemon sole, herring, sprat, whiting, cod, hake, ling, Norway pout, haddock, sandeel, mackerel, *Nephrops* and elasmobranchs (Coull *et al*., 1998; Ellis *et al*., 2012; Aires et al., 2014; see Table 9.10 and volume 3, appendix 9.1).

114. The fish species most vulnerable to habitat loss includes sandeel and herring. Both are demersal spawning species (species which lay their eggs on the seabed), which have specific habitat requirements for spawning (e.g. sandy sediments for sandeel and coarse, gravelly sediments for herring). Long term habitat loss and disturbance is identified by the FeAST tool as the pressure 'Physical change (to another seabed type)' which has identified that sandeel have high sensitivity to this impact (Wright *et al*., 2000). As well as utilising the seabed for laying eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history. Therefore, loss or disturbance of this specific type of habitat could represent an impact on this species. However, studies at other offshore wind farms indicate that the presence of operational offshore wind farm structures will not lead to significant adverse effects on sandeel populations in the long term. For example, monitoring studies at other offshore wind farms, including Horns Rev I, located off the Danish coast, found that the presence of offshore wind farm structures has not led to significant adverse effects on sandeel (van Deurs *et al*., 2012; Stenberg *et al*., 2011). Furthermore, initial results of a pre to post construction monitoring study at the Beatrice Offshore Wind Farm have reported that in some areas of the offshore wind farm, there was an increase in sandeel abundance (BOWL, 2021). This provides additional evidence that there is no adverse effect on sandeel populations from operational offshore wind farms and suggests that these structures could benefit sandeel populations. The fish and shellfish ecology study area is located over low intensity spawning and low intensity nursery grounds for sandeel (Figure 9.4 and Figure 9.5) and a mix of preferred, marginal and unsuitable habitat type, with the preferred habitat types in the north-west vicinity of the site boundary (see volume 3, annex 9.1). As described in paragraph 108, the long term habitat loss in the Array equates to up to 19,270,958 m^2. As a proportion of the total site boundary, this accounts for up to 2.25%, which is a relatively small proportion in the context of available habitat (including spawning and nursery habitats) in the fish and shellfish ecology study area.

115. Habitat within the site boundary is largely unsuitable for herring spawning; this aligns with desk based sources that note the presence of spawning grounds outside the site boundary to the north west (Figure 9.2 and Figure 9.3). Therefore, the area of herring spawning grounds affected by this impact is expected to be very limited, in the context of available favourable sediments habitat outside the fish and shellfish ecology study area and across the wider northern North Sea.

116. Fish assemblages also have the potential to be impacted by long term habitat loss and disturbance as a result of the operations and maintenance of offshore wind farms. For example, monitoring at some Belgian offshore wind farms have reported slight, but significant increases in the density of some common soft sediment-associated fish species (common dragonet *Callionymus lyra*, solenette, lesser weever *Echiichthys vipera* and plaice) within the offshore wind farm (Degraer *et al*., 2020). There was also some evidence of increases in numbers of fish species associated with hard structures, including crustaceans (including edible crab), sea bass and common squid *Alloteuthis ubulate*. The authors suggested that these changes could indicate that the foundations structures were being used for egg deposition (Degraer *et al*., 2020). The authors also noted that these effects were site-specific and therefore may not necessarily be extrapolated to other offshore wind farms, although this does indicate the presence of offshore wind farm infrastructure does not lead to adverse, population wide effects. Therefore, it is unlikely that offshore wind farms cause any drastic changes to fish assemblages in the area (Degraer *et al*., 2020). For further information on the impact of colonisation of hard substrates, see paragraphs 137 *et seq*.

117. As described in paragraphs 72 and 73, several commercially important shellfish species inhabit the fish and shellfish ecology study area, including edible crab, European lobster, *Nephrops*, king and queen scallop and velvet swimming crab. As most shellfish species tend to be less mobile than finfish, they are usually more vulnerable to habitat loss and disturbance, however evidence seems inconsistent (see paragraph 72 for detail). Construction has the potential to directly damage the habitats inhabited by these species, but the potential is known to exist for recovery and increased maturity of the overall population due to decreased fishing pressure following completion of construction, with no significant change in resilience (Raoux *et al*., 2019). Long term loss of habitat directly around the Array infrastructure represents only a very small proportion of habitat within the fish and shellfish ecology study area, and so is unlikely to cause impacts on the wider shellfish populations.

118. *Nephrops* spawning and nursery habitats overlap with the locations of construction operations (including cable installation) within the fish and shellfish ecology study area (Coull *et al*., 1998), (see volume 3, appendix 9.1). However, *Nephrops* have been identified as being unlikely to be present in the site boundary based on their habitat preference of mud, which is shown to be absent in site-specific surveys).

119. Long term habitat loss is predicted to affect a relatively small proportion of the habitats within the site boundary (i.e. up to 2.25% of habitats within the site boundary; refer to Table 9.13). Lobster spawning and nursery habitats also have the potential to occur within the fish and shellfish ecology study area, though the proportion of lobster spawning and overwintering habitats affected is likely to be small in the context of the available habitats in this part of the fish and shellfish ecology study area.

120. Most fish and shellfish ecology IEFs in the fish and shellfish ecology study area (refer to Table 9.12) are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore, considered to be low.

121. Sandeel are deemed to be of high vulnerability, high recoverability and of national importance. The sensitivity of these fish is therefore considered to be medium.

122. Herring are deemed to be of high vulnerability, medium recoverability and of regional importance. However, the sensitivity of herring to this impact is considered to be low, due to the limited suitable spawning sediments overlapping with the site boundary and the core herring spawning ground being located outside the site boundary, though within the fish and shellfish ecology study area (see Figure 9.2 and Figure 9.3).

Diadromous species

123. Diadromous fish species are generally considered to be less sensitive to habitat loss than other fish species, as they are highly mobile and generally able to avoid areas subject to long term habitat loss and disturbance. Diadromous species that are likely to interact with the fish and shellfish ecology study area will do so during migrations between the North Sea and the rivers designated for diadromous fish species on the east coast of Scotland (see Table 9.11 and volume 3, appendix 9.1). As listed in Table 9.12, the diadromous species likely to migrate through the site boundary includes Atlantic salmon, sea trout and European eel. The habitats within the fish and shellfish ecology study area are not expected to be particularly important for these species and therefore long term habitat loss and disturbance during the construction and operation and maintenance phase of the Array is unlikely to cause any direct impact to the scoped in diadromous fish species (refer to Table 9.12) and would not affect migration to and from rivers.

124. As with marine fish and shellfish IEFs (see paragraph 112), indirect impacts on diadromous fish species may occur due to impacts on prey species such as to sandeel for sea trout. As outlined previously for marine species, most large fish species would be able to avoid habitat loss effects due to their greater mobility but would recover into the areas affected following cessation of construction. Sandeel are more vulnerable to the effects of habitat loss and disturbance. However, they are expected to recover quickly as the sediments recover following installation of array infrastructure and adults recolonise and also via larval recolonisation of the sandy sediments. Therefore, the indirect impacts are not expected to impact diadromous species. The impacts associated with the creation of new hard structures are presented and discussed in later assessments of colonisation of hard structures (see paragraph 137 *et seq.*).

125. Diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be low.

<u>Significance of the effect</u>

Marine fish and shellfish species

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

127. For sandeel, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

129. No secondary fish and shellfish ecology mitigation (beyond the designed in measures outlined in section 9.10) is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

130. Infrastructure left *in situ* during the decommissioning of the Array (all scour protection and cable protection) will cause permanent subtidal habitat loss. A total footprint of up to 6,786,162 m^2 may be left *in situ* post-decommissioning, due to inter-array cable protection and crossing protection, along with interconnector cable protection, cable crossing protection, and scour protection for moorings and anchors, inter-array junction boxes and OSP jackets. Associated figures are given in Table 9.13. This represents 0.79% of the site boundary.

131. The impact is predicted to be of local spatial extent, long term duration, continuous and low reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

132. The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the construction phase assessment (see paragraphs 112 to 125) ranging from low (for all marine and diadromous fish and shellfish IEFs, except sandeel) to medium (for sandeel) sensitivity.

Significance of the effect

Marine fish and shellfish species

133. Overall, the magnitude of the impact for marine fish and shellfish, except for sandeel, is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

134. For sandeel, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

136. No secondary fish and shellfish ecology mitigation (beyond the designed in measures outlined in section 9.10) is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

COLONISATION OF HARD STRUCTURES

137. Colonisation of hard structures (such as the foundations) may serve as artificial reefs, as these add hard structures to areas typically characterised by soft, sedimentary environments, essentially replicating naturally occurring rocky habitats (Karlsson *et al*., 2022). Anthropogenic structures on the seabed attract many marine organisms including benthic species normally associated with hard structures (such as the blue mussel (Karlsson *et al.,* 2022) and therefore, may have indirect impacts on fish and shellfish populations through their potential to act as artificial reefs and to bring about changes to food resources (Inger *et al.,* 2009). Karlsson *et al.* (2022) observed that at the offshore floating Hywind Scotland site, plumose anemones *Metridium senile* and fan worms *Spirobranchus sp*. dominated the bottom and mid-section of floating turbines, whilst kept *Laminaria sp*., other brown seaweeds, and blue mussels dominated the upper 20m to 0 m mean sea level of wind turbines). Additionally, man-made structures may also have direct impacts on fish through their potential to act as fish aggregation devices (Petersen and Malm, 2006). Volume 2, chapter 8 examines this impact from the perspective of benthic subtidal habitats (for example, blue mussels as a habitat type), whereas this assessment looks at the subsequent consequences for fish and shellfish populations.

Operation and maintenance phase

Magnitude of impact

138. Up to 19,270,958 m^2 of hard substrate will be installed in the construction phase, though colonisation will not occur until the operation and maintenance phase (Table 9.13). As with 'Long term habitat loss and disturbance', this represents up to 2.25% of the total site boundary. Colonisation may also occur on floating structures in the water column. Floating objects in the water column may also be beneficial to some pelagic fish which might display aggregating behaviour for shelter from predators, prey opportunities (particularly if floating objects or objects in the water column become colonised with sessile species), and for schooling companions (Deudero et al., 1999). The impact is predicted to be of local spatial extent, long term duration, continuous and low reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

Marine fish and shellfish species

139. The introduction of hard structures such as foundations will likely lead to the colonisation of this substrate by fish and shellfish species, with cod, eel, horse mackerel and a range of crustacean species known to be affected by this impact. Primary colonisation may occur within hours or days by demersal and semi-pelagic species (Andersson, 2011). Colonisation has been seen to occur for a number of years following the initial construction, until a structured recolonised population is formed (Krone *et al*., 2013). The colonisation of these structures hence may attract fish from the surrounding areas to occupy the habitat with increased complexity, which will then increase the carrying capacity of the area (Andersson and Öhman, 2010; Bohnsack, 1989).

140. The extent and nature of the colonisation of the hard structures by new species will be determined by the dominant natural substrate character of the fish and shellfish ecology study area (largely muddy sand, sand and slightly gravelly sand). For example, Andersson and Öhman (2010) found that when hard structures are placed on an area of seabed already characterised by rocky substrates, few species will

be added to the area but an increase in total hard structures in the environment could sustain a higher abundance of species. However, when hard structures are introduced onto a soft seabed, most of the colonising fish will be those which are associated with rocky habitats (Andersson *et al.,* 2010). These species will replace the original soft-bottom population and form a new baseline species assemblage (Desprez, 2000). However, it was noted by Desprez (2000) that these effects were site-specific and therefore may not necessarily be extrapolated to other offshore wind farms.

141. The longest monitoring programme conducted to date is at the Lilgrund Offshore Wind Farm in the Öresund Strait in southern Sweden, which showed no overall increase in fish numbers from the introduction of hard infrastructure. The redistribution towards the foundations within the area was noted for some species (including cod, eel and eelpout *Zorces viviparus*) and more species were recorded after construction than before, consistent with the hypothesis that localised increases in biodiversity may occur following the introduction of hard infrastructure. Overall, results from earlier studies reported in the scientific literature did not provide robust data (e.g. some were visual observations with no quantitative data) that could be generalised to the effects of the addition of hard infrastructure on fish abundance in offshore wind farm areas (Wilhelmsson *et al*., 2010). More recent papers are, however, beginning to assess population changes and observations of recolonisation in a more quantitative manner (Bouma and Lengkeek, 2012; Krone *et al*., 2013), with hard structures consistently increasing species richness in the long term, but changing species composition towards a shellfish-dominated hard structures community, thus having an impact of local ecological function (Coolen, *et al.,* 2020).

142. It is uncertain whether artificial reefs facilitate recruitment into the local population, or if these observations are simply a result of concentrating biomass from surrounding areas (Inger *et al*., 2009). Evidence demonstrates that the abundance of fish can be greater in the vicinity of foundations than in the surrounding area, which supports the conclusion by Linley *et al.* (2007) that finfish species were likely to have a neutral to beneficial likelihood of benefitting from introduction of these structures. Increases in species richness were also noted by Coolen *et al.* (2020), following the introduction of hard structures. Some studies have also shown evidence of increased abundances of small demersal fish species in the vicinity of wind turbine structures, most likely due to the increase in abundance of epifaunal communities which increase the structural complexity of the habitat (e.g. mussel and barnacles *Cirripedia* spp.) (Wilhelmsson *et al*., 2006a; 2006b). Some commercially important species including cod and other pelagic species have been recorded aggregating around vertical steel constructions in the North Sea (Andersson, 2011; Wilhelmsson *et al*., 2006a). Monitoring of fish populations in the vicinity of an offshore wind farm off the coast of the Netherlands indicated that the offshore wind farms acted as a refuge for at least part of the cod population (Lindeboom *et al*., 2011; Winter *et al*., 2010). Similarly, horse mackerel, mackerel, herring, and sprat have been found to utilise the new hard structures for spawning, or predation on the newly developed community (Glarou *et al*., 2020).

143. Contrastingly, post construction fisheries surveys conducted in line with the Food and Environmental Protection Act licence (under the Food and Environment Protection Act 1985) requirements for the Barrow and North Hoyle offshore wind farms, found no evidence of fish abundance across these sites being affected, either beneficially or adversely, by the presence of the offshore wind farms (Cefas, 2009; BOWind, 2008). These suggested that any effects, if seen, are likely to be highly localised, site dependent and while of uncertain duration, the evidence suggests effects are not necessarily adverse, although uncertainty does exist surrounding this issue.

144. The greatest potential benefit from the introduction of hard structures is likely to exist for crustacean species, such as crab and lobster, due to expansion of their natural habitats and the creation of additional heterogenous hard structure refuge areas (Linley *et al*., 2007). Where foundations are placed within areas of sandy and coarse gravelly sediments, this will represent novel habitat and new potential sources of food in these areas and could potentially extend the habitat range of shellfish species such as edible crab, which strongly associate with wind farm foundations (Hooper and Austen, 2014). There is evidence from post-construction monitoring surveys at the Horns Rev offshore wind farm in the North Sea that hard structures are particularly successful for hatchery and nursery grounds for the edible crab, as well as several other species. They concluded that crustacean larvae and juveniles rapidly colonise the hard structures from the breeding areas (BioConsult, 2006). A variety of shellfish IEFs have been identified as being likely to be present within the site boundary (refer to Table 9.12).

145. Other shellfish species, such as the blue mussel, have the potential for great expansion of their normal habitat due to increased hard structures in areas of sandy habitat, such as those in the fish and shellfish ecology study area. Krone *et al.* (2013) found that over a three-year period, almost the entire vertical surface of area of the platform piles had been colonised by three key species blue mussel, the amphipod *Jassa* spp. and anthozoans (mainly *Metridium senile*). These three species were observed to occur in depth-dependant bands, attracting pelagic fish species such as horse mackerel *Trachurus trachurus* and demersal pouting *Trisopterus luscus* in great numbers. Layers of shell detritus were visible at the base of the foundations due to the mussel populations above and both velvet swimming crab and brown crabs were recorded here. These species were not typical of baseline species assemblage, providing further evidence of localised changes in fish and shellfish assemblages in the vicinity of foundation structures.

146. The colonisation of new habitats may potentially lead to the introduction of INNS (see volume 2, chapter 8 for detailed discussion). With respect to fish and shellfish populations, this may have indirect adverse impacts on shellfish populations as a result of competition. However, no INNS were identified in the fish and shellfish ecology study area during the site-specific benthic subtidal ecology surveys. There is also little evidence of adverse effects on fish and shellfish IEFs resulting from colonisation of other offshore wind farms by INNS. The post-construction monitoring report for the Barrow Offshore Wind Farm demonstrated no evidence of INNS on or around the monopiles (EMU, 2008a), and a similar study of the Kentish Flats monopiles only identified slipper limpet *Crepidula fornicata* (EMU, 2008b). A study into the spread of INNS by wind farm hard structure colonisation suggested the risk of this occurring was minor, and requires more research to fully understand, with implementation of precautionary built-in measures recommended to prevent spread where possible (Baulaz, *et al.,* 2023). Potential adverse impacts of the introduction of INNS are discussed further in detail in volume 2, chapter 8.

147. Marine fish and shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, and local to national importance (recoverability is not relevant to this impact during the operation maintenance phase). The sensitivity of the receptor is therefore, considered to be low.

Diadromous species

148. Diadromous species that are likely to interact with the fish and shellfish ecology study area are only likely to do so by passing through the area during migrations to and from rivers located on the east coast of Scotland, such as to rivers with designated sites, with diadromous fish species listed as qualifying features, as presented in Table 9.11. In most cases, it is expected that diadromous fish are unlikely to utilise the increase in hard structures within the fish and shellfish ecology study area for feeding or shelter opportunities as they pass through the Array.

149. There is the potential for impacts upon diadromous fish species resulting from increased predation by marine mammal species within offshore wind farms and both Atlantic salmon and sea trout have been identified as having the potential to migrate through the site boundary. Tagging of harbour seal *Phoca vitulina* and grey seal *Halichoerus grypus* around Dutch and UK wind farms provided significant evidence that the seal species were utilising wind farm sites as foraging habitats (Russel *et al.,* 2014), specifically targeting introduced structures such as foundations. However, a further study using similar methods concluded that there was no change in seal behaviour within the offshore wind farm (McConnell *et al*., 2012), so it is not certain exactly to what extent seals utilise offshore wind developments and effects may be site-specific. It is possible that if seals do utilise offshore wind developments as foraging areas, diadromous fish species may be impacted by the increased predation in an area where predation was lower prior to development. It is, however, unlikely that this would result in significant predation on diadromous species. Research has shown that Atlantic salmon smolts spend little time in the coastal waters, and actively swim in away from natal rivers making their way to feeding grounds in the north soon after maturation (Gardiner *et al.,* 2018a; Gardiner *et al*., 2018b; Newton *et al.,* 2017; Newton *et al*., 2019; Newton *et al.,* 2021) (see volume 3, appendix 9.1 for further detail on Atlantic salmon migration). Due to the evidence that Atlantic salmon tend not to forage in the coastal waters of Scotland, they are

therefore at low risk of impact from increased predation from seals and other predators in the fish and shellfish ecology study area as their presence in the region will be transitory.

150. Sea trout may be at higher risk of increased predation from seals than Atlantic salmon due to their higher usage of coastal environments. Given that sea trout are typically more coastal than Atlantic salmon, greater abundance would be expected further inshore than compared with the offshore waters of the site boundary (approximately 80 km offshore). Sea trout are generalist, opportunistic feeders with their diet comprising mainly of fish, crustaceans, polychaetes and surface insects with proportion of each of these prey categories varying dependent on season (Rikardsen *et al*., 2006; Knutsen *et al*., 2001). Due to the potential for increase in juvenile crustacean species and other shellfish species, which are possible prey items from sea trout, it is possible that foraging sea trout may be attracted to the hard structures introduced by installation of the Array. This attraction could in turn lead to increased predation of seal species upon sea trout species. However, there is little evidence at present documenting an increased abundance of sea trout around foundations (increases in fish abundance tend to be hard bottom dwelling fish species), therefore the effect of increased prey items attracting sea trout has not been recorded, to date. Given that it is unlikely that sea trout will spend time foraging around the foundations, there is a low risk of impact from increased predation from marine predators in the fish and shellfish ecology study area.

151. The low risk of impacts on diadromous fish species extends to the freshwater pearl mussel, which is included in the diadromous species section, as part of its life stage is reliant on diadromous fish species including Atlantic salmon and sea trout.

152. Most diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be low.

153. Atlantic salmon are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be low.

154. Sea trout are deemed to be of medium vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be low.

Significance of the effect

Marine fish and shellfish species

155. Some fish and shellfish species may benefit from the colonisation of hard structures, whereas others (more likely to be less mobile, demersal species associated with soft sediment habitats), may be adversely affected.

156. Overall, for the IEF species listed in Table 9.12, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. At worst, the effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms, though could be minor beneficial for some species. This is likely to be a conservative prediction as there is some evidence (although with uncertainties) that some fish and shellfish populations are likely to benefit from introduction of hard structures.

Diadromous species

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

Secondary mitigation and residual effect

158. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

UNDERWATER NOISE FROM PILING AND UXO CLEARANCE IMPACTING FISH AND SHELLFISH RECEPTORS

159. Underwater noise may arise due to UXO clearance and piling for the installation of the wind turbines and OSPs. This impact is relevant to the construction phase of the Array and may cause direct and indirect impacts to receptors.

160. The following scenarios were investigated through site specific underwater noise modelling:

- single piling – wind turbine anchor piles (3,000 kJ);
- single piling – OSP jacket foundation piles (4,400 kJ);
- two concurrent piling events – wind turbine anchor piles (3,000 kJ); and
- two concurrent piling events – wind turbine anchor pile (3,000 kJ) and OSP jacket pile (4,400 kJ).

161. Underwater noise modelling was undertaken related to the MDS as outlined in Table 9.13 with the detail of the assessment provided in volume 3, appendix 10.1.

Construction phase

Magnitude of impact

162. The installation of wind turbine anchors and OSP foundations may lead to injury and/or disturbance to fish and shellfish species due to underwater noise during piling within the fish and shellfish ecology study area. The MDS (Table 9.13), considers the greatest impact from underwater noise on fish and shellfish IEFs, based on the greatest hammer energy. This scenario is represented by the installation of up to 265 semi-submersible floating foundations, with up to six anchors per foundation and one 4.5 m diameter pile per anchor (1,590 piles) for wind turbines, and up to three large and 12 smaller jacket foundations (total 216 piles) for OSPs, with all piles installed via impact piling.

163. For wind turbines, piling was assumed to take place over a period of up to eight hours per pile with up to eight piles installed in each 24 hour period. OSP foundations will take place at an average of three piles over 24 hours (maximum duration of up to eight hours per pile) with up to eight piles installed in each 24 hour period. A maximum duration of 1,728 hours of piling activity, over a maximum of 72 months, may take place during the construction phase, based on the maximum duration of the piling phase.

164. Underwater noise modelling was undertaken for both single piling and concurrent piling (i.e. piling at more than one location simultaneously). To ensure a precautionary assessment, modelling of a concurrent piling scenario based on a 3,000 kJ hammer energy for the foundation piles and 4,400 kJ hammer energy for the OSP jacket piles has been undertaken, alongside single piling scenarios, using the maximum 4,400 kJ hammer energy for the OSP jacket piles. These are discussed further below in relation to injury impacts with relevant contours also presented and discussed in the context of potential behavioural impacts on fish and shellfish ecology receptors.

165. UXO clearance (including detonation) also has the capability to cause injury and/or disturbance to fish and shellfish IEFs. Clearance will be completed prior to the construction phase (pre-construction). The MDS (Table 9.13) assumes clearance of 15 UXOs within the site boundary, with a maximum of 698 kg NEQ. The UXO clearance campaign will involve subsonic combustion with a single donor charge of up to 0.025 kg NEQ for each clearance event, and up to 0.5 kg NEQ to neutralise residual explosive material at each location. Total duration of UXO clearance campaigns is eight days, with up to two detonations within 24 hours.

166. To understand the magnitude of noise emissions from piling and UXO clearance during construction activity, underwater noise modelling has been undertaken considering the key parameters summarised above. Further, implications of UXO on fish injury are discussed in paragraphs 173 to 183. Compared to piling, UXO detonations will be single, isolated events of very short duration; as such, potential behavioural effects upon fish and shellfish will be extremely short lived and reversible.

167. The impact is predicted to be of regional spatial extent, medium term duration, intermittent and high reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

168. The following sections apply to both marine fish and diadromous fish species.

169. Underwater noise can potentially have an adverse impact on fish species ranging from physical injury/mortality to behavioural effects, with focus given to the impacts on herring and cod, as well as a range of other species identified as IEFs. Peer reviewed guidelines have been published by the Acoustical Society of America (ASA) and provide directions and recommendations for setting criteria (including injury and behavioural criteria) for fish. These guidelines (Popper *et al*., 2014) provide the most relevant and best available guidelines for impacts of underwater noise on fish species (see volume 3, appendix 10.1).

170. The Popper *et al*. (2014) guidelines broadly group fish into the following categories according to the presence or absence of a swim bladder and on the potential for that swim bladder to improve the hearing sensitivity and range of hearing (Popper *et al*., 2014):

a) Group 1: Fishes lacking swim bladders (e.g. elasmobranchs and flatfish). These species are only sensitive to particle motion, not sound pressure and show sensitivity to only a narrow band of frequencies;

b) Group 2: Fishes with a swim bladder but the swim bladder does not play a role in hearing (e.g. salmonids and some Scombridae). These species are considered to be more sensitive to particle motion than sound pressure and show sensitivity to only a narrow band of frequencies;

c) Group 3: Fishes with swim bladders that are close, but not connected, to the ear (e.g. gadoids and eels). These fishes are sensitive to both particle motion and sound pressure and show a more extended frequency range than Groups 1 and 2, extending to about 500 Hz; and

d) Group 4: Fishes that have special structures mechanically linking the swim bladder to the ear (e.g. clupeids such as herring, sprat and shads). These fishes are sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3.

171. Relatively few studies have been conducted on impacts of underwater noise on invertebrates, including crustacean species, and little is known about the effects of anthropogenic underwater noise upon them (Hawkins and Popper, 2016; Morley *et al.*, 2013; Williams *et al*., 2015). There are therefore no injury criteria that have been developed for shellfish, however, these are expected to be less sensitive than fish species and therefore injury ranges of fish could be considered conservative estimates for shellfish species (risk of behavioural effects are discussed further below for shellfish).

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

Injury

173. Table 9.19 summarises the fish injury criteria recommended for pile driving based on the Popper *et al*. (2014) guidelines, noting that dual criteria are adopted in these guidelines to account for the uncertainties associated with effects of underwater noise on fish.

Table 9.19: Criteria for Onset Injury to Fish Due to Impulsive Piling (Popper *et al*., 2014)[a]

Group	Type of Animal	Parameter	Mortality and Potential Mortal Injury	Recoverable Injury	Temporary Threshold Shift (TTS)
1	Fish: no swim bladder (particle motion detection)	Sound exposure level (SEL), dB re 1 μPa²s	>219	>216	>186
		Peak, dB re 1 μPa	>213	>213	-
2	Fish: where swim bladder is not involved in hearing (particle motion detection)	SEL, dB re 1 μPa²s	210	203	>186
		Peak, dB re 1 μPa	>207	>207	-
3 and 4	Fish: where swim bladder is involved in hearing (primarily pressure detection)	SEL, dB re 1 μPa²s	207	203	186
		Peak, dB re 1 μPa	>207	>207	-
N/A	Eggs and larvae	SEL, dB re 1 μPa²s	>210	(*N*) Moderate (*Intermediate*) Low (*F*) Low	(*N*) Moderate[a] (*Intermediate*) Low (*F*) Low
		Peak, dB re 1 μPa	>207		

[a] Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near field (N; i.e. 10s of metres), intermediate (I; i.e. 100s of metres), and far field (F; i.e. 1000s of metres); Popper *et al*. (2014).

174. The full results of the underwater noise modelling are presented in volume 3, appendix 10.1. To inform the assessment for fish and shellfish ecology receptors, predicted injury ranges associated with the installation of one 4.5 m diameter pile have been presented. The metrics presented are for cumulative sound exposure level (SEL_{cum}) for moving fish and static fish (Table 9.20), and SPL_{pk} (Table 9.21). This modelled scenario resulted in the greatest predicted injury ranges and therefore forms the focus of the assessment for injury, noting that in most cases, the maximum hammer energy would not be reached during piling.

175. For the cumulative SEL metric, the injury ranges presented indicate that injury may occur out to ranges of tens to a few hundred metres, based on the MDS (e.g. mortality ranges for the 3,000 kJ hammer energy of 15 m to 50 m for fleeing receptors and 328 m to 1,460 m for static receptors; see Table 9.20). Practically, the risk of fish injury will be considerably lower due to the hammer energies being lower than the absolute maximum modelled, through soft starts. The expected fleeing behaviour of fish from the area affected when exposed to high levels of noise and the soft start procedure, which will be employed for all piling mean that it is likely that those fish species which flee from a noise source will have ample time to vacate the areas where injury may occur prior to noise levels reaching that level.

176. For peak pressure noise levels when piling energy is at its maximum for the foundation pile installation (Table 9.21) mortality and recoverable injury to fish may occur within approximately 266 m to 414 m of the piling activity (lower estimate for Group 1 fish species, higher estimate for Groups 2, 3 and 4 species). The potential for mortality or mortal injury to fish eggs would also occur at distances of up to 414 m (Table 9.21). When piling for OSP foundations (i.e. maximum hammer energy of 4,400 kJ; Table 9.22), greater injury ranges are predicted (e.g. mortality ranges of 25 m to 425 m for fleeing receptors and 855 m to 3,380 m for static receptors based on the cumulative SEL metric; Table 9.22). Underwater noise modelling using the peak SPL metric showed a similar pattern with mortality and recoverable injury to ranges of up to 615 m to 1,055 m for the maximum hammer energy of 4,400 kJ. For eggs and larvae, the mortality range is also 1,055 m for the 4,400 kJ hammer energy (Table 9.23).

177. Based on the two noise criteria (SEL and SPL), injury will occur in the range of tens to hundreds of metres (Table 9.20 to Table 9.23), with the injury ranges larger for the greater hammer energy of 4,000 kJ for OSP jacket pile installations. However, these are maximum energy scenarios, which, in most cases, will not be reached. Additionally, injury ranges at the start of each piling sequence will be much smaller than the maximum scenario due to soft starts; at 660 kJ for OSP foundations and 450 kJ for foundation piles.

Table 9.20: Potential Injury and Disturbance Ranges for Single Wind Turbine Foundation Pile Installation at 3,000 kJ Based on the Cumulative SEL Metric for Fleeing and Static Fish

Hearing Group	Response	Threshold, SEL (dB re 1 μPa²s)	Range (m) Fleeing Fish	Range (m) Static Fish
Group 1 Fish: No swim bladder (particle motion detection)	Mortality	219	15	328
	Recoverable injury	216	20	472
	TTS	186	8,380	13,200
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	210	32	1,015
	Recoverable injury	203	110	2,300
	TTS	186	8,380	13,200
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	50	1,460
	Recoverable injury	203	110	2,300
	TTS	186	8,380	13,200
Fish eggs and larvae (static)	Mortality	210	1,015	1,015

Table 9.21: Potential Injury and Disturbance Ranges for Single Wind Turbine Foundation Pile Installation at 3,000 kJ Based on the Peak SPL Metric

Hearing Group	Response	Threshold, $L_{0\text{-}pk}$ (dB re 1 μPa)	Range (m)
Group 1 Fish: No swim bladder (particle motion detection)	Mortality	213	266
	Recoverable injury	213	266
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	207	414
	Recoverable injury	207	414
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	414
	Recoverable injury	207	414
Fish eggs and larvae	Mortality	207	414

Table 9.22: Potential Injury and Disturbance Ranges for Single OSP Jacket Pile Installation at 4,400 kJ Based on the Cumulative SEL Metric for Moving and Static Fish

Hearing Group	Response	Threshold, $L_{0\text{-}pk}$ (dB re 1 μPa)	Range (m) Fleeing Fish	Range (m) Static Fish
Group 1 Fish: No swim bladder (particle motion detection	Mortality	219	25	855
	Recoverable injury	216	37	1,220
	TTS	186	21,100	26,960
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	210	112	2,440
	Recoverable injury	203	1,440	5,120
	TTS	186	21,100	26,960
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	425	3,380
	Recoverable injury	203	1,440	5,120
	TTS	186	21,100	26,960
Fish eggs and larvae (static)	Mortality	210	2,440	2,440

Table 9.23: Potential Injury Ranges for Single OSP Jacket Pile Installation at 4,400 kJ Based on the Peak SPL Metric

Hearing Group	Response	Threshold, $L_{0\text{-}pk}$ (dB re 1 μPa)	Range (m)
Group 1 Fish: No swim bladder (particle motion detection)	Mortality	213	615
	Recoverable injury	213	615
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	207	1,055
	Recoverable injury	207	1,055
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	1,055
	Recoverable injury	207	1,055
Fish eggs and larvae	Mortality	207	1,055

178. Construction may occur utilising two pile installation vessels operating concurrently. The potential cumulative SEL injury ranges for fish due to impact pile driving of piles are modelled as following the same piling plans with all phases starting at the same time. For injury, the MDS is that of two adjacent piles, separated by a distance of 950 m due to the maximal overlap of noise propagation contours leading to the maximum generated noise levels. Conversely, for disturbance the maximum separation between two piling locations would lead to the larger area ensonified at any one time and therefore the greatest disturbance (discussed further below).

179. Injury ranges for concurrent piling of OSP jacket pile installation at 4,400 kJ and foundation piles at 3,000 kJ at each site are given in Table 9.24. The peak metric will remain the same as the single installation case. For all other piling scenarios, injury ranges would be smaller; the full range of modelled scenarios are given in volume 3, appendix 10.1. As expected, these show that for this precautionary cumulative piling scenario, injury ranges are similar or slightly larger than the single piling scenarios for fleeing fish, but considerably larger (e.g. double the ranges) for static fish receptors.

Table 9.24: Potential Injury and Disturbance Ranges for Concurrent OSP Jacket Pile Installation at 4,400 kJ and Wind Turbine Foundation Pile at 3,000 kJ Based on the Cumulative SEL Metric for Fleeing and Static Fish

Hearing Group	Response	Threshold, SEL (dB re 1 µPa^{2}s)	Range (m) Fleeing Fish	Range (m) Static Fish
Group 1 Fish: No swim bladder (particle motion detection)	Mortality	219	26	1,680
	Recoverable injury	216	40	2,360
	TTS	186	31,200	45,100
Group 2 Fish: Swim bladder not involved in hearing (particle motion detection)	Mortality	210	143	4,460
	Recoverable injury	203	1,920	9,060
	TTS	186	31,200	45,100
Group 3 and 4 Fish: Swim bladder involved in hearing (primarily pressure detection)	Mortality	207	605	6,120
	Recoverable injury	203	1,920	9,060
	TTS	186	3,120	45,100
Fish eggs and larvae	Mortality	210	4,460	4,460

180. Underwater noise modelling has also been undertaken for UXO clearance/detonation. The criteria used in this underwater noise assessment for explosives are given in Table 9.25 following Popper *et al.* (2014). There are no thresholds in Popper *et al.* (2014) in relation to eggs and larvae in terms of sound pressure.

Table 9.25: Criteria For Injury To Fish Due To Explosives (Popper *et al*., 2014)[b]

Group	Type of Animal	Parameter	Mortality and Potential Mortal Injury	Recoverable Injury	TTS
1	Fish: no swim bladder (particle motion detection)	Peak, dB re 1µPa	229 – 234	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low
2	Fish: where swim bladder is not involved in hearing (particle motion detection)	Peak, dB re 1µPa	229 – 234	(N) High (I) High (F) Low	(N) High (I) Moderate (F) Low
3 and 4	Fish: where swim bladder is involved in hearing (primarily pressure detection)	Peak, dB re 1µPa	229 – 234	(N) High (I) High (F) Low	(N) High (I) High (F) Low

[b] Note: Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near field (N; i.e. 10s of metres), intermediate (I; i.e. 100s of metres), and far field (F; i.e. 1000s of metres); Popper *et al.* (2014).

181. Underwater noise modelling was undertaken for a range of orders of detonation, from a realistic maximum design case high order detonation to low order detonations (e.g. deflagration and clearance shots) to be used as mitigation to reduce noise levels. Table 9.26 details the injury ranges for fish of all groups in relation to various orders of detonation. The method of low order has been committed to (Table 9.13) and as such will be the dominant method of UXO clearance, although higher order detonations may also occur if low order is not successful or unintentionally as part of the low order process.

182. The predicted injury ranges for low and high order disposal order detonations of UXOs are presented in Table 9.26 and demonstrate the effectiveness of the low order methods to reduce the risk of injury to fish and shellfish ecology receptors (i.e. injury ranges of tens of metres for low order, but up to 930 m for high order detonations).

183. Due to a combination of dispersion (i.e. where the waveform elongates), multiple reflections from the sea surface, and seabed and molecular absorption of high frequency energy, the noise is unlikely to still be impulsive once it has propagated more than a few kilometres. Consequently, caution should be used when interpreting any results with predicted injury ranges in the order of tens of kilometres. Furthermore, the modelling assumes that the UXO acts like a charge suspended in open water whereas it is likely to be partially buried in the sediment. In addition, it is possible that the explosive material will have deteriorated over time meaning that the predicted noise levels are likely to be over-estimated. In combination, these factors mean that the results should be treated as precautionary potential impact ranges which are likely to be substantially lower than predicted.

Table 9.26: Potential Impact Ranges for Low Order, Low Yield, and High Order UXO Clearance Activities, Based on Injury Criteria in Table 9.25

UXO Type	PTS Range (lower range)	PTS Range (upper range)
0.25 Low order Donor charge	40	67
0.5 kg Clearing Shot	51	85
227 kg UXO – High Order Explosion	640	384
698 kg UXO – High Order Explosion	930	558

Shellfish

184. Of the key shellfish species of the fish and shellfish ecology study area, crustaceans such as European lobster and crab tend to be physiologically resilient to noise due to the lack of gas within their bodies (Popper *et al*., 2001). To date, no lethal effects of underwater noise have been described for edible crab, European lobster or *Nephrops*. A report by Christian *et al*. (2003) found no significant difference between acute effects of seismic airgun exposure (a similar impulsive high amplitude noise source to piling; >189 dB re 1 µPa (peak–peak) @ 1 m) upon adult snow crabs *Chionoecetes opilio* in comparison with control crabs, and Parry and Gason (2006) investigated whether there was a link between seismic surveys and changes in commercial rock lobster *Panulirus cygnus* based on rates associated with acute to mid-term mortality over a 26-year period. No statistically significant correlation was found (Parry and Gason, 2006).

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

186. There is no evidence to suggest shellfish eggs and larvae are at risk of direct harm from underwater noise such as piling (Edmonds *et al*., 2016). Rather, of the few studies that have focussed on the eggs and larvae of shellfish species, evidence of impaired embryonic development and mortality has been found to arise from playback of seismic survey noise among gastropods and bivalves (De Soto *et al*., 2013, Nedelec *et al*., 2014). Limited information exists on the impact of impulsive sound upon crustacean eggs, and no research has been conducted on commercially exploited decapods around the UK. Of the evidence that is available all studies focus on the impact of seismic noise, which delays hatching of snow crab eggs, causing resultant larvae to be smaller than controls (DFO, 2004). Pearson *et al*. (1994) found no statistically significant difference between the mortality and development rates of stage II (their free-swimming, planktonic larval stage) Dungeness crab *Metacarcinus magister* larvae exposed to single field-based discharges (231 dB re 1 µPa (zero-peak) @ 1 m) from a seismic airgun.

187. Roach *et al.* (2018) examined the effects on catch rates of European lobster of a temporary closure of lobster fishing grounds during offshore wind farm construction (including piling). Monitoring data at the Westermost Rough Offshore Wind Farm (north-east coast of England) found that the size and abundance of European lobster increased following temporary closure of the area during its construction. While not looking specifically at the effects of underwater noise on shellfish species, this study implies that the activities associated with construction of the wind farm (which included piling of foundations for 80 wind turbines) did not impact on the resident European lobster populations and instead allowed some respite from fishing activities for a short period time before reopening following construction (Roach *et al*., 2018). The results therefore suggest that population level injury impacts on shellfish species are unlikely to occur due to piling operations.

Behaviour

188. Behavioural reaction of fish to underwater noise has been found to vary between species based on their hearing sensitivity. Typically, fish sense noise via particle motion in the inner ear which is detected from noise-induced motions in the fish's body. The detection of sound pressure is restricted to those fish which have air filled swim bladders; however, particle motion (induced by noise) can be detected by fish without swim bladders. Further, the presence of a swim bladder does not necessarily mean that the fish can detect pressure. Some fish have swim bladders that are not involved in the hearing mechanism and can only detect particle motion.

189. Popper *et al*. (2014) provides qualitative behavioural criteria for fish from a range of noise sources. These categorise the risks of effects as "high", "moderate" or "low" at three distances from the source: "near" (i.e. tens of metres), "intermediate" (i.e. hundreds of metres) or "far" (i.e. thousands of metres). The behavioural criteria for piling operations are summarised in Table 9.27 for the four fish groupings.

Table 9.27: Potential Risk for the Onset of Behavioural Effects in Fish from Piling (Popper *et al*., 2014)[c]

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

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

190. Highly sensitive hearing specialist species such as herring have an otic bulla; a gas filled sphere, connected to the swim bladder, which enhances hearing ability. The gas filled swim bladder in species groups such as cod and salmon may be involved in their hearing capabilities, so although there is no direct link to the inner ear, these species are able to detect lower noise frequencies and as such are considered to be of medium sensitivity to noise. Flat fish and elasmobranchs have no swim bladders and as such are considered to be relatively less sensitive to sound pressure.

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

192. Further, a study by Pearson *et al*. (1992) examined the effects of geophysical survey noise on caged rockfish *Sebastes* spp. and observed a startle or "C-turn response" at peak pressure levels beginning around 200 dB re 1 µPa. This response was less common with the larger fish. Studies by McCauley *et al*. (2000) exposed various fish species in large cages to seismic airgun noise and assessed behaviour, physiological and pathological changes. The study observed that:

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

193. Post construction monitoring at the Beatrice Offshore Wind Farm (BOWL, 2021) concluded that, for sandeel, there was no evidence of adverse impacts on sandeel populations between pre and post construction levels over a six year period. Similarly for cod, there was no change in the presence of spawning between pre and post construction (although spawning intensity was found to be low across both surveys). Based on these studies, it can therefore be assumed that noise impacts associated with installation of an offshore wind development are temporary and that fish communities (specifically cod and sandeel in this case) show a high degree of recoverability following construction.

194. Impacts of underwater noise on marine invertebrates is limited, and no attempt has been made to set exposure criteria (Hawkins *et al*., 2014). Aquatic decapod crustaceans are equipped with receptor types potentially capable of responding to the particle motion component of underwater noise (e.g. the vibration of the water molecules which results in the pressure wave) and ground borne vibration (Popper *et al*., 2001). It is generally their cilia that provide the sensitivity, although these animals also have other sensor systems which could be capable of detecting vibration. It has also been reported that sound wave signature of piling noise can travel considerable distances through sediments (Hawkins and Popper, 2016), with implications for demersal and sediment dwelling fish (e.g. sandeel) and shellfish (e.g. *Nephrops*) in close to piling operations.

195. At Westermost Rough Offshore Wind Farm, monitoring of European lobster revealed no population level effects on shellfish species. (Roach *et al*., 2018). While there may be some residual uncertainty regarding behavioural effects while piling operations are ongoing, the evidence suggests that long term effects will not occur, and any effects will be reversible.

196. Scott *et al*. (2020) provides a recent review of the existing published literature on the influence of anthropogenic noise and vibration and on crustaceans. The review concluded that some literature sources identified behavioural and physiology effects on crustaceans from anthropogenic noise, though several that showed no effect. Scott *et al*. (2020) notes that, to date, no effect or influence of noise or vibrations have been reported on mortality rates or fisheries catch rates or yields. Further, no studies have indicated a direct effect of anthropogenic noise on mortality, whether it be immediate or delayed (Scott *et al*., 2020).

Summary – marine fish and shellfish species

197. Behavioural effects are expected over much larger ranges than injury ranges. For example, Figure 9.7 shows the modelled underwater noise levels for SPL_{pk} based on the results from volume 3 appendix 10.1, relative to key fish spawning habitats in the vicinity of the fish and shellfish ecology study area. Figure 9.8 shows noise contours for the maximum (4,400 kJ) hammer energy in relation to cumulative herring spawning larval densities (i.e. the core herring spawning habitat in the fish and shellfish study area). The northern piling location was chosen as the point closest to the most sensitive habitats/areas.

198. Noting that there are no published or agreed thresholds for behavioural effects on fish from piling operations, the noise contours presented below suggest that behavioural responses will extend over ranges of 33 km to 49 km; for example, assuming avoidance occurs at levels in excess of 160 dB re 1 μPa SPL_{pk}, which is a lower threshold than the levels at which behavioural effects in fish were detected in a number of studies (including McCauley *et al*., 2000). These results broadly align with qualitative thresholds for behavioural effects on fish as set out in Table 9.27, with moderate risk of behavioural effects in the range of hundreds of metres to thousands of metres from the piling activity, depending on the species. As previously discussed, these behavioural response thresholds are likely to be highly precautionary for the less sensitive group 1 and group 2 fish species. For some of the more sensitive groups 3 and 4 fish species in the fish and shellfish study area (e.g. cod and herring), further detail is given below.

199. For cod (group 3 fish; Figure 9.7), low intensity spawning grounds are ubiquitious in the north sea and overlap with the site boundary. Based on modelling at the south location, underwater noise levels with the potential to cause behaviour effects (approximately 160 dB re 1 μPa SPL_{pk}) area predicted to coincide with a very small proportion of this spawning habitat, which is vast and surrounds the Array from inshore waters, out to the North Sea's offshore waters. The same is true for sandeel (group 2 fish), plaice (group 1 fish) and whiting (group 3 fish; Figure 9.7); whilst the Array exists over low intensity spawning grounds exists for these species, underwater noise levels from piling using a 4,400 kJ hammer energy is expected to travel across a very small proportion of their spawning habitats, which, like for cod, is vast around the Array.

200. Herring (group 4) spawning grounds exist to the north of the Array, with Figure 9.8 showing the core spawning habitats (as mapped using cumulative herring larval abundance data) and noise contours associated with piling at the closest possible location within the Array. Based on modelling at the north location, underwater noise levels with the potential to cause behavioural effects (i.e. approximately 160 dB re 1 μPa SPL_{pk}) is predicted to coincide with a small proportion of this spawning habitat. Further, the core, regular spawning ground for herring is well outside the 160 dB contour (Figure 9.8). It is acknowledged that spawning grounds are not fixed boundaries, and spawning does not occur at an equal density across the mapped grounds, with variation inside and outside mapped grounds annually and throughout the spawning season.

201. A concurrent piling scenario was also modelled in addition to the single piling scenarios; see volume 3, appendix 10.1 for full details. This is presented in Figure 9.9 and it should be noted the contours presented are for single strike cumulative SEL metric (as opposed to SPL_{pk} for the previous figures). Underwater noise modelling for concurrent piling assumed piling at the northern location concurrently with the central location, which is representative of the largest separation of the piling vessels, as detailed within volume 1, chapter 4, and a maximum separation of 30 km, to represent the scenario would result in disturbance over the greatest area. Although there is a possibility of a separation between vessels of up to 41 km, variation in seabed bathymetries and water depths make the separation modelled the scenario resulting in maximum disturbance. Figure 9.9 shows the noise contours associated with this concurrent piling scenario in the cumulative SEL_{SS} metric, alongside a single piling scenario in the same metric. These demonstrate that while the area of disturbance is expected to be greater, the range of effects from the site boundary is not greater than that of a single piling scenario and therefore cumulative piling would not result in a greater risk to the core herring spawning grounds within the fish and shellfish study area.

202. Most marine fish are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore, considered to be low.

203. Herring are deemed to be of medium vulnerability, high recoverability and regional importance. The sensitivity of the receptor is therefore, considered to be medium.

204. Shellfish are deemed to be of low vulnerability, high recoverability and regional importance. The sensitivity of the receptor is therefore, considered to be low.

Summary – diadromous species

205. As with marine fish, diadromous fish species close to piling operations may experience injury or mortality. However, diadromous fish species tend to be highly mobile and may only utilise the environment within the fish and shellfish ecology study area to pass through during migration. As such, piling is unlikely to result in significant mortality of diadromous species. The use of soft start piling procedures (see Table 9.18), may allow individuals in close proximity to piling to flee the ensonified area before the greatest hammer energies are reached, therefore reducing the likelihood of injury and mortality on diadromous species (depending on the species and their responses to elevated noise levels).

206. The studies discussed in paragraphs 188 to 196 are also relevant to diadromous fish species which, like marine species, may experience behavioural effects in response to piling noise, including a startle response, disruption of feeding, or avoidance of an area. As discussed in paragraph 198, behavioural effects (including avoidance) would be expected to occur at ranges of up to 33 km to 49 km, depending on the species and their relative sensitivities to underwater noise (i.e. in order of lowest to highest sensitivities: lamprey species, Atlantic salmon and sea trout, European eel and shad species). Harding *et al.* (2016) examined behavioural and physiological responses in Atlantic salmon when subjected to noise similar to piling. No responses were produced, though the noise levels tested were estimated at <160 dB re 1 µPa RMS, which is considerably below the level at which injury or behavioural disturbance would be expected for Atlantic salmon. Due to the distance between the Array and the coast, these behavioural impacts are unlikely to cause barrier effects between the fish and shellfish ecology study area and the migration routes of diadromous species along the east coast of Scotland, due to the relatively small area around piling events where noise levels are high enough to cause behavioural responses (as demonstrated in Figure 9.7 to Figure 9.9).

207. Diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore considered to be low.

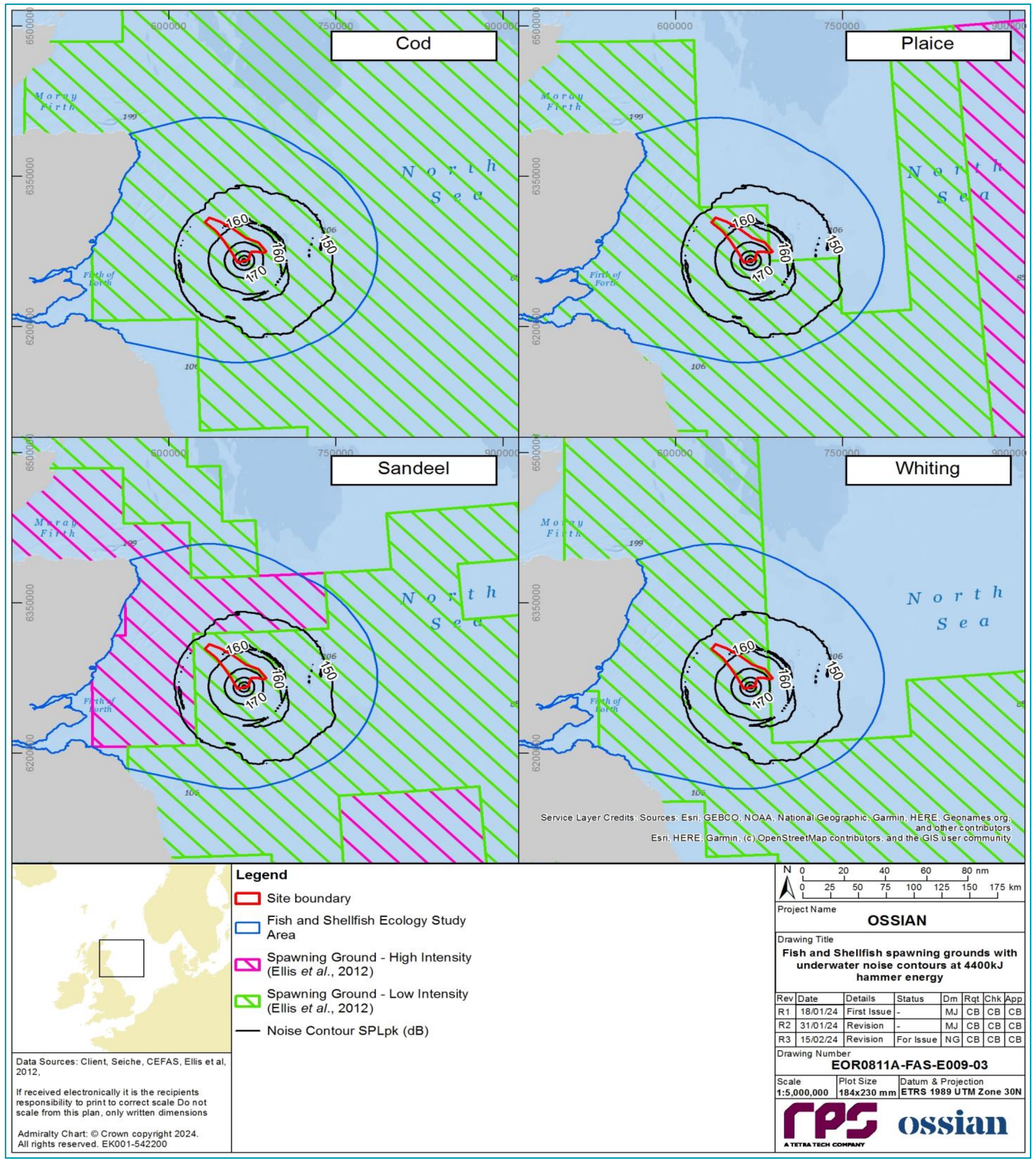

Figure 9.7: Cod, Plaice, Sandeel, and Whiting Spawning Grounds with Subsea 10 dB Sound SPL_{pk} Contours for Piling at 4,400 kJ Hammer Energy at the South Modelled Location

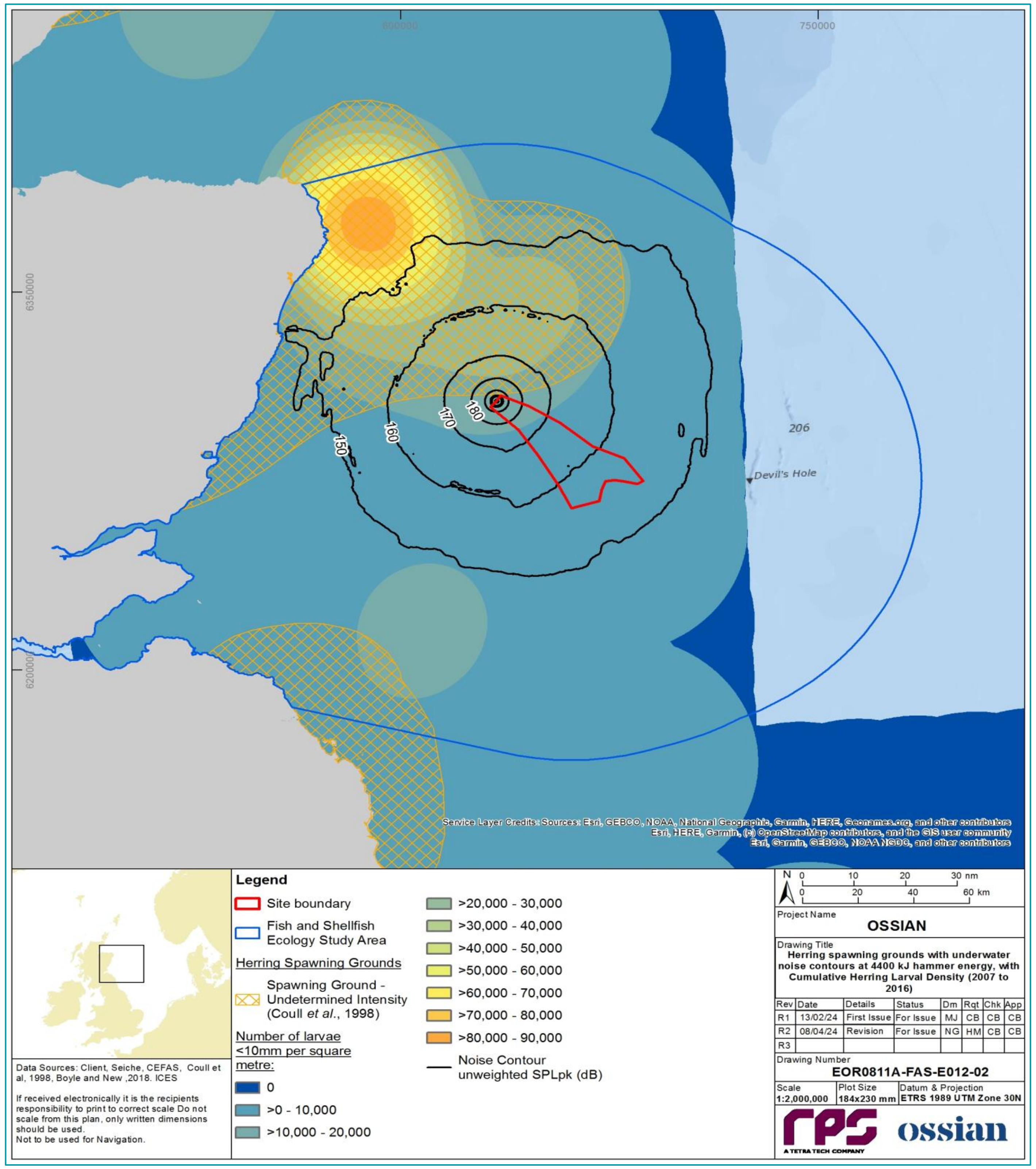

Figure 9.8: **Herring Larval Densities (combined 2007 to 2016 data) with Subsea 10 dB Sound SPL$_{pk}$ Contours for Piling at 4,400 kJ Hammer Energy at the North Modelled Location**

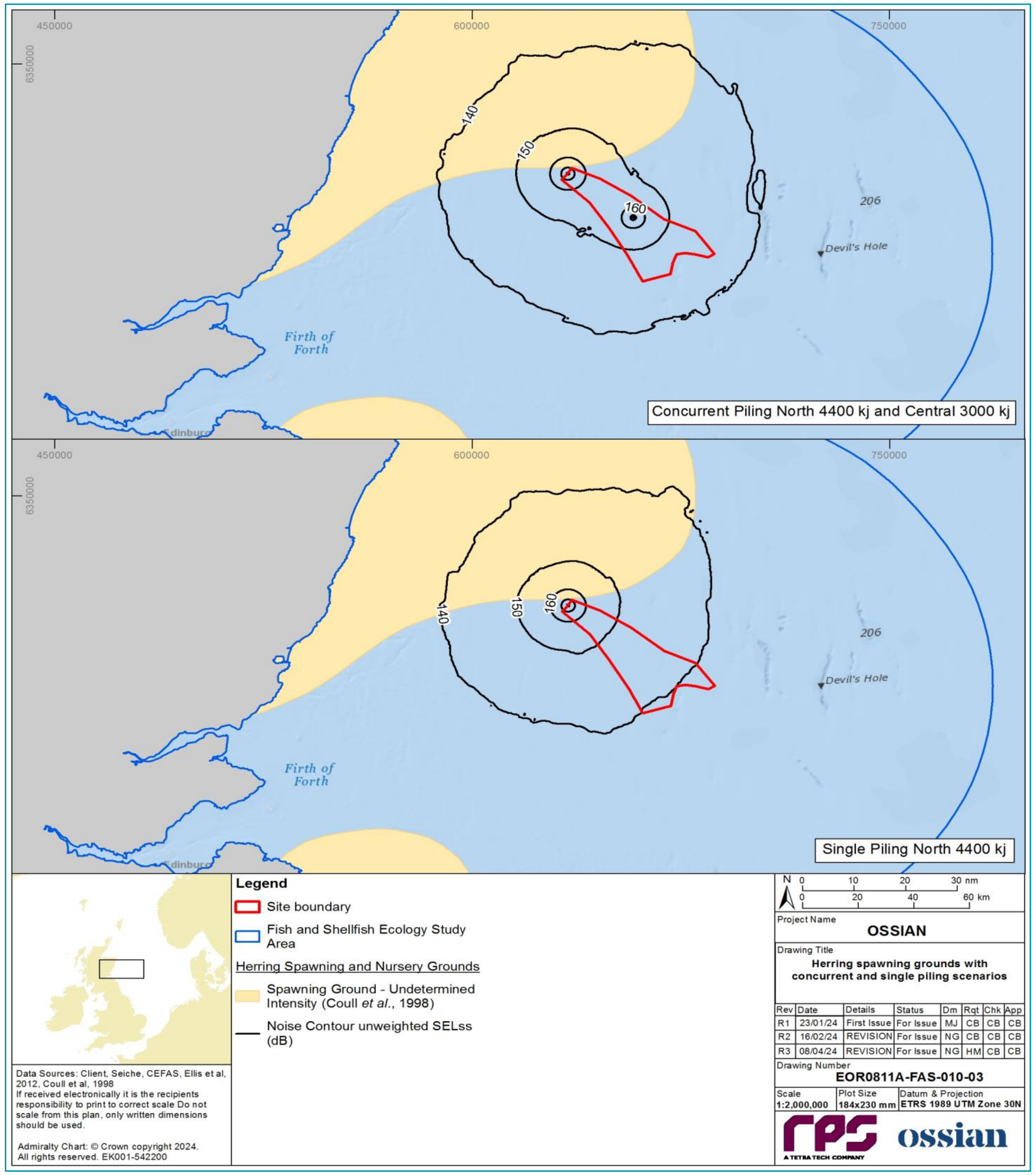

Figure 9.9: **Concurrent and Single Piling Scenarios Based Upon Using 3,000 kJ and 4,400 kJ Hammer Energies. Note, Contours are Shown in Cumulate SEL$_{SS}$ Metric for Illustrative Purposes Only**

Significance of the effect

208. Overall, the magnitude of the impact for most marine fish and shellfish is deemed to be low, and the sensitivity of most marine fish IEFs is considered low. The effect will, therefore, be of **minor** significance, which is not significant in EIA terms.

209. For herring, the magnitude of the impact is deemed to be low, and the sensitivity of herring is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms. This is due to the hearing sensitivity of herring, coupled with the presence of a small proportion of undetermined intensity spawning grounds within range of underwater sound levels which may give rise to behavioural effects.

210. For diadromous fish, the magnitude of the impact is deemed to be low, and the sensitivity of most marine fish IEFs is considered low. The effect will, therefore, be of **minor** significance, which is not significant in EIA terms.

Secondary mitigation and residual effect

211. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

UNDERWATER NOISE FROM THE OPERATION OF FLOATING WIND TURBINES AND ANCHOR MOORING LINES IMPACTING FISH AND SHELLFISH RECEPTORS

212. Underwater noise has the potential to arise from wind turbine operation and movement of anchor mooring lines. This impact is relevant to the operation and maintenance phase and has the potential to cause direct and indirect impacts to fish and shellfish receptors.

213. The assessment presented below is informed by volume 3, appendix 10.1, which presents evidence for the conclusions for the impact.

Operation and maintenance phase

Magnitude of impact

214. The presence of operational floating wind turbines may result in the generation of underwater noise, occurring at a very low frequency and low sound pressure level (Andersson *et al.,* 2011). As shown in Table 9.13, the MDS assumes the maximum scale of the Array (based upon the maximum number of turbines), which accounts for up to 265 semi-submersible floating wind turbine foundations with up to 224 m hub height, placed 25 m deep in the water column with up to 100 m excursion limit. The MDS also accounts for noise generated from up to 1,590 catenary mooring lines and movement of these during the operation and maintenance phase. This impact has the potential to affect fish and shellfish receptors for the 35 year operation and maintenance phase.

215. Studies have demonstrated that underwater noise from operational fixed wind turbines is only high enough to possibly cause a behavioural reaction in fish and shellfish species within metres from a wind turbine. In addition, noise generated by operational fixed wind turbines is of a low frequency and low sound pressure level (Andersson *et al.,* 2011). Therefore, noise levels from operational wind turbines at a level where there is a potential effect on fish and shellfish receptors are considered highly unlikely to occur (Sigray and Andersson, 2011). These observations from earlier fixed offshore wind farms (with smaller wind turbines) are supported by modelling of the noise emissions from larger fixed offshore wind turbines, which demonstrate that the risk of injury or behavioural effects on fish and shellfish populations is negligible (SSER, 2022a).

216. Putland (2022) presented a study into operational noise of floating offshore wind turbines; their findings indicate that operational noise is comparable to that of fixed bottom wind turbines, generating low level noise which is unlikely to cause significance disturbance effects to fish. Risch *et al.,* (2023) have also reported consistent results. In this study, acoustic data was collected from two floating offshore wind farms, currently deployed off the Scottish east coast: Kincardine and Hywind Scotland. At Kincardine five wind turbines rated at 9.5 MW were deployed on semi-submersible foundations, while at Hywind Scotland five 6 MW rated wind turbines were deployed on spar-buoys. As described in volume 3 appendix 10.1, it was found that the predicted noise fields for unweighted sound pressure levels were above the median ambient noise levels in the North Sea for a maximum of 3.5 km to 4.0 km from the centre of the Kincardine site and 3.0 km to 3.7 km from the centre of Hywind Scotland (Risch *et al.,* 2023). As noted above, while fish and shellfish receptors may be able to perceive noise, the noise levels are too low to result in injury or behavioural effects. The study also concluded that noise emissions from floating offshore wind turbines were predicted to be similar to the operational noise of fixed offshore wind turbines and found that the biggest difference between fixed and floating offshore wind turbines in relation to underwater noise generation is related to moorings, rather the operational wind turbine noise.

217. It is acknowledged in volume 3, appendix 10.1 that underwater noise may occur due to mooring line slackening and tensioning which has the potential to produce transient ‘pinging’ or ‘snapping’ noises during the operation and maintenance phase of the Array (Liu, 1973). Presence of snapping transient noise was identified during acoustic underwater noise measurements at the floating Hywind Demonstrator Project in Norway in 2011 (Martin *et al.,* 2011). The data were subsequently analysed and Stephenson (2015) extrapolated results from a single wind turbine to a theoretical array and it was found that with up to 115 snapping events per day, the resultant potential cumulative SEL over a 24 hour period was 156 dB re 1 μPa^2s at 150 m from the wind turbines. This value is below the ranges for recoverable injury and Temporary Threshold Shift (TTS) for Groups 3 and 4 fish.

218. With specific reference to operational turbines, the distances and exposures of fish reported by various studies (as set out in volume 3, appendix 10.1) conclude that while sound levels would likely be audible, these would not be at a level sufficient to cause injury or behavioural changes to fish. This is due to the slight increase in SPL compared to the ambient noise measured before the construction of the wind farms and even when the highest increases in SPL was assumed (i.e. 20 to 25 dB re 1 μ Pa), these are unlikely to result in a measurable impact on fish and shellfish receptors.

219. Therefore, it is concluded that the risk of effects on fish (either injury or behavioural responses) from underwater noise from this impact is very low, whether that is from the structure-borne noise expected from any offshore wind turbine, regardless of foundation type, and the additional noise generated by movements in the mooring lines.

220. Therefore, this impact is predicted to be highly localised in extent, long term duration and continuous and low reversibility during the operation and maintenance phase (impact is reversible upon decommissioning). The magnitude is therefore considered to be negligible.

Sensitivity of the receptor

221. The sensitivity of fish and shellfish IEFs to underwater noise for both marine fish and shellfish and diadromous fish species can be found in the assessment of ‘underwater noise from piling and UXO clearance impacting fish and shellfish receptors’ in the construction phase assessment (see paragraph 159 *et seq*.) with a summary of these sensitivities presented in in paragraph 197 *et seq*.).

Marine fish and shellfish species

222. Most marine fish are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore, considered to be low.

223. Herring are deemed to be of medium vulnerability, high recoverability and regional importance. The sensitivity of the receptor is therefore, considered to be medium.

224. Shellfish are deemed to be of low vulnerability, high recoverability and regional importance. The sensitivity of the receptor is therefore, considered to be low.

Diadromous species

225. Diadromous fish species are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore considered to be low.

Significance of the effect

Marine fish and shellfish species

226. Overall, for all marine fish and shellfish considered as IEFs, the magnitude of the impact is deemed to be negligible and the sensitivity of the receptor is considered to be low to medium.

227. The effect for all marine fish and shellfish IEFs will, therefore, be of **negligible** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

229. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

INCREASED SSCS AND ASSOCIATED DEPOSITION

230. Increased SSCs and associated deposition may arise due to the movement of hanging mooring lines along the seabed during the operation and maintenance phase of the Array.

231. Sediment modelling was undertaken related to the MDS as outlined in Table 9.13 with the detail of the assessment provided in volume 3, appendix 10.1.

Site preparation and construction phases

Magnitude of impact

232. The site preparation activities and installation of infrastructure associated with the Array may lead to increases in SSCs and associated deposition. There has been no modelling conducted or Physical Processes assessment available upon which to base this assessment, as this impact was scoped out of the Physical Processes assessment during this phase (volume 2, chapter 7). As such, this has been assessed qualitatively here. The following activities have been considered:

- seabed preparation activities: boulder and sand wave clearance;
- DEA installation; and
- inter-array and interconnector cable installation and burial (Table 9.13).

233. Boulder and sandwave clearance may be required for along inter-array and interconnector cables within a corridor of up to 25 m width, as set out in Table 9.13. For perspective, modelling conducted for Berwick Bank Offshore Wind Farm considered a clearance width of 25 m for site preparation activities such as sand wave clearance (SSER, 2022b). This modelling showed that the resulting sediment plume would be very small, with SSCs of <100 mg/l. SSCs were predicted to peak during the deposition of cleared material, with concentrations reaching 2,500 mg/l at the release site, but the plume was predicted to be at its most extensive during the redistribution of the deposited material on successive tides (SSER, 2022b). Under these circumstances, concentrations of 100 mg/l to 250 mg/l were predicted with average values <100 mg/l extending out to one tidal excursion (SSER, 2022b). Sedimentation of deposited material was focussed within 100 m of the site of release with a maximum depth 0.5 m to 0.75 m, whilst the finer sediment fractions were distributed in the vicinity at much smaller depths (circa 5 mm to 10 mm) over a maximum distance of one tidal excursion (SSER, 2022b). As the seabed sediments at Berwick Bank Offshore Wind Farm are more coarse than those of the Array fish and shellfish ecology study area (which comprises largely deep circalittoral sand; Figure 9.2), the smaller sedimentation depths associated with finer sediment fractions (5 mm to 10 mm; (SSER, 2022b)) are more likely to be associated with site preparation activities for the Array.

234. Up to 1,590 DEAs may be pulled up to 60 m along the seabed during the construction phase; this will be undertaken in a controlled manner to ensure that DEAs are installed at the correct position and to appropriate depth. DEAs were not assessed in any publicly available EIAs for projects within the regional fish and shellfish ecology study area, though are discussed in a study on the environmental effects of wind turbine foundations (Horwath *et al.*, 2020). This study concluded that floating foundations that use embedded anchors may have similar seabed-disturbing activities during installation when compared to monopiles, depending on the size of the anchors and method of installation (Horwath *et al.*, 2020). The study noted that the extent that anchors drag along the seabed due to the forces on floating foundations is unknown but is likely to produce some additional SSCs (Horwath *et al.*, 2020). Therefore, the low magnitude of impact associated with foundation installation at Berwick Bank Offshore Wind Farm, could be applied to the use of DEAs at the Array. Modelling of SSCs associated with foundation installation at Berwick Bank Offshore Wind Farm predicted plumes to have peak concentrations of <5 mg/l, with average values typically less than one fifth of this, and dropping to 1 mg/l to 2 mg/l within a very short distance, typically less than 500 m of the installation activity (SSER, 2022b). The sediment plumes were expected to be temporary, returning to background levels within a few tidal cycles (SSER, 2022b). The average sedimentation depth was predicted to be typically 0.05 mm to 0.1 mm during pile installation, with that maximum dropping to <0.003 mm one day following cessation of operations (SSER, 2022b). This suggests that associated deposition would be imperceptible from the background sediment transport activity, with plotted sediment depths less than typical grain diameters (SSER, 2022b). As per the Array, drill arisings will result from foundation installation at Berwick Bank Offshore Wind Farm. The assessment for these however, is considered under long term habitat loss and disturbance (paragraphs 106 *et seq.*) as this material will be deposited on the seabed in the same area which will be occupied by scour protection and is unlikely to be redistributed as a result of hydrodynamic processes.

235. Finally, cable installation and burial have the potential to result in increased SSCs and associated deposition. The MDS considers up to 1,261 km of inter-array cables and 236 km of interconnector cables (noting that up to 116 km of the total inter-array cables will be dynamic, and not buried at the seabed) (Table 9.13). As described in the Project Description (volume 1, chapter 3), the final cable installation methods have not yet been confirmed, and will be identified at the final design stage (post-consent), however cable plough, jet trencher, mass flow excavator, and mechanical cutter are potential options. At the Berwick Bank Offshore Wind Farm, jet trenching was assumed for the modelling, which predicted peak increases in SSCs of 100 mg/l in the immediate vicinity of the cable installation, with the sediment subsequently re-suspended and dispersed on subsequent tides, giving rise to concentrations of up to 500 mg/l (SSER, 2022b). The material was predicted to settle during slack water and then be resuspended to form an amalgamated plume. Sedimentation was predicted to be greatest at the location of the trenching and up to 30 mm in depth one day following cessation of inter-array cable installation (SSER, 2022b). Levels of sedimentation were predicted to reduce significantly, down to single figures, within close proximity (i.e. 100 m) of the trench (SSER, 2022b).

236. The impact is predicted to be of local spatial extent, long term duration, intermittent, and of high reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

Marine fish and shellfish species

237. In terms of SSC, adult fish species, such as herring and cod, are more mobile than many of the other fish and shellfish IEFs, and therefore would be likely to show avoidance behaviour within areas affected by increased SSC (EMU, 2004), making them less susceptible to physiological changes resulting from this impact. Juvenile fish are more likely to be affected by habitat disturbances such as increased SSC than adult fish, which is well researched for commercially important salmonid species (Bisson and Bilby, 1982; Berli *et al*., 2014). This is due to the decreased mobility of juvenile fish, with these animals therefore being less able to avoid impacts. Juvenile fish are likely to occur throughout the fish and shellfish ecology study area, with some species using offshore areas as nursery habitats, while inshore areas are more important as nurseries for other species (full list of species with spawning and nursery grounds overlapping the fish and shellfish ecology study area available in volume 3, appendix 9.1).

238. A study by Appleby and Scarratt (1989) found development of eggs and larvae have the potential to be affected by suspended sediments at concentrations of thousands of mg/l. Modelling undertaken of SSC associated with the fish and shellfish ecology study area operation and maintenance phase identified increases in SSC due to movement of mooring lines and cabling. These concentrations of SSC may affect the development of eggs and larvae; however, these concentrations are only expected to be present in the immediate vicinity of the release site with dispersion of the released material continuing on successive tides. These levels are unlikely to affect the development of eggs and larvae.

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

240. The species which are likely to be affected by sediment deposition are those which either feed or spawn on or near the seabed. Demersal spawners within the vicinity of the Array include sandeel, which have low intensity spawning and nursery grounds within the fish and shellfish ecology study area (Ellis *et al*., 2012), however sandeel eggs are likely to be tolerant to some level of sediment deposition due to the nature of re-suspension and deposition within their natural high energy environment. Therefore, effects on sandeel spawning populations are predicted to be limited. Sandeel populations are also sensitive to sediment type within their habitat, preferring coarse to medium sands and showing reduced selection or avoidance of gravel and fine sediments (Holland *et al.*, 2005). This is as identified by the FeAST tool as the pressure 'siltation changes' (low) which has identified that sandeel have medium sensitivity to this impact (Wright *et al*., 2000). Therefore, any increase in the fine sediment fraction of their habitat may cause avoidance behaviour until such time that currents remove fine sediments from the seabed, although modelled sediment deposition levels are expected to be highly localised and at very low levels.

241. Herring occur mostly in pelagic habitats, but utilise benthic environments for spawning, and are known to prefer gravelly and coarse sand environments for this purpose, with low intensity nursery grounds present within the site boundary and low intensity spawning grounds nearby (Coull *et al*., 1998). With respect to the effects of sediment deposition on herring spawning activity, it has been shown that herring eggs may be tolerant of very high levels of SSC (Messieh *et al*., 1981; Kiorbe *et al*., 1981). Detrimental effects may be seen if smothering occurs and the deposited sediment is not removed by the currents (Birklund and Wijsmam, 2005), however this natural removal by the currents and tidal physical processes would be expected to occur quickly in this case (i.e. within a couple of tidal cycles), given the low levels of deposition expected close to the installed foundations and the mooring lines during the operation and maintenance phase.

242. All fish and shellfish ecology IEFs in the fish and shellfish ecology study area, including sandeel, herring, *Nephrops*, and elasmobranch species, are deemed to be of low to medium vulnerability, high recoverability and local to national importance. The sensitivity of these IEFs is therefore considered to be low.

Diadromous species

243. Diadromous fish species known to occur in the area are also expected to have some tolerance to naturally high SSC, given their migration routes typically pass through estuarine habitats which have background SSC which are considerably higher than those expected to occur because of the operation and maintenance phase of the Array. As it is predicted that operation and maintenance activities associated with the Array will produce only temporary and rapidly dissipating increases in SSC, with levels well below those experienced in estuarine environments, it would be expected that any diadromous species should only be temporarily affected (if they are affected at all, based on the migration routes). Any adverse impacts on these species are likely to be short term behavioural effects, such as avoidance (Boubee *et al*., 1996), or temporary slightly erratic alarmed swimming behaviour (Chiasson, 2011), and are not expected to create a barrier to migration between feed grounds in the North and Atlantic and natal rivers or estuaries used by these species. However, these studies were laboratory based, and do not cover the species found within the fish and shellfish ecology study area, so the potential for other responses does exist, but these are unlikely, given the naturally highly turbid nature of estuarine environments that these species are adapted to traverse. Investigations into the impacts of offshore increased suspended sediments on diadromous species such as Atlantic salmon are limited (Kjelland *et al*., 2015), although there is the potential for increased turbidity to improve salmon survival rates during migrations due to a lowering of predation rates from reduced visibility (Gregory and Levings, 1998).

244. Diadromous fish species IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptors is therefore considered to be low.

Significance of the effect

Marine fish and shellfish species

245. Overall, for all marine fish and shellfish species considered as IEFs, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

247. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

Operation and maintenance phase

Magnitude of impact

248. The potential of an increase in SSCs may arise because of mooring lines or cables making contact with and moving on the seabed, disturbing seabed materials and causing scouring and increased SSCs within

the water column. The greatest potential for the increase in SSCs is from catenary moorings which have the greatest length of mooring lines in contact with the seabed. Any increase in SSCs and associated deposition will include native material only, and although comprises predominantly mobile sand material, the low rates of sediment transport, will ensure it is redeposited close by after a short period of suspension, thus not impacting significantly on seabed morphology. Any significant changes to the seabed morphology will not recover immediately, due to the low rates of sediment transport, however the evidence of mobile sediments implies any impacts will be fully recoverable after some time (volume 2, chapter 7).

249. In line with the physical processes assessment, the first MDS was considered to be the number of foundations with the greatest length of mooring line on the seabed per foundation, rather than over the site boundary as a whole, as the effects are considered to be very localised, with no interactions between adjacent foundations. This was assumed as up to 130 semi-submersible turbine foundations with up to 9 catenary mooring lines each (Table 9.13). This first MDS is hereafter referred to as the '130 turbine MDS' for clarity. The second MDS considered was based on up to 265 semi-submersible turbine foundations with up to 6 catenary mooring lines each (Table 9.13) and is hereafter referred to as the '265 turbine MDS' for clarity. This was included in the assessment for fish and shellfish ecology as the 130 turbine MDS represents a potentially higher impact to fish and shellfish IEFs and at a localised level (due to a higher number of mooring lines per foundation), but it does not consider the overall footprint of impact over the Array fish and shellfish ecology study area as a whole. Thus, the 265 turbine MDS represents a higher overall length of mooring lines in contact with the seabed over the Array fish and shellfish ecology study area as a whole, but a lower potential for impact associated with fish and shellfish IEFs in the immediate vicinity of individual turbines.

250. The mooring line radius for both MDSs is 700 m, with a touchdown distance of between 25 m and 150 m from the foundation, and overall length of 750 m. During operation, approximately 680 m of the catenary mooring line will be in contact with the seabed which amounts to up to 6,120 m per foundation for the 130 turbine MDS and up to 4,080 m per foundation for the 265 turbine MDS (Table 9.13). Overall, up to 795,600 m of mooring line may be in contact with the seabed under the 130 turbine MDS, and up to 1,081,200 m under the 265 turbine MDS (Table 9.13), highlighting the differences between the two MDSs. The tidal range at the Array fish and shellfish ecology study area is less than 4 m; therefore it is not anticipated that tidal movements will result in substantial horizontal and vertical movements. As such, the mooring lines are not considered to notably increase the SSCs under standard operating conditions for both the MDSs.

251. Under harsher weather conditions, the dynamic interaction between the mooring lines and the seabed will increase with intensity and direction of the storm. Horizontal movement of the floating foundations may result in the lifting of the mooring lines located on the windward side of the turbine, as tension on these mooring lines increases. Mooring lines on the leeward side would experience the opposite effect, whereby the length of mooring line in contact with the seabed increases as they slacken, up to a maximum of 710 m for some mooring lines in the most extreme storm conditions. The length where disturbance is likely to occur will be less, as this will be greater closer to the touchdown point and negligible towards the anchor point. Furthermore, the dimensions of the mooring lines are small, with a chain thickness of 185 mm, and horizontal diameter of 620 mm, which will limit the volumes of seabed material they have the potential to disturb, even if they were to become completely embedded.

252. Movement on the seabed by inter-array cables will be limited to a small section between the touch down point and the point where the cable becomes static, resulting in minor increases to SSCs in the vicinity of the touchdown point only. Regarding inter-array cables, the total length of the dynamic inter-array cables will be 116 km with a maximum external cable diameter of 300 mm for both MDSs considered. Movement of the inter-array cables may be reduced using buoyancy modules and clump weights (subject to engineering design) thus limiting movement on the seabed to a very small proportion of the total dynamic cable length between the touchdown point and where it transitions to a static cable. Static inter-array and interconnector cables on the seabed will be buried or fixed with cable protection where target burial depths cannot be achieved. Thus, the potential disturbance area is restricted to small areas in the vicinity of up to two dynamic cable touchdown points per turbine. Increased SSCs would therefore be spatially limited, smaller, and adjacent to any disturbance resulting from the mooring lines.

253. The spacing between the floating foundations is a minimum 1.4 km for the 130 turbine MDS and a minimum of 1 km for the 265 turbine MDS (Table 9.13). These spacings are large enough for any impacts to SSCs to be considered as isolated, considering the low current speeds and sediment transport rates in the physical processes study area. Any dynamic interactions between the seabed and mooring lines or dynamic cables will likely be experienced similarly at adjacent foundations under tidal and storm conditions, with the foundations moving in the same direction and orientated the same way as their neighbouring foundations. Thus, storm conditions will not impact upon minimum foundation spacing and seabed disturbance areas from mooring lines are considered sufficiently far apart to be isolated even under storm conditions for both MDSs considered.

254. Horizontal movement of the floating foundations may result in the lifting of the mooring lines located on the windward side of the turbine, as tension on these mooring lines increases. Mooring lines on the leeward side would experience the opposite effect, whereby the length of mooring line in contact with the bed increases as they slacken, up to a maximum of 710 m for some mooring lines in the most extreme storm conditions. The length where disturbance is likely to occur will be less, as this will be greater closer to the touchdown point and negligible towards the anchor point. Furthermore, the dimensions of the mooring lines are small, with a chain thickness of 185 mm, and horizontal diameter of 620 mm, which will limit the volumes of seabed material they have the potential to disturb, even if they were to become completely embedded.

255. Regarding inter-array cables, the total length of the dynamic inter-array cables will be 116 km with a maximum external cable diameter of 300 mm. Movement of the inter-array cables may be reduced through the use of buoyancy modules and clump weights (subject to engineering design) thus limiting movement on the seabed to a very small proportion of the total dynamic cable length between the touchdown point and where it transitions to a static cable. Static inter-array and interconnector cables on the seabed will be buried or fixed with cable protection where target burial depths cannot be achieved. Thus, the potential disturbance area is restricted to small areas in the vicinity of up to two dynamic cable touchdown points per turbine. Increased SSCs would therefore be spatially limited, smaller, and adjacent to any disturbance resulting from the mooring lines, of which there are up to nine per floating foundation.

256. A small proportion of the dynamic cable between the touchdown point to the point where it becomes static may move on the seabed. However, installation of clump weights and buoyancy modules, or alternative solutions as required, will reduce the movement of the dynamic component of the cable from the touchdown point to the transition point to minimise wear.

257. The impact is predicted to be of local spatial extent, long term duration, intermittent, and of high reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

258. The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the site preparation and construction phase assessment (see paragraph 237 *et seq.*).

Significance of the effect

Marine fish and shellfish species

259. Overall, for all marine fish and shellfish species considered as IEFs, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

261. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

Decommissioning phase

Magnitude of impact

262. Decommissioning of infrastructure associated with the Array may lead to increases in SSCs and associated deposition. The MDS is represented by the removal of all infrastructure, as this represents the largest potential for increased SSCs and associated deposition (Table 9.13). Note, the decommissioning strategy is not defined, and cables, cable protection, and scour protection may potentially be left *in situ*. If some infrastructure remains *in situ*, the MDS presented here will be an overestimation, and SSCs will be lower.

263. Decommissioning activities are assumed to result in increased SSCs and associated deposition that are lesser than or equal to those produced during construction. The impacts of decommissioning activities are therefore predicted to be no greater than those presented in paragraphs 232 *et seq.* for the site preparation and construction activities. In actuality, the release of sediment in the decommissioning phase will be lower as it doesn't include activities such as seabed preparation and DEA installation.

264. Therefore, this impact is predicted to be of local spatial extent, short term duration, intermittent, and of high reversibility. The magnitude is therefore considered to be low.

Sensitivity of the receptor

265. The sensitivity of the fish and shellfish IEFs, for both marine and diadromous species, can be found in the preparation and construction phase assessment (see paragraph 237 *et seq*.).

Significance of the effect

Marine fish and shellfish species

266. Overall, for all marine fish and shellfish species considered as IEFs, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

Diadromous species

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

Secondary mitigation and residual effect

268. No secondary fish and shellfish ecology mitigation is considered necessary because the likely effect in the absence of mitigation is not significant in EIA terms.

EFFECTS TO FISH AND SHELLFISH RECEPTORS DUE TO EMF FROM SUBSEA ELECTRICAL CABLING

269. Effects to fish and shellfish ecology due to Electromagnetic Fields (EMFs) from subsea electrical cabling EMF may arise due to the operation of inter-array and interconnector cables during the operation and maintenance phase as outlined in Table 9.13. The conduction of electricity through subsea power cables will result in emission of localised EMFs which could potentially impact the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species (including elasmobranchs) and diadromous fish species (Centre for Marine and Coastal Studies (CMACS), 2003). This section also involves the assessment of the impacts of EMFs from the dynamic inter-array cables in the water column on fish and shellfish IEFs within the fish and shellfish ecology study area.

Operation and maintenance phase

Magnitude of impact

270. The presence of inter-array and interconnector cables within the fish and shellfish ecology study area will result in the emission of localised EMFs affecting fish and shellfish IEFs. EMF comprise both the electrical (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in microtesla (µT) or milliGauss (mG). Background measurements of the magnetic field are approximately 50 µT in the North Sea, and the naturally occurring electric field in the North Sea is approximately 25 µV/m (Tasker *et al*., 2010).

271. As shown in Table 9.13, the MDS assumes there may be up 1,261 km of 66 kV or 132 kV inter-array cables installed within the site boundary. Of these, a maximum of 116 km of these inter-array cables will be in the water column as dynamic cables, with the rest of these installed on the seabed. There may be up to 236 km of 275 kV AC or 525 kV DC interconnector cables with total length buried to a minimum depth target burial depth of 0.4 m (subject to a CBRA).

272. It is common practice to block the direct electrical field using conductive sheathing, meaning that the only EMFs that are emitted into the marine environment are the magnetic field and the resultant induced electrical field. It is generally considered impractical to assume that cables can be buried at depths that will reduce the magnitude of the magnetic field, and hence the sediment-sea water interface induced electrical field, to below that at which these fields could be detected by certain marine organisms on or close to the seabed (Gill *et al*., 2005; Gill *et al*., 2009). By burying a cable, the magnetic field at the seabed is reduced due to the distance between the cable and the seabed surface as a result of field decay with distance from the cable (CSA, 2019).

273. A variety of design and installation factors affect EMF levels in the vicinity of the cables. These include current flow, distance between cables, cable orientation relative to the earth's magnetic field (DC only), cable insulation, number of conductors, configuration of cable and burial depth. Clear differences between AC and DC systems are apparent: the flow of electricity associated with an AC cable changes direction (as per the frequency of the AC transmission) and creates a constantly varying electric field in the surrounding marine environment (Huang, 2005). Conversely, DC cables transmit energy in one direction creating a static electric and magnetic field. Average magnetic fields of DC cables are also higher than those of equivalent AC cables.

274. The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source. A recent study conducted by CSA (2019) found that inter-array and interconnector cables buried between depths of 1 m to 2 m reduces the magnetic field at the seabed surface four-fold. For cables that are unburied and instead protected by thick concrete mattresses or rock berms, the field levels were found to be similar to buried cables.

275. CSA (2019) found magnetic field levels directly over live AC subsea power cables associated with offshore wind energy projects range between 65 mG (at seafloor) and 5 mG (1 m above sea floor) for inter-array cables. At lateral distances from the cable, magnetic fields greatly reduced at the sea floor to between 10 mG and <0.1 mG.

276. While the majority of cables will be buried beneath surface sediments as set out in the MDS (Table 9.13), a small proportion of inter-array cables will be dynamic cables within the water column (up to 116 km length across the Array). EMFs produced by these dynamic cables also have the potential to impact fish and shellfish ecology receptors. As set out above, EMF intensity from subsea cables (which include dynamic cables) decreases at approximately the inverse square/power of the distance away from the cable (Hutchison *et al.,* 2018), and this attenuation is the same for buried, unburied, and dynamic cables (Hutchison *et al.,* 2021). So whilst the EMF levels from dynamic cables and buried cables will remain the same along the entire cable, the surface sediments and cable protection maintain distance between fish and shellfish species and cables on the seabed thus reducing interaction. For dynamic cable portions pelagic species may pass closer to cables within the water column and have the potential to be exposted to increased levels of EMFs. Nonetheless levels of EMF will be returned to baseline levels within a few metres of the cable and therefore the area of effect is highly limited in extent, particularly in the context of the habitats available in the fish and shellfish study area and the water depths within the Array.

277. The impact is predicted to be of local spatial extent, long term duration, continuous and low reversibility during the operation and maintenance phase (impact is reversible upon decommissioning). It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of the receptor

278. Fish (particularly elasmobranchs) and shellfish species are able to detect applied or modified magnetic fields. Species for which there is evidence of a response to E and/or B fields include elasmobranchs (shark, skate and ray); plaice (Gill *et al*., 2005; CSA, 2019), and crustaceans such as crab and lobster (Scott *et al*., 2021). It can be inferred that the life functions supported by an electric haptic sense (Caputi *et al*., 2013) may include detection of prey, predators or conspecifics in the local environment (Pedraja *et al*., 2018) to assist with feeding, predator avoidance, and social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*., 2005; Normandeau *et al*., 2011, Formicki *et al*., 2019).

279. Studies examining the effects of EMFs from AC subsea power cables on fish behaviours have been conducted to determine the thresholds for detection and response to EMFs. Table 9.28 provides an up-to-date summary of the scientific studies conducted to assess sensitivity of EMFs on varying fish species. The overall amount of research into the impacts of EMFs have indicated that marine fish and shellfish species are known to have some level of sensitivity to this effect, and so these have been split out for separate consideration within this assessment.

Table 9.28: Relationship Between Geomagnetic Field Detection Electro Sensitivity, and the Ability to Detect 50/60-Hz AC Fields in Common Marine Fish and Shellfish Species (Adapted from CSA, 2019)

Species Group	Detect Geomagnetic Field	Detect Electric Field	Evidence from Laboratory Studies of 50/60 Hz EMF from AC Power Cables	Evidence from Field Studies of AC Power Cables
Skate	Yes, multiple species (Normandeau *et al*., 2011)	Yes, multiple species (Normandeau *et al*., 2011)	No responses expected at 60 Hz (Kempster *et al*., 2013)	No attraction at California AC cable sites operating at up to 914 mG (Love *et al*., 2016).
Flounder	Potentially, due to observed orientation behaviours (Metcalfe *et al*., 1993)	Not tested	Not tested	No population-level effects, but some evidence of delayed crossing of cables by species moving across where these cables are laid. It is unclear whether this effect was due to cable EMF or prior sediment disturbance (Vattenfall, 2006).
Tuna and mackerel	Yes, for some species (Walker, 1984)	Not tested (Normandeau *et al*., 2011)	Not tested	Some evidence of attraction of mackerel to monopile structure, but no effect from cables (Bouma and Lengkeek, 2008).
Lobster and crab	Yes, for some lobster species (Lohmann *et al*., 1995; Hutchison *et al*., 2018)	Not tested (Normandeau *et al*., 2011)	No effect at 800,000 µT (Ueno *et al*., 1986)	Distribution unaffected by 60 Hz AC cable operating up to 800 mG (Love *et al*., 2017).

Marine fish species

280. Several field studies have observed behaviours of fish and other species around AC submarine cables in the USA (Table 9.28). Observations at three energised 35 kV AC subsea power cable sites off the coast of California that run from three offshore platforms to shore, which are unburied along much of the route, did not show that fish were repelled by or attracted to the cables (Love *et al*., 2016). A study investigating the effect of EMFs on lesser sandeel larvae spatial distribution found that there was no effect on the larvae (Cresci *et al*., 2022), and a prior study concluded the same for herring (Cresci *et al*., 2020).

281. Elasmobranchs (i.e. shark, skate and ray) are known to be the most electro-receptive of all fish. These species possess specialised electro-receptors which enable them to detect very weak voltage gradients (down to 0.5 µV/m) in the environment naturally emitted from their prey (Gill *et al*., 2005). Both attraction and repulsion reactions to electrical fields have been observed in elasmobranch species. Spurdog *Squalus acanthias*, an elasmobranch species known to occur within the fish and shellfish ecology study area, avoided electrical fields at 10 µV/cm (Gill and Taylor, 2001), although it should be noted that this level (i.e. 10 µV/cm is equivalent to 1,000 µV/m) is considerably higher than levels associated with offshore electrical cables. A Collaborative Offshore Wind Research into the Environment (COWRIE) sponsored mesocosm study demonstrated that the lesser spotted dogfish *Scyliorhinus canicula* and thornback ray were able to respond to EMF of the type and intensity associated with subsea cables; the responses of some ray individuals suggested a greater searching effort when the cables were switched on (Gill *et al*., 2009). However, the responses were not predictable and did not always occur (Gill *et al*., 2009). In another study, EMF from 50 Hz to 60 Hz AC sources appears undetectable in elasmobranchs. Kempster and Colin (2011) have noted the physiological capacity for detection of EMFs in basking shark, which may migrate through the fish and shellfish ecology study area (noting abundances of basking shark in the North Sea area generally low), but no current evidence exists on specific impacts of EMFs of any strength on this species, apart from the likely detection capacity of a standard electrical field benchmark level of 1 V/m (Wilding *et al*., 2020). More generally, Kempster *et al*. (2013) reported that small shark could not detect EMF produced at 20 Hz and above, and Hart and Collin (2015) found no significant repellent effect of a magnetic field of 14,800 G on shark catch rates, suggesting a low sensitivity to these fields.

282. In summary, the range over which these fish species can detect electric fields is limited to a scale of metres around electrical cables buried to depths of 1 m to 2 m (CSA, 2019). Pelagic species (such as

herring) generally swim well above the seafloor, though may still be exposed to the EMFs from the dynamic cables in the water column. The length of dynamic cables (up to 116 km) is small in the context of the large site boundary and the water depths within it, and EMFs from these cables is likely to only be detected within a matter of metres. Beyond this range, levels of EMFs will be expected to be at baseline levels for this part of the North Sea, resulting in impacts that would therefore be highly localised.

283. Demersal species (e.g. elasmobranchs) that dwell on the bottom, are more likely to come into the ZoI of subsea power cables and thus encounter higher EMF levels when near the cable. Demersal species are also likely to be exposed for longer periods of time and may be largely constrained in terms of location. However, the rapid decay of the EMF with horizontal and vertical distance (Bochert and Zettler, 2006) (i.e. within metres) reduces the extent of potential impacts.

284. Most marine fish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore considered to be low.

285. Elasmobranch species in the fish and shellfish ecology study area are deemed to be of medium vulnerability, high recoverability, and local to national importance. The sensitivity of the receptor is therefore considered to be low.

Shellfish species

286. Crustaceans, including lobster and crab, have been shown to demonstrate a response to B fields, with the Caribbean spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (CSA, 2019). EMF exposure has been shown to result in varying egg volumes for edible crab compared to controls. Exposed larvae were significantly smaller, but there were no statistically significant differences in hatched larval numbers, deformities, mortalities, or fitness (Scott, 2019). Exposure to EMF has also been shown to affect a variety of physiological processes within crustaceans. For example, Lee and Weis demonstrated that EMF exposure affected moulting in fiddler crab species (*Uca pugilator* and *Uca pugnax*) (Lee and Weis, 1980).

287. Observations of crab movement and location inside large cages off south California and in Puget Sound were reported by Love *et al*. (2016) and these were reported to be unaffected by proximity to energised AC subsea power cables, indicating crab also were not attracted to or repelled by energised AC subsea power cables that were either buried or unburied. Similarly, no significant change in distance or speed of travel over time when American lobster *Homarus americanus* were exposed to magnetic fields of 53 to 65 μT (Hutchison *et al*., 2020). However, studies on the Dungeness crab and edible crab have reported behavioural changes during exposure to increased EMF and both species showed increased activity when compared to crab that were not exposed (Scott *et al*., 2018; Woodruff *et al*., 2012). Crab may also spend less time buried, which is normally a natural predator avoidance behaviour (Rosaria and Martin, 2010), and some species have been noted not to cross subsea cables (Love *et al*., 2017), potentially reducing habitats available for predation.

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

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

290. Further research by Scott *et al*. (2021) found that physiological and behavioural impacts on edible crab occurred at 500 μT and 1000 μT, causing disruption to the L-lactate and D-glucose circadian rhythm and altering total haemocyte count, and also causing attraction to EMF exposed areas and reduced roaming time. However, these physiological and behavioural impacts did not occur at 250 μT. Seeing as even in the event of an unburied cable the maximum magnetic field reported was 78.27 μT (Normandeau *et al*., 2011), it can be assumed that the magnetic fields generated by the cables will be lower than 250 μT, and therefore will not present any adverse impacts on edible crab. Harsanyi *et al*. (2022) noted that chronic exposure to EMF effects could lead to physiological deformities and reduced swimming test rates in lobster and edible crab larvae. However, these deformities were in response to EMF levels of 2,800 μT and therefore are considerably higher than EMF effects expected for buried cables. The report recommends burying of cables in order to reduce any potential impacts associated with high levels of EMF in line with the designed in measures outlined in section 9.10.

291. As with marine fish species discussed above, the range over which these species can detect electric fields is limited to a scale of metres around electrical cables buried to depths of 1 m to 2 m (CSA, 2019). Demersal shellfish species (e.g. decapod crustaceans) that dwell on the bottom, are more likely to come into the ZoI of subsea power cables and thus encounter higher EMF levels when near the cable, are likely to be exposed for longer periods of time and may be largely constrained in terms of location. However, the rapid decay of the EMF with horizontal and vertical distance (Bochert and Zettler, 2006) (i.e. within metres) reduces the extent of potential impacts.

292. Most marine shellfish ecology IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and local to national importance. The sensitivity of the receptor is therefore considered to be low.

293. Decapod crustaceans in the fish and shellfish ecology study area are deemed to be of medium vulnerability, high recoverability, and local to national importance. The sensitivity of the receptor is therefore considered to be low.

Diadromous species

294. EMFs may also interfere with the navigation of sensitive diadromous species. Species for which there is evidence of a response to E and/or B fields include river lamprey, sea lamprey, European eel, and Atlantic salmon (Gill *et al*., 2005; CSA, 2019). Effects of EMFs surrounding subsea cables on allis shad, twaite shad and sparling are currently poorly researched, with recommendations made to investigate these potential effects in future (Gill *et al*., 2012; Sinclair *et al*., 2020; noting that shad species are pelagic and therefore unlikely to interact with EMF from installed cables on the seabed). As with marine fish, however, diadromous fish species may be exposed to EMFs from the dynamic cables in the water column. EMFs emitted from these dynamic cables is likely to only be detected within a matter of metres; beyond which, baseline levels will be established. As such, impacts from EMFs from the dynamic cables are highly localised. Lamprey possess specialised ampullary electroreceptors that are sensitive to weak, low frequency electric fields (Bodznick and Northcutt, 1981; Bodznick and Preston, 1983), which are hypothesised to be used for prey-detection, although further research is required in this area (Tricas and Carlston, 2012). Chung-Davidson *et al*. (2008) found that weak electric fields may play a role in the reproduction of sea lamprey and it was suggested that electrical stimuli mediate different behaviours in feeding-stage and spawning-stage individuals. This study (Chung-Davidson *et al*., 2008) showed that migration behaviour of sea lamprey was affected (i.e. adults did not move) when stimulated with electrical fields of intensities of between 2.5 mV/m and 100 mV/m, with normal behaviour observed at

electrical field intensities higher and lower than this range. It should be noted, however, that these levels are considerably higher than modelled induced electrical fields expected from AC subsea cables (see Table 9.29). There is currently no evidence of lamprey responses to magnetic B fields (Gill and Bartlett, 2010).

295. Atlantic salmon and European eel have both been found to possess magnetic material of a size suitable for magnetoreception, and these species can use the earth's magnetic field for orientation and direction-finding during migration (Gill and Bartlett, 2010; CSA, 2019). Mark and recapture experiments undertaken at the operational Nysted Offshore Wind Farm showed that eel did cross the interconnector cable (Hvidt *et al*., 2003). Studies on European eel in the Baltic Sea have highlighted some limited effects of subsea cables (Westerberg and Lagenfelt, 2008), with evidence of direct detection of EMF through the lateral line of this species (Moore and Riley, 2009). The swimming speed during migration was shown to change in the short term (tens of minutes) with exposure to AC electric subsea cables, even though the overall direction remained unaffected (Westerberg and Langenfelt, 2008). The authors concluded that any delaying effect (i.e. on average 40 minutes) would not be likely to influence fitness in a 7,000 km migration, with little to no impact on migratory behaviour noted beyond 500 m from wind farm development infrastructure (Ohman *et al*., 2007). Research in Sweden on the effects of a High Voltage Direct Current (HVDC) cable on the migration patterns of a range of fish species, including salmonids, failed to find any effect (Westerberg *et al*., 2007; Wilhelmsson *et al*., 2010). Research conducted at the Trans Bay cable, a DC subsea cable near San Francisco, California, found that migration success and survival of chinook salmon *Oncorhynchus tshawytscha* was not impacted by the cable. However, as with the Hutchison *et al*. (2018) study on lobster, behavioural changes were noted when these fish were near the cable (Kavet *et al*., 2016) with salmon appearing to remain around the cable for longer periods. These studies demonstrate that while DC subsea power cables can result in altered patterns of fish behaviour, these changes are temporary and do not interfere with migration success or population health.

296. Table 9.29 provides a summary of the scientific studies conducted to assess sensitivity of EMF on varying diadromous fish species.

Table 9.29: Relationship Between Geomagnetic Field Detection Electro Sensitivity, and the Ability to Detect 50/60-Hz AC Fields in Diadromous Fish Species (Adapted from CSA, 2019)

Species Group	Detect Geomagnetic Field	Detect Electric Field	Evidence from Laboratory Studies of 50/60Hz EMF from AC Power Cables	Evidence from field studies of AC power cables
American/European eel	Yes, for multiple species (Normandeau *et al.*, 2011).	Mixed evidence (Normandeau *et al.*, 2011).	No effect of 950 mG magnetic field at 50 Hz on swim behaviour or orientation (Orpwood *et al.*, 2015).	Unburied AC cable did not prevent migration of eel (Westerberg *et al.*, 2007).
Salmon	Yes, for multiple species (Yano *et al.*, 1997, Putman *et al.*, 2014).	Not tested (Normandeau *et al.*, 2011).	No effect of 950 mG magnetic field at 50 Hz on swim behaviour (Armstrong *et al.*, 2015).	Not surveyed.

297. Diadromous fish IEFs in the fish and shellfish ecology study area are deemed to be of low vulnerability, high recoverability and national to international importance. The sensitivity of the receptor is therefore, considered to be low.

Significance of the effect

Marine fish and shellfish species

298. For most fish and shellfish IEF species, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

299. For European lobster, *Nephrops*, edible crab and elasmobranchs, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Diadromous species

300. Overall, the magnitude of the impact is deemed to be low, and the sensitivity of diadromous IEFs is considered to be low. The effect will, therefore, be of **negligible to minor** significance, which is not significant in EIA terms.

9.12. CUMULATIVE EFFECTS ASSESSMENT

9.12.1. METHODOLOGY

301. The CEA assesses the LSE[1] associated with the Array together with other relevant plans, projects and activities. Cumulative effects are defined as the combined effect of the Array in combination with the effects from a number of different projects, on the same receptor or resource. Further details on CEA methodology are provided in volume 1, chapter 6.

302. The projects and plans selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise (see volume 3, appendix 6.4 of the Array EIA Report). Volume 3, appendix 6.4 further provides information regarding how information pertaining to other plans and projects is gained and applied to the assessment. Each project or plan has been considered on a case-by-case basis for screening in or out of this chapter's assessment based upon data confidence, impact-receptor pathways and the spatial/temporal scales involved.

303. In undertaking the CEA for the Array, it should be noted that other projects and plans under consideration will have differing potential for proceeding to an operational stage and hence a differing potential to ultimately contribute to a cumulative impact alongside the Array. Therefore, a tiered approach has be adopted which provides a framework for placing relative weight upon the potential for each project/plan to be included in the CEA to ultimately be realised, based upon the project/plan's current stage of maturity and certainty in the projects' parameters. The tiered approach which will be utilised within the Array CEA employs the following tiers:

- tier 1 assessment – Array with Proposed offshore export cable corridor(s) and Proposed onshore transmission infrastructure and all plans/projects which became operational since baseline characterisation, those under construction, and those with consent and submitted but not yet determined;
- tier 2 assessment – All plans/projects assessed under Tier 1, plus those projects with a Scoping Report; and
- tier 3 assessment – All plans/projects assessed under Tier 2, which are reasonably foreseeable, plus those projects likely to come forward when an Agreement for Lease (AfL) has been granted.

304. The specific projects scoped into the CEA for fish and shellfish ecology are outlined in Table 9.30 and presented in Figure 9.10.

305. The range of potential cumulative impacts that are identified and included in Figure 9.10, is a subset of those considered for the Array alone CEA assessment. This is because some of the potential impacts identified and assessed for likely significant effects for the Array alone, are localised and temporary in nature. It is considered therefore, that these potential impacts have limited or no potential to interact with

similar changes associated with other plans or projects. These have therefore not been taken forward for detailed assessment.

306. Similarly, some of the potential impacts considered within the Array alone assessment are specific to a particular phase of development (e.g. construction, operation and maintenance or decommissioning). Where the potential for cumulative effects with other plans or projects only have potential to occur where there is spatial or temporal overlap with the Array during certain phases of development, impacts associated with a certain phase may be omitted from further consideration where no plans or projects have been identified that have the potential for cumulative effects during this period.

307. For the purposes of the fish and shellfish ecology assessment of effects, cumulative effects have been assessed within a 50 km buffer of the Array, with the exception to underwater noise during the construction phase, where a larger buffer of 100 km was applied to account for the larger ZoI associated with underwater noise (i.e. behavioural effects to ranges of tens of kilometres from the site boundary).

Table 9.30: List of Other Projects and Plans Considered Within the CEA for Fish And Shellfish Ecology

Project/Plan	Status [i.e. Application, Consented, Under Construction, Operational]	Distance from Site Boundary (km)	Description of Project/Plan	Dates of Construction (If Applicable)	Dates of Operation (If Applicable)	Overlap with the Array
Tier 1						
Proposed offshore export cable corridor(s)	Planned	0.00	The Proposed offshore export cable corridor(s) for the Array	2030 to 2037	2038 to 2072	Spatial overlap with the screening buffer and temporal overlap between the construction and operation and maintenance phases of the Array.
Offshore Wind Projects and Associated Cables						
Berwick Bank Offshore Wind Farm	Planning	56.84	Berwick Bank Offshore Wind Farm is proposed for up to 307 wind turbines with a capacity of up to 4.1 GW	2025 to 2032	2033 to 2057	Outside spatial overlap for majority of impacts (i.e. 50 km buffer), but within screening buffer for noise impacts (i.e. 100km). However no temporal overlap for construction phase and therefore Berwick Bank Offshore Wind Farm will not be considered further in the CEA.
Cables and Pipelines						
Eastern Green Link 2	Marine Licence Application	24.37	Transmission cable between Scotland and England	2025 to 2029	2030 to 2050	Spatial overlap with the screening (50 km) buffer. No temporal overlap with the construction phase. Operation and maintenance phase of Eastern Green Link 2 overlaps temporally with that of the Array.
Tier 2						
Offshore Wind Projects and Associated Cables						
Morven Offshore Wind Farm	Scoping	5.50	Up to 191 wind turbines at a capacity of 2,300 MW	2031 to 2037	2038 onwards	Spatial overlap with the screening (50 km) buffer. Construction and operation and maintenance phases of Morven Offshore Wind Farm overlap temporally with those of the Array.
Muir Mhor Offshore Wind Farm	Scoping	51.38	Project construction expected to start construction in 2026 with commercial operation starting in 2029.	2027 to 2029	2030 onwards	No spatial overlap with the screening (50 km) buffer. Operation and maintenance phase of Muir Mhor Offshore Wind Farm overlaps temporally with those of the Array.
Salamander Offshore Wind Farm	Scoping	79.49	Salamander Offshore Wind Farm is proposed for up to 100MW	Unknown	Unknown	Spatial overlap with screening buffer for underwater noise impacts only (100 km). The construction of Salamander Offshore Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Cenos Offshore Wind Farm	Scoping	91.70	Cenos Offshore Wind Farm is proposed for up to 1400MW	Unknown	Unknown	Spatial overlap with screening buffer for underwater noise impacts only (100 km). The construction of Cenos Offshore Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Tier 3						
Offshore Wind Projects and Associated Cables						
Bellrock Offshore Wind Farm	Pre-Planning	8.67	Bellrock Offshore Wind Farm is proposed for a capacity of 1200MW.	Unknown	Unknown	Spatial overlap with the screening (50 km) buffer. The construction of Bellrock Offshore Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Bowdun Offshore Wind Farm	Pre-Planning	25.36	Up to 60 wind turbines at a capacity of 1,000 MW	Unknown	Unknown	Spatial overlap with the screening (50 km) buffer. Temporal overlap is currently unknown. The construction of Bowdun Offshore Wind Farm might overlap with the construction and operation and maintenance phases of the Array.

Project/Plan	Status [i.e. Application, Consented, Under Construction, Operational]	Distance from Site Boundary (km)	Description of Project/Plan	Dates of Construction (If Applicable)	Dates of Operation (If Applicable)	Overlap with the Array
Campion Offshore Wind Farm	Pre-Planning	44.15	Up to 100 wind turbines at a capacity of 2,000 MW	Unknown	Unknown	Spatial overlap with the screening (50 km) buffer. The construction of Campion Offshore Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Flora Floating Wind Farm	Pre-Planning	68.41	Flora Floating Wind Farm is proposed for up to 50 MW.	Unknown	Unknown	Spatial overlap with screening buffer for underwater noise impacts only (100 km). The construction of Flora Floating Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Aspen Floating Wind Farm	Pre-Planning	85.61	Aspen Floating Wind Farm is proposed for up to 1,350 MW.	Unknown	Unknown	Spatial overlap with screening buffer for underwater noise impacts only (100 km). The construction of Aspen Floating Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Cedar Floating Wind Farm	Pre-Planning	51.65	Cedar Floating Wind Farm is proposed for up to 1,008 MW.	Unknown	Unknown	Spatial overlap with screening buffer for underwater noise impacts only (100 km). The construction of Cedar Floating Wind Farm might overlap with the construction and operation and maintenance phases of the Array.
Morven Offshore Export Cable Corridor(s)	Pre-planning	5.50	Proposed offshore export cable corridor(s) for Morven Offshore Wind Farm	Unknown	Unknown	Spatial overlap with the screening (50 km) buffer. The construction of Morven Offshore Export Cable Corridor(s) might overlap with the construction and operation and maintenance phases of the Array.
Cables and Pipelines						
Eastern Green Link 3	Planned	Unknown	Transmission cable between Scotland and England (between Peterhead and Lincolnshire)	Unknown	Unknown	The construction of Eastern Green Link 3 might overlap with the construction and operation and maintenance phases of the Array.
Eastern Green Link 4	Planned	Unknown	Transmission cable between Scotland and England	Unknown	Unknown	The construction of Eastern Green Link 4 might overlap with the construction and operation and maintenance phases of the Array..

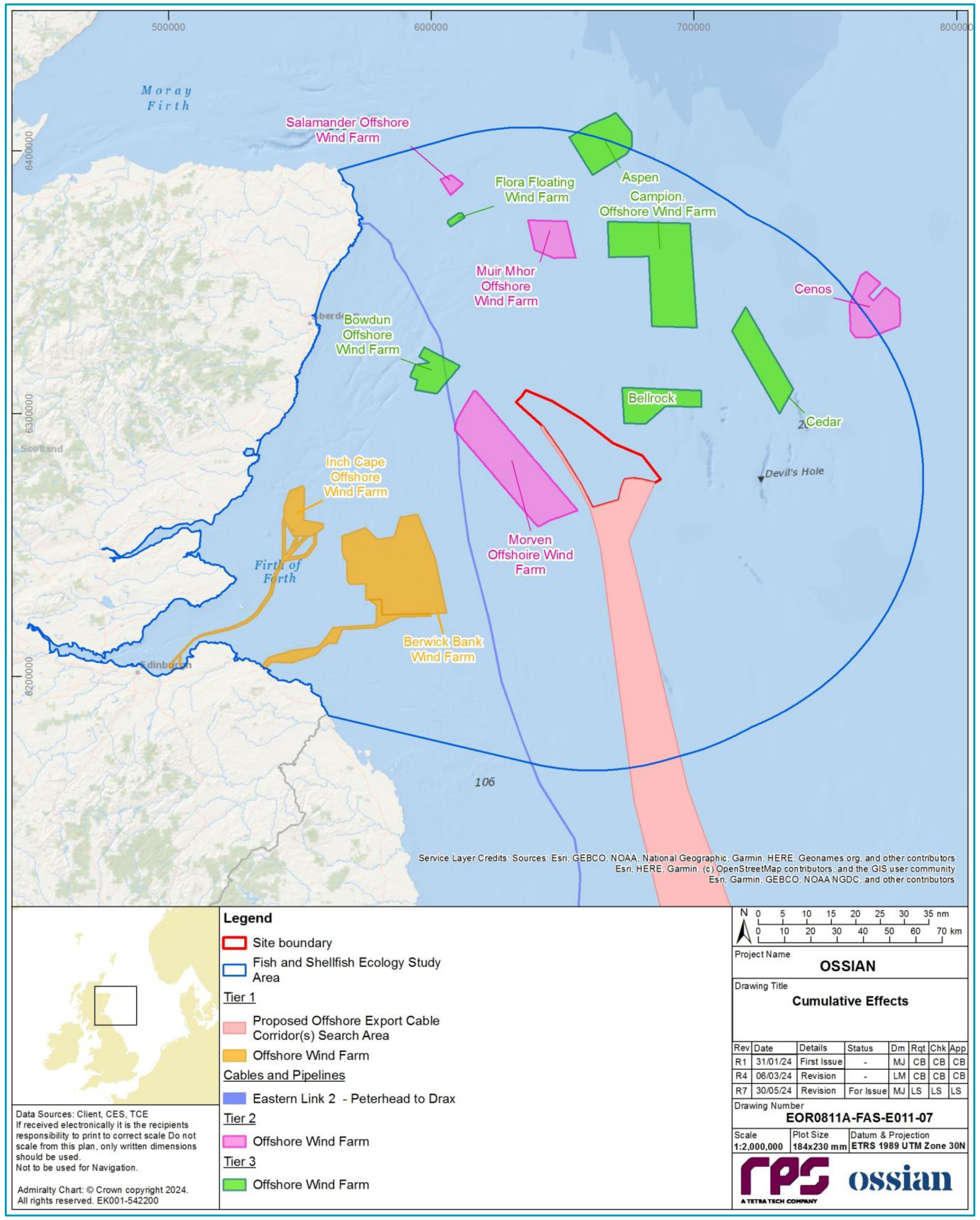

Figure 9.10: Other Projects/Plans Considered in the Cumulative Effects Assessment for Fish and Shellfish Ecology

9.12.2. MAXIMUM DESIGN SCENARIO

308. The MDS identified in Table 9.13 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. The cumulative effects presented and assessed in this section have been selected from the details provided in volume 1, chapter 3 of the Array EIA Report as well as the information available on other projects and plans (see volume 3, appendix 6.4), to inform a 'maximum design scenario'. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the Project Description (volume 1, chapter 3) (e.g. different wind turbine layout), to that assessed here, be taken forward in the final design scheme.

309. All impacts for the project alone (Table 9.13) have been assessed within the CEA with the exception of increased SSCs and associated deposition during the operation and maintenance phase. This is due to the limited scale of impacts associated with the mooring lines in contact with the seabed during the operation and maintenance phase (each mooring line in seabed contact being of 680 m length (volume 2, chapter 7). Similarly, effects of underwater noise from wind turbine operation were predicted to have a negligible effect on fish and shellfish IEFs due to the highly localised area in which effects could occur. As such, there is no potential for cumulative effects from these impacts.

Table 9.31: Maximum Design Scenario Considered for Each Impact as Part of the Assessment of Likely Significant Cumulative Effects on Fish and Shellfish Ecology

Potential Cumulative Effect	Phase[5] C	O	D	Tier	Maximum Design Scenario
Temporary habitat loss and disturbance	✓	✓	×	1	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Site Preparation and Construction Phases** • Proposed offshore export cable corridor(s) **Operation and Maintenance Phase** • Proposed offshore export cable corridor(s); and • Eastern Green Link 2 **Decommissioning Phase** There are currently no known projects which will result in a cumulative effect during the decommissioning phase of the Array, although the magnitude of the impact is likely to be similar or less than during the construction phase.
	✓	✓	×	2	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Site Preparation and Construction Phases** • Morven Offshore Wind Farm; and • Tier 1 projects. **Operation and Maintenance Phase** • Morven Offshore Wind Farm; and • Tier 1 projects. **Decommissioning Phase** There are currently no known projects which will result in a cumulative effect during the decommissioning phase of the Array, although the magnitude of the impact is likely to be similar or less than during the construction phase.

[5] C = Construction, O = Operation and maintenance, D = Decommissioning.

Potential Cumulative Effect	Phase[5] C	O	D	Tier	Maximum Design Scenario
	✓	✓	×	3	**Site Preparation and Construction Phases** • Morven Offshore Export Cable Corridor(s); • Bellrock Offshore Wind Farm; • Bowdun Offshore Wind Farm; • Campion Offshore Wind Farm; • Eastern Green Link 3; • Eastern Green Link 4; and • Tier 1 and Tier 2 projects. **Operation and Maintenance Phase** • Morven Offshore Export Cable Corridor(s); • Bellrock Offshore Wind Farm; • Bowdun Offshore Wind Farm; • Campion Offshore Wind Farm; • Eastern Green Link 3; • Eastern Green Link 4; and • Tier 1 and Tier 2 projects. **Decommissioning Phase** There are currently no known projects which will result in a cumulative effect during the decommissioning phase of the Array, although the magnitude of the impact is likely to be similar or less than during the construction phase.
Long term habitat loss and disturbance	✓	✓	×	1	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Construction and Operation and Maintenance Phases** • Proposed offshore export cable corridor(s); and • Eastern Green Link 2. **Decommissioning Phase** There are currently no known projects which will result in a cumulative effect during the decommissioning phase of the Array, although the magnitude of the impact is likely to be similar or less than during the construction phase.
	✓	✓	×	2	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Construction and Operation and Maintenance Phases** • Morven Offshore Wind Farm; and • Tier 1 projects. **Decommissioning Phase** There are currently no known projects which will result in a cumulative effect during the decommissioning phase of the Array, although the magnitude of the impact is likely to be similar or less than during the construction phase.

Potential Cumulative Effect	Phase[5] C	O	D	Tier	Maximum Design Scenario
	✓	✓	×	3	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Construction and Operation and Maintenance Phases** • Morven Offshore Export Cable Corridor(s); • Bellrock Offshore Wind Farm; • Bowdun Offshore Wind Farm; • Campion Offshore Wind Farm; • Eastern Green Link 3; • Eastern Green Link 4; and • Tier 1 and Tier 2 projects. **Decommissioning Phase** There are currently no known projects which will result in a cumulative effect during the decommissioning phase of the Array, although the magnitude of the impact is likely to be similar or less than during the construction phase.
Colonisation of hard structures	×	✓	×	1	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Operation and Maintenance Phase** • Proposed offshore export cable corridor(s); and • Eastern Green Link 2.
	×	✓	×	2	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Operation and Maintenance Phase** • Morven Offshore Wind Farm; and • Tier 1 projects.
	×	✓	×	3	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Operation and Maintenance Phase** • Morven Offshore Export Cable Corridor(s); • Bellrock Offshore Wind Farm; • Bowdun Offshore Wind Farm; • Campion Offshore Wind Farm; • Eastern Green Link 3; • Eastern Green Link 4; and • Tier 1 and Tier 2 projects.
Underwater noise from piling and UXO clearance impacting fish and shellfish receptors	✓	×	×	1	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Construction Phase** • Proposed offshore export cable corridor(s); and • Berwick Bank Offshore Wind Farm.
	✓	×	×	2	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Construction Phase** • Morven Offshore Wind Farm; • Cenos Offshore Wind Farm; • Salamander Offshore Wind Farm; and • Tier 1 projects.

Potential Cumulative Effect	Phase[5] C	O	D	Tier	Maximum Design Scenario
	✓	×	×	3	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Construction Phase** • Morven Offshore Export Cable Corridor(s); • Bellrock Offshore Wind Farm; • Bowdun Offshore Wind Farm; • Campion Offshore Wind Farm; • Cedar; • Flora Floating Wind Farm; • Aspen; and • Tier 1 and Tier 2 projects.
Effects to fish and shellfish receptors due to EMF from subsea electrical cabling	×	✓	×	1	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Operation and Maintenance Phase** • Proposed offshore export cable corridor(s); and • Eastern Green Link 2.
	×	✓	×	2	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Operation and Maintenance Phase** • Morven Offshore Wind Farm; and • Tier 1 projects.
	×	✓	×	3	The MDS is as described above for the Array alone (Table 9.13) and has been assessed cumulatively with the following plans and projects: **Operation and Maintenance Phase** • Morven Offshore Export Cable Corridor(s); • Bellrock Offshore Wind Farm; • Bowdun Offshore Wind Farm; • Campion Offshore Wind Farm; • Eastern Green Link 3; • Eastern Green Link 4; and • Tier 1 and Tier 2 projects.

9.12.3. CUMULATIVE EFFECTS ASSESSMENT

310. An assessment of the likely significance of the cumulative effects of the Array upon fish and shellfish ecology receptors arising from each identified impact is given below.

TEMPORARY HABITAT LOSS AND DISTURBANCE

311. There is potential for cumulative temporary habitat loss and disturbance because of activities associated with the Array and the other plans and projects. Activities include sand wave and boulder clearance and relocation, cable installation, jack up vessel use, and cable repair and reburial and similar activities associated with the projects considered. For the purposes of this Array EIA Report, this impact has been assessed using the tiered approach outlined in section 9.9. The plans and projects screened into the CEA for this impact and their respective tiers are outlined in Table 9.30. Cumulative habitat loss and disturbance is not considered for decommissioning as there is insufficient information to determine the decommissioning programme of plans/projects screened into the CEA, however the magnitude of impact is likely to be similar to, or less than, the cumulative effect of construction.

Tier 1

Construction phase

Magnitude of impact

312. There was one Tier 1 project identified with potential for cumulative effects associated with this impact during the site preparation and construction phase:

- Proposed offshore export cable corridor(s) (Table 9.30).

313. Currently, there is no EIA Report available for the Proposed offshore export cable corridor(s), though site preparation and construction phase activities for the Proposed offshore export cable corridor(s) are expected to be of a lesser extent than those represented by the MDS for the Array alone, which represented up to 40.41 km^2 of temporary habitat loss and disturbance (Table 9.13). Further, (as outlined in paragraph 64 for the Array alone), the impacts of cable installation and seabed preparation are expected to be temporary and reversible following completion of construction operations.

314. Other activities associated with the Array during this phase are not likely to occur within the Tier 1 project, such as jack up vessel use and temporary wet storage. The cumulative magnitude of impact of the Array with the Tier 1 project represents no additional material impact than that defined for the assessment of the Array alone (section 9.11).

315. The maximum duration of the offshore construction phase for the Array is up to eight years (2031 to 2038), and between 2030 and 2037 for the Proposed offshore export cable corridor(s) (Table 9.30). Therefore, there may be seven years of overlap between the site preparation and construction activities of the Array and the Proposed offshore export cable corridor(s). Given the reversibility of temporary habitat loss and disturbance and the fact that construction operations would only affect a small proportion of the total habitat loss and disturbance footprint at any one time, any cumulative impacts with the Tier 1 project may be of a lesser spatial extent than if the temporal overlap between site preparation and construction activities was longer.

316. Within this phase of development of the Array, site preparation and construction activities are anticipated to occur intermittently; activities will be spread across the full allotted timeframe with only a small proportion of the MDS footprint for this impact being affected at any one time.

317. The cumulative impact is predicted to be of local spatial extent, medium term duration (between 2031 to 2038), intermittent, and of high reversibility. It is predicted that the impact will affect the receptors directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

318. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 70 *et seq.*)

Significance of effect

319. For marine and shellfish species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

320. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms.

321. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

322. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Operation and maintenance phase

323. There were two Tier 1 projects identified with potential for cumulative effects associated with this impact:

- Proposed offshore export cable corridor(s); and
- Eastern Green Link 2 (Table 9.30).

324. Whilst there is currently no EIA Report available for the Proposed offshore export cable corridor(s), the activities and footprints of disturbance associated with its site preparation and construction phase are expected to be similar to those of the Eastern Green Link 2 project (discussed below), given both projects are both HVDC subsea power cables. Site preparation and construction phase activities for the Proposed offshore export cable corridor(s) are expected to be of a lesser extent than those represented by the MDS for the Array alone, which represented up to 51.41 km^2 of temporary habitat loss and disturbance (Table 9.13). Further, (as outlined in paragraph 64 for the Array alone), the impacts of operation and maintenance activities (including cable repair and remedial burial) are expected to be temporary and reversible.

325. Site preparation and construction activities at the Eastern Green Link 2 project are planned to occur between 2024 to 2029, so will not overlap with this phase of the Array (Table 9.30). Within the Environmental Appraisal Report for the Eastern Green Link 2, no values were provided for temporary habitat loss and disturbance during its operation and maintenance phase (which coincides with the site preparation and construction phase of the Array). However, it would be substantially lower than the MDS value of 15.2 km^2 provided for the site preparation and construction phase (Table 9.23); (National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc, 2022).

326. Other activities associated with the Array during this phase are not likely to occur within the Tier 1 projects, such as jack up vessel use and temporary wet storage. The cumulative magnitude of impact of the Array with the Tier 1 projects represents no additional material impact than that defined for the assessment of the Array alone (paragraphs 63 *et seq.*).

327. Any operation and maintenance phase activities (e.g. cable repair or cable reburial) will only affect a small proportion of habitats at any one time.

328. The cumulative impact is predicted to be of local spatial extent, long term duration), intermittent, and of high reversibility. It is predicted that the impact will affect the receptors directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

329. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 70 *et seq.*)

Significance of effect

330. For marine and shellfish species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

331. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms.

332. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

333. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 2

Construction phase

Magnitude of impact

334. In addition to the Tier 1 projects, there was one Tier 2 project identified with potential for cumulative LSE[1] associated with this impact: the site preparation and construction phases of the Morven Offshore Wind Farm (Table 9.30). According to the Morven Offshore Wind Farm Scoping Report, site preparation and construction activities applicable to this impact for the Morven Offshore Wind Farm are expected to be:

- site preparation (sand wave clearance and boulder clearance and relocation);
- cable installation; and
- jack up vessel use for infrastructure installation (Morven Offshore Wind Limited, 2023).

335. Unlike for the Array, there is no offshore temporary wet storage included within the Scoping Report for Morven Offshore Wind Farm (Morven Offshore Wind Limited, 2023). Otherwise, temporary habitat loss and disturbance impacts associated with the Morven Offshore Wind Farm are expected to be similar in nature and extent to the Array. As outlined in paragraphs 155 to 157 for the Array alone, the impacts of site preparation and construction activities are expected to be temporary and reversible. The cumulative magnitude of the Tier 2 assessment represents no additional material impact to that defined for the assessment of the Array alone (paragraphs 63 *et seq.*)

336. The maximum duration of the offshore construction phase for the Array is up to eight years (2031 to 2038), and between 2027 to 2033 for the Morven Offshore Wind Farm (Table 9.30). Therefore, there will not be significant overlap between the site preparation and construction activities of the Array and Morven Offshore Wind Farm (two years). Given the reversibility of temporary habitat loss and disturbance, and the fact that construction operations would only affect a small proportion of the total habitat loss and disturbance footprint at any one time any cumulative impacts with the Morven Offshore Wind Farm may be of a lesser spatial extent than if the temporal overlap between site preparation and construction activities was longer.

337. The cumulative impact is predicted to be of local spatial extent, medium term duration (between 2031 to 2038), intermittent, and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

338. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 70 *et seq.*)

Significance of effect

339. For marine and shellfish species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

340. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms. This is largely due to the area of unsuitable habitat for sandeel, that sandeel spawning grounds within the fish and shellfish ecology area is of low intensity and because modelling shows the abundance of buried sandeel to be very low.

341. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

342. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Operation and maintenance phase

Magnitude of impact

343. In addition to the Tier 1 projects, there was one Tier 2 project identified with potential for cumulative effects associated with this impact: the operation and maintenance phase of the Morven Offshore Wind Farm (Table 9.30). As with the Array, operation and maintenance activities applicable to this impact for the Morven Offshore Wind Farm are expected to include cable repair and reburial and the use of jack up vessels for operation and maintenance activities (Morven Offshore Wind Limited, 2023). Within the Scoping Report for Morven Offshore Wind Farm, it is stated that the extent of these activities is expected to be lower than that of the site preparation and construction phase (Morven Offshore Wind Limited, 2023).

344. For the Array, up to 51.41 km^2 of temporary habitat loss and disturbance may occur due to operation and maintenance activities (Table 9.13) although only a small proportion of this total footprint is likely to be impacted at any one time.

345. The cumulative spatial extent of this impact in the operation and maintenance phase therefore likely to be small in relation to the fish and shellfish ecology study area in which cumulative effects have been considered, although there is the potential for repeated disturbance to the habitats in the immediate vicinity infrastructure and cables. The cumulative magnitude of impact of the Tier 2 assessment represents no additional material impact than that defined for the assessment of the Array alone (paragraphs 63 *et seq.*)

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

Sensitivity of receptor

347. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 70 *et seq.*)

Significance of effect

348. For marine and shellfish species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

349. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms. This is largely due to the area of unsuitable habitat for sandeel, that sandeel spawning grounds within the fish and shellfish ecology area is of low intensity and because modelling shows the abundance of buried sandeel to be very low.

350. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

351. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 3

Construction phase

Magnitude of impact

352. In addition to the Tier 1 and Tier 2 projects, there were six Tier 3 projects identified with potential for cumulative effects associated with this impact:

- Morven Offshore Export Cable Corridor(s);
- Bellrock Offshore Wind Farm;
- Bowdun Offshore Wind Farm;
- Campion Offshore Wind Farm;
- Eastern Green Link 3; and
- Eastern Green Link 4 (Table 9.30).

353. As these are Tier 3 projects, there are no Scoping Reports in the public domain. Therefore, there is no information available on the impact that these Tier 3 projects will have on fish and shellfish ecology. Temporary habitat loss and disturbance impacts associated the Bellrock, Bowdun and Campion Offshore Wind Farms are expected to be similar in nature and extent to the Array. As outlined in paragraphs 126 to 128 for the Array alone, the impacts of site preparation and construction activities are expected to be temporary and reversible. The impacts of cable installation, seabed preparation, and jack up vessel use are likely to be reversible. The cumulative magnitude of impact of the Tier 3 assessment represents no additional material impact to that defined for the assessment of the Array alone (paragraphs 63 *et seq.*)

354. Impacts associated with the Morven Offshore Export Cable Corridor(s) and Eastern Green Link 3 and 4 are likely to be similar to those assessed in Tier 1 for the Proposed offshore export cable corridor(s) and Eastern Green Link 2 (see paragraphs 312 *et seq.*).

355. The maximum duration of the offshore construction phase for the Array is up to eight years (2031 to 2038). There are currently no dates available for the construction phase of various Tier 3 projects. Therefore, there may be minimal overlap between the site preparation and construction activities of the Array and that of the Tier 3 projects (Table 9.30).

356. The cumulative impact is predicted to be of local spatial extent, medium term duration (between 2031 and 2038 for the Array's site preparation and construction), intermittent, and of high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

357. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 70 *et seq.*)

Significance of effect

358. For marine and shellfish species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

359. For sandeel, the cumulative magnitude of the impact is deemed to be low, and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms. This is largely due to the area of unsuitable habitat for sandeel, that sandeel

spawning grounds within the fish and shellfish ecology area is of low intensity and because modelling shows the abundance of buried sandeel to be very low.

360. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

361. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Operation and maintenance phase

Magnitude of impact

362. In addition to the Tier 1 and Tier 2 projects, there were six Tier 3 projects identified with potential for cumulative effects associated with this impact:

- Morven Offshore Export Cable Corridor(s);
- Bellrock Offshore Wind Farm;
- Bowdun Offshore Wind Farm;
- Campion Offshore Wind Farm;
- Eastern Green Link 3; and
- Eastern Green Link 4 (Table 9.30).

363. As these are Tier 3 projects, there are no Scoping Reports or EIA documents available in the public domain. Therefore, there is no information available on the impact that these Tier 3 projects will have on fish and shellfish ecology. The activities associated with Bellrock, Bowdun, and Campion Offshore Wind Farms are likely to be similar to those of the Array (paragraphs 126 to 128). These activities include cable repair and reburial and use of jack up vessels for infrastructure maintenance. There are currently no dates available for the construction phase of various INTOG projects, though are of small scale (3 MW to 1,350 MW; Table 9.30) compared to the Array.

364. For the Array, up to 51.41 km^2 of temporary habitat loss and disturbance may occur due to operation and maintenance activities (Table 9.13). Temporary habitat loss and disturbance impacts associated the Bellrock Offshore Wind Farm, Bowdun Offshore Wind Farm, and Campion Offshore Wind Farm are expected to be similar in nature and extent to the Array. As outlined in paragraphs 126 to 128 for the Array alone, the impacts of operation and maintenance phase activities are expected to be temporary and reversible, and only a small proportion of habitat will be affected at any one time, with recovery of sediments occurring following installation of infrastructure.

365. Impacts associated with the Morven Offshore Export Cable Corridor(s) and Eastern Green Link 3 and 4 are likely to be similar to those assessed in Tier 1 for the Proposed offshore export cable corridor(s) and Eastern Green Link 2 (see paragraphs 323 *et seq*.).

366. The cumulative spatial extent of this impact in the operation and maintenance phase likely to be small in relation to the whole fish and shellfish ecology study area, although there is the potential for repeated disturbance to the habitats in the immediate vicinity infrastructure and cables. The cumulative magnitude of impact for Tier 3 represents no additional material impact to that defined for the assessment of the Array alone (paragraphs 63 *et seq*.)

367. The cumulative impact is predicted to be of local spatial extent, long term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

368. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 70 *et seq.*)

Significance of effect

369. For marine and shellfish species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of most fish IEFs (including herring) is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

370. For sandeel, the cumulative magnitude of the impact is deemed to be low, and the sensitivity is considered to be medium. The effect will, therefore, be of **minor** adverse significance which is not significant in EIA terms. This is largely due to the area of unsuitable habitat for sandeel, that sandeel spawning grounds within the fish and shellfish ecology area is of low intensity and because modelling shows the abundance of buried sandeel to be very low.

371. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

372. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

LONG TERM HABITAT LOSS AND DISTURBANCE

373. There is potential for cumulative long term habitat loss and disturbance due to infrastructure installed during the construction of the Array and the other plans and projects given in Table 9.30. This long term habitat loss and disturbance will persist into the operation and maintenance phase as infrastructure is installed, and as such, the construction and operation and maintenance phases have been assessed together. Infrastructure installed includes foundations, scour protection, cable protection, cable crossing protection, junction boxes, mooring lines, and anchors. For the purposes of this Array EIA Report, this impact has been assessed using the tiered approach outlined in 9.12.1. The plans and projects screened into the CEA for this impact and their respective tiers are outlined in Table 9.31.

Tier 1

All phases

Magnitude of impact

374. There were two Tier 1 projects identified with potential for cumulative LSE[1] associated with this impact:

- all phases of the Proposed offshore export cable corridor(s); and
- the operation and maintenance and decommissioning phases of the Eastern Green Link 2 (Table 9.31).

375. There is currently no EIA Report available for the Proposed offshore export cable corridor(s). However, given that the Proposed offshore export cable corridor(s) is a HDVC subsea power cable, it is expected that the amount of infrastructure installed which may constitute long term habitat loss will be lower than

that for the Array. It is likely that long term habitat loss will occur at the Tier 1 projects because of cable protection and crossing protection.

376. For the Array, up to 19.27 km^2 of long term habitat loss and disturbance may occur due to the installation of infrastructure, and an additional 778,464 m^2 due to long term seabed disturbance from mooring lines and dynamic cabling (Table 9.13). Within the Environmental Appraisal Report for the Eastern Green Link 2, a total footprint of up to 2.20 km^2 long term habitat loss and disturbance was predicted to occur (Table 9.32) (National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc, 2022). It should be noted that footprint of long term habitat loss associated with the Eastern Green Link 2 will be spread out over a large portion of the North Sea (see Figure 9.10, therefore will be substantially far from that of the Array at points (i.e. much of the habitat loss would occur outside the fish and shellfish ecology study area). This was comprised of up to 2 km^2 of rock berm and up to 0.2 km^2 of pipeline and cable crossing protection (National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc, 2022).

Table 9.32: Cumulative Footprint of Long Term Habitat Loss and Disturbance (km^2) for the Tier 1 Projects

Project	Total Footprint of Long Term Habitat Loss and Disturbance (km^2)	Reference
The Array	20.08 (comprised of 19.27 km^2 + 778,464 m^2)	Table 9.13
Eastern Green Link 2	2.20	National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc (2022)
Proposed offshore export cable corridor(s)	Not available, but likely to be of a similar magnitude to that of Eastern Green Link 2 due to the similarities between these two Tier 1 projects.	N/A
Total	**22.28**	

377. This impact presents some measurable but minor long term loss of and alteration to the affected areas of seabed within the entire fish and shellfish ecology study area and wider North Sea as a whole. The cumulative magnitude of impact of the Array with the Tier 1 projects represents no additional material impact than that defined for the assessment of the Array alone (paragraphs 108 *et seq.*). Following decommissioning, many of the hard structures (e.g. scour and cable protection) may be left *in situ*. Therefore, the long term habitat loss effect may persist beyond decommissioning. However, at this stage, it is not possible to quantify the extent of this habitat loss using the MDS methodology.

378. The cumulative impact is predicted to be of local spatial extent, long term duration, continuous and of low reversibility within the construction and operation and maintenance phase. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

379. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 112 *et seq.*).

Significance of effect

380. For most fish and shellfish IEF species (including herring), the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

381. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

382. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

383. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 2

<u>All phases</u>

384. In addition to the Tier 1 projects, there was one Tier 2 project identified with potential for cumulative LSE[1] associated with this impact: the operation and maintenance and decommissioning phases of Morven Offshore Wind Farm (Table 9.30). According to the Morven Offshore Wind Farm Scoping Report, infrastructure associated with long term habitat loss and disturbance is expected to include foundations, scour protection, cable protection, and cable crossing protection, although further detail on extents and footprints was not provided in the Scoping Report for Morven Offshore Wind Farm (Morven Offshore Wind Limited, 2023).

385. For the Array, up to 19.27 km^2 of long term habitat loss and disturbance may occur due to the installation of infrastructure, and an additional 778,464 m^2 due to long term seabed disturbance from mooring lines and dynamic cabling (Table 9.13). Long term habitat loss and disturbance impacts associated with the Morven Offshore Wind Farm are expected to be similar in nature and extent to the Array, with the exception of the fixed foundations at Morven Offshore Wind Farm, of which the extent of habitat loss is not possible to quantify at this stage using the MDS methodology. As outlined in paragraphs 87 *et seq.* for the Array alone, the impacts of site preparation and construction and operation and maintenance activities are expected to be temporary and reversible, the cumulative magnitude of impact is still not expected to represent additional material impact than that defined for the assessment of the Array alone (paragraphs 108 *et seq.*) because it represents only a small proportion of the habitats within the fish and shellfish ecology study area and the wider North Sea area.

386. Following decommissioning, many of the hard structures (e.g. scour and cable protection) may be left *in situ*. Therefore, the long term habitat loss effect may persist beyond decommissioning. At this stage, it is not possible to quantify the extent of this habitat loss due to a lack of an accurate MDS for these projects, however when considering experience from other similar projects it is considered likely that impacts from scour and cable protection would be localised to small discrete areas representing a very small proportion of seabed within project boundaries.

387. The cumulative impact is predicted to be of local spatial extent, long term duration, continuous and of low reversibility within the construction and operation and maintenance phase. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

388. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 112 *et seq.*).

Significance of effect

389. For most fish and shellfish IEF species (including herring), the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

390. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

391. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

392. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 3

All phases

Magnitude of impact

393. In addition to the Tier 1 and Tier 2 projects, there were six Tier 3 projects identified with potential for cumulative effects associated with this impact:

- Morven Offshore Export Cable Corridor(s);
- Bellrock Offshore Wind Farm;
- Bowdun Offshore Wind Farm; and
- Campion Offshore Wind Farm;
- Eastern Green Link 3; and
- Eastern Green Link 4 (Table 9.30).

394. As these are Tier 3 projects, there are no Scoping Reports or EIA documents publicly available. Therefore, there is no information available on the impact that these Tier 3 projects will have on fish and shellfish ecology.

395. For the Array, up to 19.27 km^2 of long term habitat loss and disturbance may occur due to the installation of infrastructure, and an additional 778,464 m^2 due to long term seabed disturbance from mooring lines and dynamic cabling (Table 9.13). The three Tier 3 offshore wind farms are either fully floating or containing some floating wind turbines, similar to the Array, which is a fully floating project. Long term habitat loss and disturbance impacts associated with Bellrock Offshore Wind Farm, Bowdun Offshore Wind Farm and Campion Offshore Wind Farm are expected to be similar in nature and extent to the Array, with the exception of the fixed foundations at Bowdun Offshore Wind Farm, of which the extent of habitat loss is not possible to quantify using the MDS methodology at this stage. As outlined in paragraphs 87 *et seq*. for the Array alone, the impacts of site preparation and construction and operation and maintenance activities are expected to be temporary and reversible.

396. Impacts associated with the Morven Offshore Export Cable Corridor(s) and Eastern Green Link 3 and 4 are likely to be similar to those assessed in Tier 1 for the Proposed offshore export cable corridor(s) and Eastern Green Link 2 (see paragraphs 374 *et seq.*).

397. Following decommissioning, many of the hard structures (e.g. scour and cable protection) may be left *in situ*. Therefore, the long term habitat loss impact may persist beyond decommissioning. At this stage, it is not possible to quantify the extent of this habitat loss using the MDS methodology, however when considering experience from other similar projects it is considered likely that impacts from scour and cable protection would be localised to small discrete areas representing a very small proportion of seabed within project boundaries

398. The cumulative spatial extent of this impact in the construction and operation and maintenance phase likely to be small in relation to the whole fish and shellfish ecology study area. The cumulative magnitude of impact of the Tier 3 assessment is not expected to represent additional material impact than that defined for the assessment of the Array alone (paragraphs 108 *et seq.*).

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

Sensitivity of receptor

400. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 112 *et seq.*).

Significance of effect

401. For most fish and shellfish IEF species (including herring), the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

402. For sandeel, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

403. For diadromous species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

404. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

COLONISATION OF HARD STRUCTURES

405. The introduction of the hard structures at the Array and the other projects may potentially affect fish and shellfish ecology receptors by providing new habitat and ecosystem function in areas typically otherwise characterised by soft, sedimentary environments, essentially replicating naturally occurring rocky habitats (Karlsson *et al.*, 2022). Hard structures include foundations, scour protection, cable protection, cable crossing protection, and subsea junction boxes. These artificial hard structures are expected to be colonised by a range of organisms, which could lead to local biodiversity increases which may be beneficial to some fish and shellfish (particularly demersal generalists) or be detrimental to others (such as sandeel and crabs, during certain life history stages when they bury into the seabed). For the purposes of this Array EIA Report, this impact has been assessed using the tiered approach outlined in section9.12.1. The plans and projects screened into the CEA for this impact and their respective tiers are outlined in Table 9.31.

Tier 1

All phases

Magnitude of impact

406. There were two Tier 1 projects identified with potential for cumulative LSE[1] associated with this impact:

- Proposed offshore export cable corridor(s); and
- Eastern Green Link 2 (Table 9.31).

407. There is currently no Offshore EIA Report available for the Proposed offshore export cable corridor(s). However, given that the Proposed offshore export cable corridor(s) and Proposed onshore transmission infrastructure is a HDVC subsea power cable, it is expected that the amount of infrastructure installed which may lead to colonisation of hard structures will be lower than that for the Array. The preferred means of cable protection for the Proposed offshore export cable corridor(s) would be burial, with rock protection required at crossing points or where target burial depth cannot be achieved. It is likely that colonisation of hard structures will occur at the Tier 1 projects because of cable protection and crossing protection.

408. Within the Environmental Appraisal Report for the Eastern Green Link 2, a total footprint of up to 2.20 km^2 of artificial hard substrates was predicted to be installed (Table 9.33), comprised of up to 2 km^2 of rock berm and up to 0.2 km^2 of pipeline and cable crossing protection (National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc, 2022). For the Proposed offshore export cable corridor(s), the area of installed hard substrate is expected to be similar to that of the Eastern Green Link 2, given the similarity in nature of the two Tier 1 projects, although it is not possible to accurately quantify the extent of the footprint at this time. The cumulative spatial extent of this impact in the operation and maintenance phase therefore likely to be small in relation to the whole fish and shellfish ecology study area.

Table 9.33: Cumulative Footprint of Hard Structures Installed (km^2) for the Tier 1 Projects

Project	Total Footprint of Hard Substrates Installed (km^2)	Reference
The Array	19.27	Table 9.13
Eastern Green Link 2	2.20	National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc (2022)
Proposed offshore export cable corridor(s)	Not available, but likely to be of a similar magnitude to that of Eastern Green Link 2 due to the similarities between these two Tier 1 projects.	N/A
Total	**21.47**	

409. It is expected that these artificial hard structures will be colonised by epifaunal species local to the fish and shellfish ecology study area. However, this impact will represent a shift in the baseline seabed conditions from soft to hard substrate in the areas where the infrastructure is installed. This could result in beneficial effects, such as increased biodiversity, greater shelter/protection opportunities, greater prey availabilities and potential reef effects (Bender *et al.,* 2020; Langhamer and Wihelmsson, 2009).

410. Although this impact is expected to be beneficial in terms of increasing biodiversity and enhancing reef effects, the installation of hard structures will result in habitat loss for subtidal sands and gravels, which may be suitable burial substrate for species like edible crab and sandeel. However, given the wide availability of such habitats over the fish and shellfish ecology study area and wider North Sea, and the localised nature of this impact, this impact is only expected to result in minor loss or alteration to the soft bottom sediments. The cumulative magnitude of impact of the Array with the Tier 1 projects is not expected to represent additional material impact than that defined for the assessment of the Array alone (paragraph 138).

411. Following decommissioning, many of the hard structures (e.g. scour and cable protection) may be left *in situ*. Therefore, colonisation on these hard structures may persist beyond decommissioning. However, at this stage, it is not possible to quantify the extent of this colonisation effect using the MDS methodology.

412. Overall, for all IEFs, the cumulative impact is predicted to be of local spatial extent, long term duration, continuous, and low reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

413. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 139 *et seq.*).

Significance of effect

414. Some fish species may benefit from the colonisation of hard structures, whereas others (more likely to be less mobile, demersal species, may be adversely affected. Overall, for fish and shellfish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. At worst, the effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms, though could be minor beneficial for some species. This is likely to be a conservative prediction as there is some evidence (although with uncertainties) that some fish and shellfish populations are likely to benefit from introduction of hard structures.

415. For diadromous fish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

416. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 2

All phases

Magnitude of impact

417. In addition to the Tier 1 projects, there was one Tier 2 project identified with potential for cumulative effects associated with this impact: the operation and maintenance phase of Morven Offshore Wind Farm (Table 9.30). According to the Morven Offshore Wind Farm Scoping Report, hard structures installed at the Morven Offshore Wind Farm are expected to include foundations, scour protection, and cable protection (Morven Offshore Wind Limited, 2023).

418. For the Array, up to 19.27 km^2 of hard structures may be installed (Table 9.13). Colonisation of hard structures associated with the Morven Offshore Wind Farm are expected to be similar in nature and extent to the Array, with the exception of the fixed foundations at Morven Offshore Wind Farm, of which the extent of habitat loss is not possible to quantify at this stage using the MDS methodology). As outlined in paragraphs 155 to 157 for the Array alone, the impacts of site preparation and construction and operation and maintenance activities are expected to be of local spatial extent, long term duration, continuous, and low reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

419. As per the Tier 1 assessment, it is expected that the hard structures will be colonised by local epifauna, but will still represent a shift in the baseline conditions from soft sediments to hard substrate, which could be beneficial for some fish and shellfish ecology receptors (Bender *et al.,* 2020; Langhamer and Wihelmsson, 2009).

420. Following decommissioning, many of the hard structures (e.g. scour and cable protection) may be left *in situ*. Therefore, colonisation on these hard structures may persist beyond decommissioning. However, at this stage, it is not possible to quantify the extent of this colonisation effect using the MDS methodology.

421. Overall, for all IEFs, the cumulative impact is predicted to be of local spatial extent, long term duration, continuous, and low reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

422. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 139 *et seq.*).

Significance of effect

423. Some fish species may benefit from the colonisation of hard structures, whereas others (more likely to be less mobile, demersal species, may be adversely affected. Overall, for fish and shellfish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. At worst, the effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms, though could be minor beneficial for some species. This is likely to be a conservative prediction as there is some evidence (although with uncertainties) that some fish and shellfish populations are likely to benefit from introduction of hard structures.

424. For diadromous fish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

425. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 3

<u>All phases</u>

Magnitude of impact

426. In addition to the Tier 1 and Tier 2 projects, there were six Tier 3 projects identified with potential for cumulative effects associated with this impact:

- Morven Offshore Export Cable Corridor(s);
- Bellrock Offshore Wind Farm;
- Bowdun Offshore Wind Farm;
- Campion Offshore Wind Farm;
- Eastern Green Link 3; and
- Eastern Green Link 4 (Table 9.30).

427. As these are Tier 3 projects, there are no Scoping Reports or EIA documents publicly available. Therefore, there is no information available on the impact that these Tier 3 projects will have on fish and shellfish ecology. For the Array, up to 19.27 km^2 of hard structures may be installed (Table 9.13). Colonisation of hard structures associated the Bellrock Offshore Wind Farm, Bowdun Offshore Wind Farm and Campion Offshore Wind Farm are expected to be similar in nature and extent to the Array. The cumulative magnitude of impact of the Tier 3 projects is not expected to represent additional material impact than that defined for the assessment of the Array alone (paragraph 138).

428. It is expected that the hard structures will be colonised by local epifauna but will still represent a shift in the baseline conditions from soft sediments to hard substrate, which could be beneficial for some fish and shellfish ecology receptors. However, this is expected to have beneficial effects, such as increased biodiversity and reef effects (Bender *et al.*, 2020; Langhamer and Wihelmsson, 2009). Although a shift from soft sediments to hard structures will constitute habitat loss for the offshore subtidal sands and gravels, which may provide suitable substrate for burying crabs and sandeel, for example, the localised nature of the footprints is likely to only result in a minor loss to the soft bottom substrates in the fish and shellfish ecology study area and wider North Sea as a whole.

429. Impacts associated with the Morven Offshore Export Cable Corridor(s) and Eastern Green Link 3 and 4 are likely to be similar to those assessed in Tier 1 for the Proposed offshore export cable corridor(s) and Eastern Green Link 2 (see paragraphs 406 *et seq.*).

430. Following decommissioning, many of the hard structures (e.g. scour and cable protection) may be left *in situ*. Therefore, colonisation on these hard structures may persist beyond decommissioning. However, at this stage, it is not possible to quantify the extent of this colonisation effect using the MDS methodology.

431. Overall, for all IEFs, the cumulative impact is predicted to be of local spatial extent, long term duration, continuous, and low reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

432. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 139 *et seq.*).

Significance of effect

433. Some fish species may benefit from the colonisation of hard structures, whereas others (more likely to be less mobile, demersal species, may be adversely affected. Overall, for fish and shellfish, the cumulative

magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. At worst, the effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms, though could be minor beneficial for some species. This is likely to be a conservative prediction as there is some evidence (although with uncertainties) that some fish and shellfish populations are likely to benefit from introduction of hard structures.

434. For diadromous fish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, bye of **negligible to minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

435. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

UNDERWATER NOISE FROM PILING AND UXO CLEARANCE IMPACTING FISH AND SHELLFISH RECEPTORS

436. Underwater noise may arise from the Array's construction due to piling for the installation of wind turbines and OSPs, and due to UXO clearance. There is the potential for cumulative impacts from underwater noise generation as a result of the construction phase of the Array and other offshore developments, which may impact fish and shellfish ecology receptors. For the purposes of this Array EIA Report, this impact has been assessed using the tiered approach outlined in section 9.12.1. The plans and projects screened into the CEA for this impact and their respective tiers are outlined in Table 9.31.

Tier 1

Site preparation and construction phase

Magnitude of impact

437. There were two Tier 1 projects identified with potential for cumulative effects associated with this impact:

- Proposed offshore export cable corridor(s); and
- Berwick Bank Offshore Wind Farm (Table 9.30).

438. The MDS for the Array's construction is given in Table 9.13, which considers the greatest impact from underwater noise on fish and shellfish IEFs, based on the greatest hammer energy. This scenario is represented by the installation of up to 265 semi-submersible floating foundations, with up to six anchors per foundation and one 4.5 m diameter pile per anchor (1,590 piles) for wind turbines, and up to three large and 12 small jacket foundations (total 216 piles) for OSPs, with all piles installed via impact piling. Herring spawning grounds exist to the north of the Array, and low intensity spawning grounds for cod exist throughout the Array, which span out to the North Sea's offshore waters. This is also the case for sandeel and plaice spawning grounds.

439. Currently, there is no EIA Report available for the Proposed offshore export cable corridor(s), though construction is likely to be of medium term duration, with noise being intermittent. Although there is no information on construction activities associated with the Proposed offshore export cable corridor(s), it is not expected that piling will be included in the project description (as this is a cable project). As such, noise impacts which have the potential to affect fish and shellfish ecology receptors are limited to UXO clearance operations during site preparation. While there is no site-specific information on these impacts, it is expected they would be similar to those assessed for the project alone (paragraphs 155 to 157).

440. Berwick Bank Offshore Wind Farm's pre-construction phase will involve clearance of up to 15 UXOs (a maximum of 300 kg) within the inter-array area or offshore export cable route, and single donor charge of up to 80 g NEQ for each clearance event. Up to 500 g NEQ may be used for a clearance shot to neutralise residual explosive material, with up to two detonations within 24 hours and clearance occurring during daylight only (SSER, 2022a).

441. During the construction phase for the Berwick Bank Offshore Wind Farm, up to 179 piles jacket foundations with up to four legs per foundation (1,432 piles) have been assessed for wind turbines. The maximum hammer energy is up to 4,000 kJ with a realistic maximum hammer energy of 3,000 kJ. Two concurrent piling events will occur with a minimum of 900 m and maximum of 49.3 km distance between these two events. Up to ten hours of absolute maximum piling per pile may occur with a wind turbine piling duration of 14,320 hours and a realistic maximum of 12,888 hours.

442. During the construction phase for the Berwick Bank Offshore Wind Farm, up to eight jacket foundations with up to six legs per foundation (64 piles) have been assessed for OSPs/offshore converter substation platforms, with a maximum hammer energy of 4,000 kJ. Piling may occur for up to eight hours, with a total piling duration of 1,792 hours (realistic maximum) or 2,048 hours (absolute maximum). The total piling phase is over 52 months within a construction period of 96 months.

443. The Berwick Bank Offshore Wind Farm underwater noise assessment considered effects (including mortality, injury and behavioural effects) on a similar range of fish and shellfish receptors as the Array. In particular, the risks to sandeel and herring were considered in detail. In line with the assessment for the Array alone, the Berwick Bank Offshore Wind Farm assessment predicted that injury effects would be limited in extent and although behavioural effects would occur across a wider area, the effects would be temporary, reversible and would not result in significant effects on fish and shellfish receptors, including spawning or nursery habitats.

444. The construction of the Array, and of Berwick Bank Offshore Wind Farm, will coincide for only two years (2031 and 2032). Furthermore, due to the large distance between the projects (56.84 km), there is limited potential for noise contours to interact.

445. The cumulative impact of underwater noise on fish and shellfish ecology receptors during the construction phase is predicted to be of regional spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact may affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

446. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 168 *et seq.*).

Significance of effect

447. For most marine fish, diadromous fish, and shellfish, the cumulative magnitude of the impact is deemed to be low, and the sensitivity of most marine fish IEFs is considered low. The effect will, therefore, be of **minor** significance, which is not significant in EIA terms.

448. For herring, the cumulative magnitude of the impact is deemed to be low, and the sensitivity of herring is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms. This is due to the hearing sensitivity of herring, coupled with the presence of a small proportion of undetermined intensity spawning grounds within range of underwater sound levels which may give rise to limited behavioural effects, noting impacts are not expected to extend to the core herring spawning habitat.

Further mitigation and residual effect

449. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 2

Site preparation and construction phase

Magnitude of impact

450. In addition to the Tier 1 projects, three Tier 2 projects were identified with potential for cumulative effects associated with this impact:

- Morven Offshore Wind Farm (site preparation and construction phases);
- Cenos Offshore Wind Farm (construction); and
- Salamander Offshore Wind Farm (construction) (Table 9.30).

451. The MDS for the Array's construction is given in Table 9.13 and summarised in paragraph 438, which considers the greatest effect from underwater noise on fish and shellfish IEFs, based on the greatest hammer energy.

452. Currently, there is no EIA Report available for the Morven Offshore Wind Farm, although piling activities during the construction phase are expected to be similar in nature to that of the Array. Although information on hammer energies and piling durations are not available for the Morven Offshore Wind Farm, the impact is likely to be of medium term duration, with noise generation being intermittent during the construction phase.

453. No EIA Report is available for the Cenos Offshore Wind Farm, although the Scoping Report indicates that the development will encompass 70 to 100 floating offshore wind turbine foundations each fitted with up to six mooring points (Flotation Energy, 2023). A range of anchoring options are under consideration for the floating foundations, including piled anchors. A single offshore fixed foundation platform comprising up to 12 pin piles, each of 3 m diameter is also proposed to form an Electrical Hub. UXO clearance may also be required should any potential UXO be identified during pre-construction geophysical surveys. Seabed preparation and construction is expected to be undertaken over a period of four years. No specific details are available regarding maximum piling durations, or the quantity of UXO clearance considered for assessment. Based upon the scale of the Cenos Offshore Wind Farm, which is smaller than the Array, these project aspects are therefore expected to be of smaller magnitude than the Array. The impact is considered to be of medium term duration, with noise generation being intermittent during the construction phase, and reversible upon completion of construction.

454. No EIA Report is available for the Salamander Offshore Wind Farm, however the Scoping Report states that the project will comprise up to seven floating offshore wind turbine foundations with several floating foundation design options under consideration (Simply Blue Energy (Scotland) Ltd., 2023). A number of anchoring mechanisms are also under consideration (including piled anchors), with between three and nine mooring lines affixed to each floating structure. UXO clearance may also be required should any potential UXO be identified during pre-construction geophysical surveys, but this will be subject to a separate Marine Licence Application. No specific details are available regarding maximum piling durations, or the quantity of UXO clearance considered for assessment, however offshore construction is expected to be undertaken over two six month phases within a two year construction programme. The Salamander Offshore Wind Farm is of a considerably smaller scale than the Array and other Tier 1 and 2 projects considered with regards to effects from underwater noise. The impact is considered to be of medium term duration, with noise generation being intermittent during the construction phase, and reversible upon completion of construction.

455. The cumulative impact of underwater noise on fish and shellfish ecology receptors during the construction phase is predicted to be of regional spatial extent, medium term duration, intermittent and of high reversibility. It is predicted that the impact may affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

456. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 168 *et seq.*).

Significance of effect

457. For most marine fish, diadromous fish, and shellfish, the cumulative magnitude of the impact is deemed to be low, and the sensitivity of most marine fish IEFs is considered low. The effect will, therefore, be of **minor** significance, which is not significant in EIA terms.

458. For herring, the cumulative magnitude of the impact is deemed to be low, and the sensitivity of herring is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

459. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 3

Site preparation and construction phase

Magnitude of impact

460. In addition to the Tier 1 and Tier 2 projects, seven Tier 3 projects were identified with potential for cumulative effects associated with this impact:

- Morven Offshore Export Cable Corridor(s);
- Bellrock Offshore Wind Farm;
- Bowdun Offshore Wind Farm;
- Campion Offshore Wind Farm;
- unknown phases of Cedar;
- unknown phases of Flora; and
- unknown phases of Aspen (Table 9.30).

461. As these are Tier 3 projects, there are no Scoping Reports in the public domain. Therefore, there is no information available on the impact that these Tier 3 projects will have on fish and shellfish ecology, though piling activities during the construction phase are expected to be similar in nature as that of the Array. Although information on hammer energies, piling durations, and UXO clearance requirements are not available for the Tier 3 projects, the impact is likely to be of medium term duration, with noise being intermittent during the construction phase.

462. The maximum duration of the offshore construction phase for the Array is up to eight years (2031 to 2038). There is currently no information available for the Cedar, Flora and Aspen projects; therefore, a precautionary assumption has been made that these may have overlapping piling phases with the Array (Table 9.30). Therefore, there may be minimal overlap between the site preparation and construction activities of the Array and that of the Tier 3 projects.

463. The cumulative impact of underwater noise on fish and shellfish ecology receptors during the construction phase is predicted to be of regional spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact may affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of receptor

464. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 168 *et seq.*).

Significance of effect

465. For most marine fish, diadromous fish, and shellfish, the cumulative magnitude of the impact is deemed to be low, and the sensitivity of most marine fish IEFs is considered low. The effect will, therefore, be of **minor** significance, which is not significant in EIA terms.

466. For herring, the cumulative magnitude of the impact is deemed to be low, and the sensitivity of herring is considered to be medium. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Further mitigation and residual effect

467. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

EFFECTS TO FISH AND SHELLFISH ECOLOGY RECEPTORS DUE TO EMF FROM SUBSEA ELECTRICAL CABLING

468. Within the operation and maintenance phases, there is potential for EMFs to be produced by the subsea electrical cabling associated with the Array and the other plans and projects. For the purposes of this Array EIA Report, this impact has been assessed using the tiered approach outlined in section 9.12.1. The plans and projects screened into the CEA for this impact and their respective tiers are outlined in Table 9.31.

Tier 1

<u>Operation and maintenance phase</u>

Magnitude of impact

469. There were two Tier 1 projects identified with potential for cumulative effects associated with this impact:

- Proposed offshore export cable corridor(s); and
- Eastern Green Link 2 (Table 9.31).

470. At the time of writing this EIA Report, there was no EIA Report available for the Proposed offshore export cable corridor(s). However, given that these two Tier 1 projects are both HDVC subsea power cables (and in contrast to the Array will not include dynamic cabling) it is expected these will be entirely buried, or protected where burial is not possible. For example, the Environmental Appraisal Report for the Eastern Green Link 2 presented calculations that a burial depth of 1 m reduced EMFs to background levels by 20 m distance from the cable (National Grid Electricity Transmission and Scottish Hydro Electric Transmission plc, 2022).

471. The MDS for the Array accounts for up to 1,261 km of 66 kV inter-array cables, with up to 116 km as ‘dynamic cables’ in the water column, and the rest buried at a depth of at least 0.4 m (Table 9.13). There will also be up to 236 km of interconnector cables buried to a minimum depth of 0.4 m and maximum depth of 3 m (Table 9.13). It has been estimated in the MDS that up to 20% of these buried cables will require cable protection, with up to 24 cable crossings also requiring protection. The Eastern Green Link 2 project has two 436 km HDVC cables, totalling 872 km of subsea cabling which may emit EMFs (National Grid Electricity Transmission and Scottish National Power Transmission, 2022), which extends outside the fish and shellfish ecology study area.

472. The EMF levels in the vicinity of subsea cables are influenced by a variety of design and installation factors, including distance between cables, cable sheathing, number of conductors, and internal cable configuration. Further, the intensity of EMF from subsea cables decreases at approximately the inverse square/power of the distance away from the cable (Hutchison *et al.*, 2021). This attenuation is the same for buried, unburied, and dynamic cables (Hutchison *et al.*, 2021). Therefore, the cumulative magnitude of impact with the Tier 1 projects is likely to be highly localised to within metres to tens of metres from cables.

473. The cumulative impact is predicted to be of local spatial extent, long term duration, continuous, and of high reversibility (as cables will be removed after the operation and maintenance phase). It is predicted that the impact will affect the receptor directly. This impact may therefore represent some measurable, long term minor alteration to fish and shellfish behaviour in the vicinity of cables buried beneath the seabed or in the water column. The magnitude is therefore considered to be low.

Sensitivity of receptor

474. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 278 *et seq.*).

Significance of effect

475. For most fish and shellfish IEF species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

476. For European lobster, *Nephrops*, edible crab and elasmobranchs, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

477. For diadromous fish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** significance, which is not significant in EIA terms.

Further mitigation and residual effect

478. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 2

Operation and maintenance phase

Magnitude of impact

479. In addition to the Tier 1 projects, there was one Tier 2 project identified with potential for cumulative effects associated with this impact: the operation and maintenance phase of the Morven Offshore Wind Farm (Table 9.30). The MDS for the Array is summarised in paragraph 471. As only a Scoping Report is available for the Morven Offshore Wind Farm, cable lengths, dimensions, and voltages are not currently available. However, given the scale of the project, it is likely that they will be of a similar extent to those of the Array, albeit with less dynamic cabling given that the Morven Offshore Wind Farm is not a floating project.

480. As presented in paragraph 120 and within the Tier 1 assessment, EMF levels in the vicinity of subsea cables are influenced by a variety of design and installation factors, including distance between cables, cable sheathing, number of conductors, and internal cable configuration. Further, the intensity of EMF from subsea cables decreases at approximately the inverse square/power of the distance away from the cable (Hutchison *et al.*, 2021). This attenuation is the same for buried, unburied, and dynamic cables (Hutchison *et al.*, 2021). Therefore, the cumulative magnitude of impact with the Tier 2 projects is likely to be highly localised to within metres to tens of metres from cables.

481. The cumulative impact is predicted to be of local spatial extent, long term duration, continuous, and of high reversibility (EMF emissions will only occur when cables are operational during the operation and maintenance phase). It is predicted that the impact will affect the receptor directly. This impact may therefore represent some measurable, long term minor alteration to fish and shellfish behaviour in the vicinity of cables buried beneath the seabed or in the water column. The magnitude is therefore considered to be low.

Sensitivity of receptor

482. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 278 *et seq.*).

Significance of effect

483. For most fish and shellfish IEF species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

484. For European lobster, *Nephrops*, edible crab and elasmobranchs, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

485. For diadromous fish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** significance, which is not significant in EIA terms.

Further mitigation and residual effect

486. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

Tier 3

Operation and maintenance phase

Magnitude of impact

487. In addition to the Tier 1 and Tier 2 projects, there were six Tier 3 projects identified with potential for cumulative effects associated with this impact:

- Morven Offshore Export Cable Corridor(s);
- Bellrock Offshore Wind Farm;
- Bowdun Offshore Wind Farm;
- Campion Offshore Wind Farm;
- Eastern Green Link 3; and
- Eastern Green Link 4 (Table 9.30).

488. The MDS for the Array accounts for up to 1,261 km of 66 kV inter-array cables, with up to 116 km as 'dynamic cables' in the water column, and the rest buried to a minimum target depth of 0.4 m (subject to CBRA) (Table 9.13). There will also be up to 236 km of interconnector cables buried to a minimum target depth of 0.4 m (subject to CBRA) (Table 9.13). It has been estimated in the MDS that up to 20% of these buried cables will require cable protection, with up to 24 cable crossings also requiring protection. As there is no published EIA, there is no project specific information regarding cable lengths, dimension, and voltages currently available for the Tier 3 projects. However, given the scale of the projects, it is likely that EMF related impacts associated with the Bellrock, Bowdun, and Campion Offshore Wind Farms will be of a similar in nature and extent to those of the Array and Morven Offshore Wind Farm.

489. Impacts associated with the Morven Offshore Export Cable Corridor(s) and Eastern Green Link 3 and 4 are likely to be similar to those assessed in Tier 1 for the Proposed offshore export cable corridor(s) and Eastern Green Link 2 (see paragraphs 469 *et seq.*).

490. As presented within the Tier 1 assessment, EMF levels in the vicinity of subsea cables are influenced by a variety of design and installation factors, including distance between cables, cable sheathing, number of conductors, and internal cable configuration. Further, the intensity of EMF from subsea cables decreases at approximately the inverse square/power of the distance away from the cable (Hutchison *et al.*, 2021). This attenuation is the same for buried, unburied, and dynamic cables (Hutchison *et al.*, 2021). Therefore, the cumulative magnitude of impact with the Tier 3 projects is likely to be highly localised to within metres to tens of metres from cables.

491. The cumulative impact is predicted to be of local spatial extent, long term duration, continuous, and of high reversibility (as cables will be removed after the operation and maintenance phase). It is predicted that the impact will affect the receptor directly. This impact may therefore represent some measurable, long term minor alteration to fish and shellfish behaviour in the vicinity of cables buried beneath the seabed or in the water column. The magnitude is therefore considered to be low.

Sensitivity of receptor

492. The sensitivities of the fish and shellfish IEFs are as previously described above for the assessment of the Array alone (paragraphs 278 *et seq.*).

Significance of effect

493. For most fish and shellfish IEF species, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** adverse significance, which is not significant in EIA terms.

494. For European lobster, *Nephrops*, edible crab and elasmobranchs, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

495. For diadromous fish, the cumulative magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **negligible to minor** significance, which is not significant in EIA terms.

Further mitigation and residual effect

496. No secondary mitigation is considered necessary because the likely cumulative effect in the absence of further mitigation (beyond the designed in measures outlined in section 9.10) is not significant in EIA terms.

9.13. PROPOSED MONITORING

497. No project specific monitoring measures are proposed given that no significant impacts were predicted from the Array alone or cumulatively with other plans and projects. However, engagement with MD-SEDD, NatureScot, and other relevant key stakeholders will be undertaken to identify and deliver proportionate measures for contributing to strategic monitoring to further address evidence gaps on fish and shellfish receptors and potential interactions with offshore wind farm projects. This may involve engaging and contributing to ongoing strategic initiatives from Scottish Marine Energy Research (ScotMER) (Scottish Government, 2024b) and include monitoring of impacts wherein data gaps exist.

9.14. TRANSBOUNDARY EFFECTS

498. A screening of transboundary impacts has been carried out and has identified that there were no likely significant transboundary effects with regard to fish and shellfish ecology from the Array upon the interests of European Economic Area (EEA) states. This was due to the relatively limited scale of effect and/or temporary nature of the impacts on fish and shellfish which would not result in effects occurring in other countries.

9.15. INTER-RELATED EFFECTS (AND ECOSYSTEM ASSESSMENT)

499. A description of the likely inter-related effects arising from the Array on fish and shellfish ecology is provided in volume 2, chapter 20 of the Array EIA Report.

500. For fish and shellfish ecology, the following potential impacts have been considered within the inter-related assessment:

- temporary habitat loss and disturbance;
- long term habitat loss and disturbance;
- increased SSCs and associated deposition;
- effects to fish and shellfish receptors due to EMF from subsea electrical cabling;
- colonisation of hard structures;
- underwater noise from piling and UXO clearance impacting fish and shellfish receptors; and
- underwater noise from the operation of floating wind turbines and anchor mooring lines impacting fish and shellfish receptors.

501. Table 9.34 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Array and also the inter-related effects (receptor-led effects) that are predicted to arise for fish and shellfish ecology receptors.

502. As noted above, effects on fish and shellfish ecology receptors also have the potential to have secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- marine mammals:
  - changes in the fish and shellfish community resulting from impacts during construction, operation and maintenance, and decommissioning of the Array may lead to loss of prey resources for marine mammals resulting in effects of negligible significance (see volume 2, chapter 10);
- offshore ornithology:
  - the assessment for offshore and intertidal ornithology considers the overall effects on foraging seabirds from potential changes in prey communities that could be caused by disturbance, habitat loss, and increased SSC. The assessment of effects demonstrated that due to the high mobility of foraging seabirds and their ability to exploit different prey species, and the small scale of potential changes in context of wider available habitat, the changes to fish and shellfish prey communities are unlikely to have a significant effect on foraging seabirds (see volume 2, chapter 11); and
- commercial fisheries:
  - changes in fish and shellfish communities from impacts during construction, operation and maintenance, and decommissioning may affect commercial fisheries receptors by effects on target species. However, as this chapter has predicted only negligible or minor effects on fish and shellfish ecology receptors, negligible or minor effects are therefore predicted for commercial fisheries (see volume 2, chapter 12), which are not significant in EIA terms.

Table 9.34: Summary of Likely Significant Inter-Related Effects for Fish and Shellfish Ecology from Individual Effects Occurring Across the Site Preparation and Construction, Operation and Maintenance and Decommissioning Phases of the Array (Array Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase[6] C	O	D	Likely Significant Inter-Related Effects
Array Lifetime Effects				
Temporary habitat loss and disturbance	✓	✓	✓	When temporary habitat loss is considered additively across the phases of the Array, the total area of habitat affected is larger than for the individual Array stages. It should be noted, however, that across the construction and operation and maintenance phases there is potential for the same areas to be repeatedly disturbed (e.g. through cable remedial burial) and therefore the total footprint across phases is likely to be overestimated. Further, similar habitats are widespread across the fish and shellfish ecology study area and the North Sea, therefore, the impact will be proportionally small in this context and recoverability of fish and shellfish into the affected areas is high. Therefore, across the lifetime of the Array, the effects on fish and shellfish receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the in combined effects are of negligible to minor adverse significance which is not significant in EIA terms.
Long term habitat loss and disturbance	✓	✓	✓	When long term habitat loss is considered additively across the phases of the Array, the total area of habitat affected is larger than for the individual Array stages. Certain locations may experience repeated disturbance (e.g. touchdown of point of mooring lines and dynamic cables) with areas of seabed considered to be unavailable to benthic species. This does not represent a change in sedimentary habitat and replacement with artificial substrates. The estimated footprint of repeated disturbance assumed within the MDS equates to up to 0.09% of the total site boundary. There are also similar habitats are widespread across the fish and shellfish ecology study area and the North Sea. Therefore, across the lifetime of the Array, the effects on fish and shellfish receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the inter-related effects are of minor adverse significance which is not significant in EIA terms.
Colonisation of hard structures	×	✓	×	This effect will arise during the operation and maintenance phase only, therefore no likely significant inter-related effects are anticipated across the lifetime of the Array. Some effects will extend through to the decommissioning phase if scour/cable protection was to be left *in situ*.
Underwater noise from piling and UXO clearance impacting fish and shellfish receptors	✓	×	×	This effect will arise during the site preparation and construction phase only, therefore no likely significant inter-related effects are anticipated across the lifetime of the Array.
Underwater noise from the operation of floating wind turbines and anchor mooring lines impacting fish and shellfish receptors	×	✓	×	This effect will arise during the operation and maintenance phase only, therefore no likely significant inter-related effects are anticipated across the lifetime of the Array. Further, any impacts (should they occur would be highly localised and would not lead to significant effects on fish (either injury or behaviour).
Increased SSCs and suspended sediments	✓	✓	✓	Effects from increased SSCs and associated deposition caused by seabed disturbance will be short lived and intermittent across each phase. Fish and shellfish IEFs potentially affected by increased SSCs and deposition are likely to have recovered in the intervening period between phases/events. Further, the species in question are considered to be of low sensitivity and/or high recoverability. Therefore, across the lifetime of the Array, the effects on fish and shellfish receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the in combined effects are of negligible to minor adverse significance which is not significant in EIA terms.
Effects to fish and shellfish receptors due to EMF from subsea electrical cabling	×	✓	×	This effect will arise during the operation and maintenance phase only, therefore no likely significant inter-related effects anticipated across the lifetime of the Array.
Receptor led effects				
Potential exists for spatial and temporal interactions between habitat loss and disturbance, underwater noise, colonisation of hard structures and EMF effects during the lifetime of the Array. These individual impacts were assigned a significance of negligible to minor adverse as standalone impacts and potential inter-related impacts may arise, though it is important to recognise that the individual activities will not necessarily occur simultaneously or in the same area of the Array. To demonstrate this, effects associated with EMF will occur during the operation and maintenance phase, whereas most noise effects will arise from foundation piling and Unexploded Ordnance (UXO) clearance undertaken beforehand, during the site preparation and construction phase. In addition, construction noise impacts will be temporary and reversable following cessation of construction, with fish and shellfish communities expected to recover into the site boundary following cessation of UXO clearance and piling. Further, any potential fish or shellfish behavioural effects as a result of EMF would be likely to occur over the same area as habitat loss/disturbance effects (i.e. within metres of the cable) and therefore habitat loss effects would not be additive to these highly localised EMF effects (i.e. these would occur in the same Zone of Influence (ZoI)). There may be localised changes in fish and shellfish communities in the areas affected by long term habitat loss, due to potential changes in substrate type and foraging opportunities, though in some cases, areas affected by habitat loss might prove beneficial for some fish and shellfish receptors. Any shifts in baseline assemblage will be limited to these areas and, therefore, effects of greater significance than the individual impacts in isolation (i.e. negligible to minor) are not predicted. As a result, the receptor-led effects are of minor adverse significance which is not significant in EIA terms.				

[6] C = Construction, O = Operation and maintenance, D = Decommissioning

9.16. SUMMARY OF IMPACTS, MITIGATION, LIKELY SIGNIFICANT EFFECTS AND MONITORING

503. Information on fish and shellfish ecology within the fish and shellfish ecology study area was collected through detailed desktop review of existing studies and datasets, in addition to site-specific surveys. This information is summarised in Table 9.8 and Table 9.9.

504. Table 9.35 presents a summary of the potential impacts and the conclusion of significant effects in EIA terms in respect to fish and shellfish ecology. The impacts assessed include:

- temporary habitat loss and disturbance;
- long term habitat loss and disturbance;
- colonisation and hard substrates;
- underwater noise from piling and UXO clearance impacting fish and shellfish receptors;
- underwater noise from the operation of floating wind turbines and anchor mooring lines impacting fish and shellfish receptors;
- increased SSCs and associated deposition; and
- effects to fish and shellfish receptors due to EMF from subsea electrical cabling.

505. Overall, it is concluded that there will be no LSE[1] in EIA terms arising from the Array during the construction, operation and maintenance or decommissioning phases.

506. Table 9.36 presents a summary of the potential impacts, designed in measures and the conclusion of LSE[1] on fish and shellfish ecology in EIA terms. The cumulative effects assessed include:

- temporary habitat loss and disturbance;
- long term habitat loss and disturbance;
- colonisation and hard substrates
- underwater noise from piling and UXO clearance impacting fish and shellfish receptors; and
- effects to fish and shellfish receptors due to EMF from subsea electrical cabling.

507. Overall, it is concluded that there will be no likely significant cumulative effects in EIA terms from the Array alongside other projects/plans.

508. No likely significant transboundary effects have been identified.

Table 9.35: Summary of Likely Significant Environmental Effects, Secondary Mitigation and Monitoring

Description of Impact	Phase	Species	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Measures	Significance of Residual Effect	Proposed Monitoring
Temporary habitat loss and disturbance	Construction, operation and maintenance, decommissioning	Marine fish and shellfish species	Negligible to Low	Low to medium	Construction: Minor adverse Operation and maintenance: Negligible to minor adverse Decommissioning: Minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with strategic monitoring programmes such as ScotMER to facilitate addressing of evidence gaps as appropriate.
		Diadromous Fish	Negligible to Low	Low to medium	Construction: Minor adverse Operation and maintenance: Negligible adverse Decommissioning: Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
Long term habitat loss and disturbance	Construction, operation and maintenance, decommissioning	Marine fish and shellfish species	Low	Low to medium	Minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
		Diadromous Fish	Low	Low	Minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
Colonisation of hard structures	Operation maintenance	Marine fish and shellfish species	Low	Low	Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
		Diadromous Fish	Low	Low	Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
Underwater noise from piling and UXO clearance impacting fish and shellfish receptors	Construction	Marine fish and shellfish species	Low	Low to medium	Minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
		Diadromous Fish	Low	Low	Minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
Underwater noise from the operation of floating wind turbines and anchor mooring lines impacting fish and shellfish receptors	Operation maintenance	Marine fish and shellfish species	Negligible	Low to medium	Negligible adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
		Diadromous Fish	Negligible	Low	Negligible adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
Increased SSCs and associated deposition	Construction, operation and maintenance, decommissioning	Marine fish and shellfish species	Low	Low	Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.

Description of Impact	Phase	Species	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Measures	Significance of Residual Effect	Proposed Monitoring
		Diadromous Fish	Low	Low	Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
Effects to fish and shellfish receptors due to EMF from subsea electrical cabling	Operation and maintenance	Marine fish and shellfish species	Low	Low	Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.
		Diadromous Fish	Low	Low	Negligible to minor adverse	None	N/A	No project specific monitoring proposed. Ossian OWFL will engage with stakeholders to facilitate addressing evidence gaps as appropriate.

Table 9.36: Summary of Likely Significant Cumulative Environment Effects, Mitigation and Monitoring

Description of Impact	Phase	Cumulative Effects Assessment Tier	Species	Magnitude of Impact	Sensitivity of Receptor	Significance of Effect	Additional Measures	Significance of Residual Effect	Proposed Monitoring
Temporary habitat loss and disturbance	Construction, operation and maintenance	Tiers 1, 2 and 3	Marine fish and shellfish species	Low	Low to medium	Minor adverse	None	N/A	None
			Diadromous Fish	Low	Low to medium	Minor adverse	None	N/A	None
Long term habitat loss and disturbance	Construction, operation and maintenance	Tiers 1, 2 and 3	Marine fish and shellfish species	Low	Low to medium	Minor adverse	None	N/A	None
			Diadromous Fish	Low	Low	Minor adverse	None	N/A	None
Colonisation of hard structures	Operation and maintenance	Tiers 1, 2 and 3	Marine fish and shellfish species	Low	Low	Negligible to minor adverse	None	N/A	None
			Diadromous Fish	Low	Low	Negligible to minor adverse	None	N/A	None
Underwater noise from piling and UXO clearance impacting fish and shellfish receptors	Construction	Tiers 1, 2 and 3	Marine fish and shellfish species	Low	Low to medium	Minor adverse	None	N/A	None
			Diadromous Fish	Low	Low	Minor adverse	None	N/A	None
Effects to fish and shellfish receptors due to EMF from subsea electrical cabling	Operation and maintenance	Tiers 1, 2 and 3	Marine fish and shellfish species	Low	Low	Negligible to minor adverse	None	N/A	None
			Diadromous Fish	Low	Low	Negligible to minor adverse	None	N/A	None

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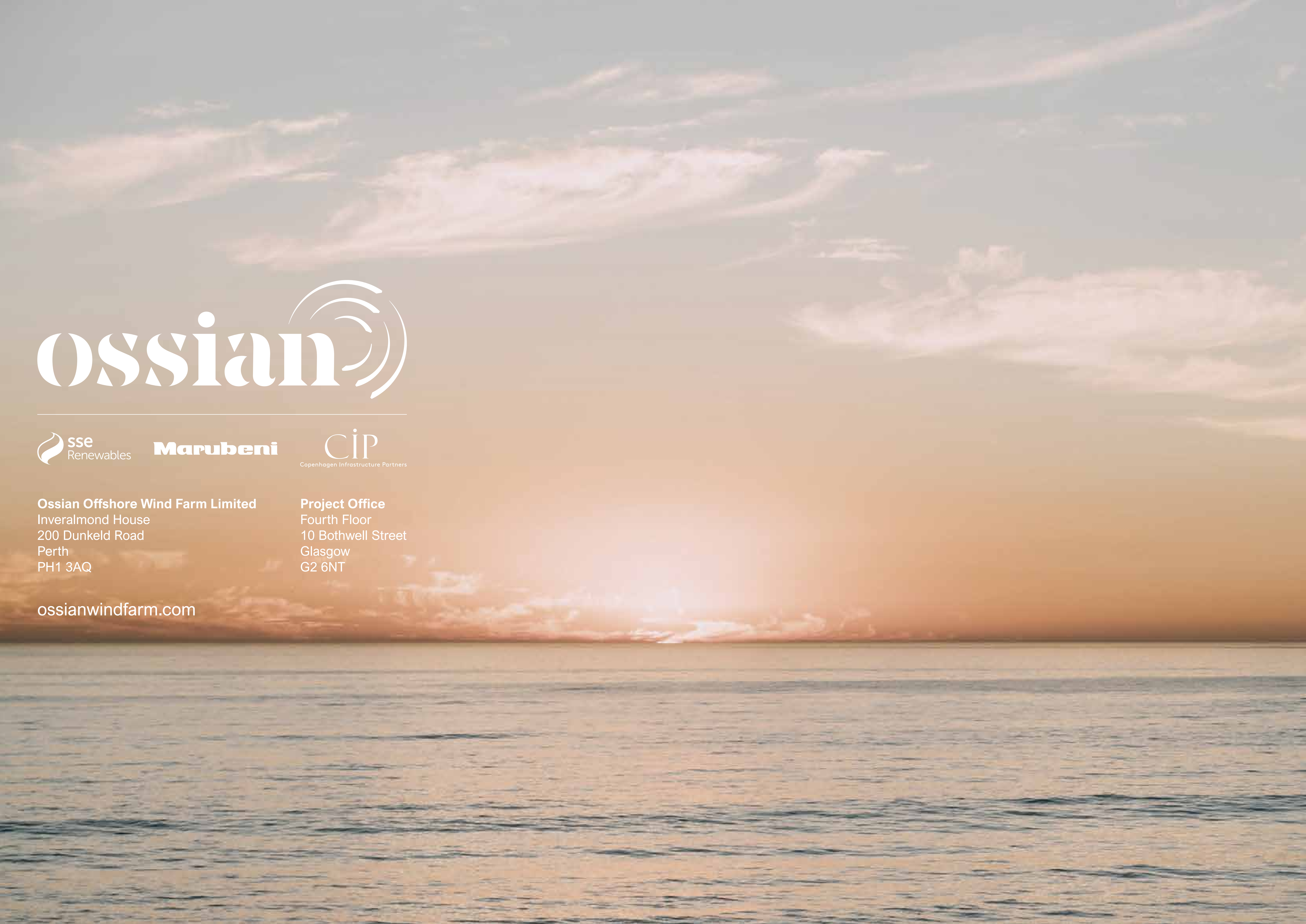

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