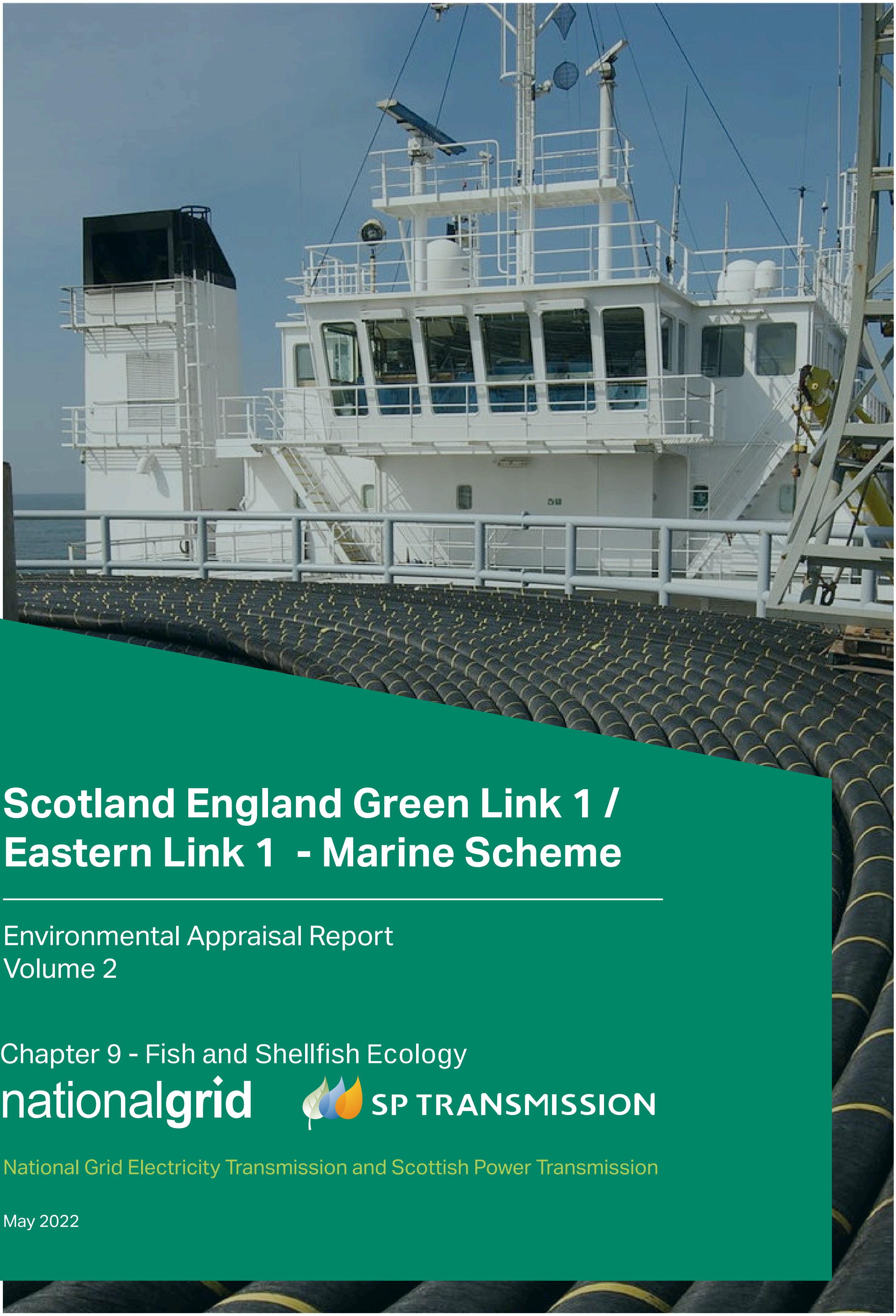

Scotland England Green Link 1 / Eastern Link 1 - Marine Scheme

Environmental Appraisal Report
Volume 2

Chapter 9 - Fish and Shellfish Ecology

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National Grid Electricity Transmission and Scottish Power Transmission

May 2022

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Wessex Archaeology (Marine Archaeology); and

Brown and May Marine Ltd (Commercial Fisheries).

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Executive Summary

This chapter of the Environmental Appraisal Report (EAR) contains an appraisal of the potential interaction of the Marine Scheme and fish and shellfish, focusing on the marine area between MHWS at the Scottish landfall area at Thorntonloch Beach in East Lothian, and MHWS at the English landfall area at Seaham, County Durham. The Marine Scheme overlaps with important spawning areas for herring, whiting, sandeel, plaice, and *Nephrops*. High-intensity nursery grounds of herring, cod, and whiting were also identified within the study area, as were important low- intensity nursery grounds of sandeel, plaice, sprat and *Nephrops*. Juvenile horse mackerel also appear to be widespread although they exhibit no spatially discrete nursery grounds within the study area.

The appraisal follows the methodology as set out within Chapter 4: Approach to Environmental Appraisal, with the identification and appraisal of effects and mitigation following the Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment in Britain and Ireland – Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2018, and updated September 2019) and based on expert judgments.

The fish and shellfish baseline is presented in Section 9.5 of this EAR chapter. This identifies relevant designated sites and features which may be impacted by the Marine Scheme. Determination of the baseline has been informed by a project specific benthic characterisation survey (Fugro, 2021) and extensive studies identified in this chapter reporting the distribution and abundance of fish and shellfish receptors in the western North Sea.

The potential effects of the Marine Scheme on fish and shellfish have been appraised in Section 9.6. Where appropriate, proportionate measures to avoid or mitigate for any identified adverse effects are identified. This appraisal concludes that, potential impacts during the installation, operation (including maintenance and repair) and decommissioning of the Marine Scheme on fish and shellfish receptors are **not significant**.

The potential for interaction between the Marine Scheme and other plans/projects to result in significant cumulative effects, is considered in Chapter 16: Cumulative and In-Combination Effects. No interaction is anticipated between the Marine Scheme and the Scottish and English Onshore Schemes, because there are no project activities associated in the marine environment due to the use of Horizontal Directional Drill (HDD) at the landfalls.

9. Fish and Shellfish Ecology

9.1 Introduction

This chapter of this Environmental Appraisal Report (EAR) presents an appraisal of the potential interaction of the Marine Scheme with fish and shellfish ecology. The appraisal of impacts on Commercial Fisheries can be found in Chapter 14.

The Marine Scheme comprises the marine component of the Scotland England Green Link 1 (SEGL1) / Eastern Link 1 (EL1) and extends from the Mean High-Water Springs (MHWS) at the Scottish landfall at Thorntonloch beach, Torness, to the MHWS at the English landfall near Seaham. The Marine Scheme is located within both Scottish and English territorial waters, up to 12 nautical miles (NM) from the coast. The Marine Scheme comprises an installation corridor of approximately 176 km in length and up to 500 m maximum width, within which cables will be installed (hereinafter referred to as the 'marine installation corridor'). The marine installation corridor extends from kilometre point (KP) 0, at the Scottish landfall, to KP 176, at its landfall in England (See Figure 9-1). The Marine Scheme activities cover the following phases: installation, operation (including maintenance and repair) and decommissioning.

A description of the works anticipated to be undertaken during installation, operation, and maintenance, and decommissioning of the Project is provided in Chapter 2: Project Description. This chapter provides an overview of the fish and shellfish ecology baseline (Section 9.5) and considers the potential impacts of the Marine Scheme on these receptors (Section 9.6). Where appropriate, the chapter goes on to identify proportionate measures to avoid or mitigate identified adverse effects (Section 9.7).

The potential for interaction between the Marine Scheme and other plans and / or projects, which may result in significant cumulative effects on fish and shellfish, is considered within Chapter 16: Cumulative and In-Combination Effects.

This chapter should be read in conjunction with Chapter 8: Benthic Ecology, Chapter 10: Marine Mammals and Chapter 11: Ornithology as a result of predator-prey relationships between these groups. Consideration of the socio-economic aspects of commercial fishing, including vessel nationalities, home port locations, and fishing methods, is discussed in Chapter 14: Commercial Fisheries.

9.2 Legislative Context

This section outlines legislation, policy, and guidance relevant to the appraisal of the potential effects on benthic ecology associated with the installation, operation (including maintenance and repair) and decommissioning of the Marine Scheme. For further information regarding the legislative and policy context refer to Chapter 3: Legislative and Policy Framework.

A number of policies and regulations aim to assure that fish and shellfish is taken into account during planning and execution of projects within UK waters. For the Marine Scheme these include the UK Marine Policy Statement (MPS) and the UK Marine Plans, specifically the Scottish National Marine Plan (Scottish Government, 2015), and the North East Inshore and North East Offshore Marine Plan[1] (HM Government, 2021), have a number of relevant policies specific to fish and shellfish which are presented in EAR Volume 3 Appendix 3.1: Marine Plan Compliance Checklist.

A number of policies and laws require decision makers to consider the environmental impacts of a project. Legislation and policy relevant to the appraisal of Marine Scheme's effects on fish and shellfish is presented in EAR Volume 3 Appendix 3.2: Topic Specific Legislation.

9.3 The Study Area

The fish and shellfish appraisal covers a 10 km study area, extending 5 km either side of the centre line of the marine installation corridor as illustrated in Figure 9-1. This study area has been selected to encompass all likely zones of influence (ZOI) for fish and shellfish as identified in Section 9.6.

[1] The Marine Scheme falls entirely within the UK territorial waters (i.e. 12 NM), therefore within the Inshore portion of the North East marine area. The marine plan for the North East area has combined both inshore and offshore portions.

In addition, all sites designated for migratory fish, landward of the Marine Scheme have been scoped into the appraisal to consider the potential for an interaction between the Marine Scheme and potential migration routes of species (defined in Section 9.5.1.2).

A benthic survey was undertaken to characterise benthic ecological conditions and identify the extent of potential fish spawning habitat across and along the 500 m wide marine installation corridor (Fugro, 2021).

9.4 Approach to Appraisal and Data Sources

9.4.1 Appraisal Methodology

This appraisal applies the methodology as detailed in Chapter 4: Approach to Environmental Appraisal. The identification and appraisal of effects and mitigation are based on a combination of professional judgment and the application of the following guidelines:

- Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment in Britain and Ireland – Terrestrial, Freshwater, Coastal and Marine (CIEEM, 2018).

In the absence of Environmental Quality Standards for *in situ* sediments in the UK, following key guidance has been used to help inform a 'Weight of Evidence' (WoE) approach to assess whether fish and shellfish are at risk from toxic contaminants:

- Centre for Environment, Fisheries and Aquaculture Science (Cefas) Chemical Action Levels (Marine Management Organisation, 2014) (Reviewed 2020) are values used in conjunction with a range of other assessment methods to make management decisions regarding the fate of dredged material. The action levels are not 'pass/fail' criteria but triggers for further assessment. In general, contaminant levels below action level 1 are of no concern and are unlikely to influence the licensing decision. Dredged material with contaminant levels between action levels 1 and 2 requires further consideration before a decision can be made and material with contaminant levels above action level 2 is generally considered unsuitable for sea disposal. For non-dredging activities Action Levels are used as a guide in assessment of sediment contamination;
- Canadian sediment quality guidelines (CCME, 2001) applied to contaminants where no other regional threshold value is available. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. The Canadian Sediment quality guidelines were developed by the Canadian Council of Ministers of the Environment as broadly protective tools to support the functioning of healthy aquatic ecosystems;
- UK Offshore Operators Association (UKOOA) sediment quality guidelines for the UK North Sea (UKOOA, 2001);
- OSPAR background concentrations and background assessment concentrations and effect range low (ERL) and effect range median (ERM) concentrations for contaminants (OSPAR, 2009); and
- Data from 'Clean Seas Environmental Monitoring Programme at TyneTees and a station at the Firth of Forth (Marine Scotland, 2020).

A non-statutory scoping report, submitted to and consulted on by the Marine Management Organisation (MMO) and Marine Scotland Licensing Operations Team (MS-LOT) in April 2021[2], identified aspects of the Project, that have the potential to impact the fish and shellfish ecology during installation, operation (including maintenance and repair), and decommissioning phases (NGET & SPT, 2021).

[2] The non-statutory scoping report is publicly available on https://marine.gov.scot/sites/default/files/segl_el1_marine_scoping_report_-_base_report_rev_2.0.pdf

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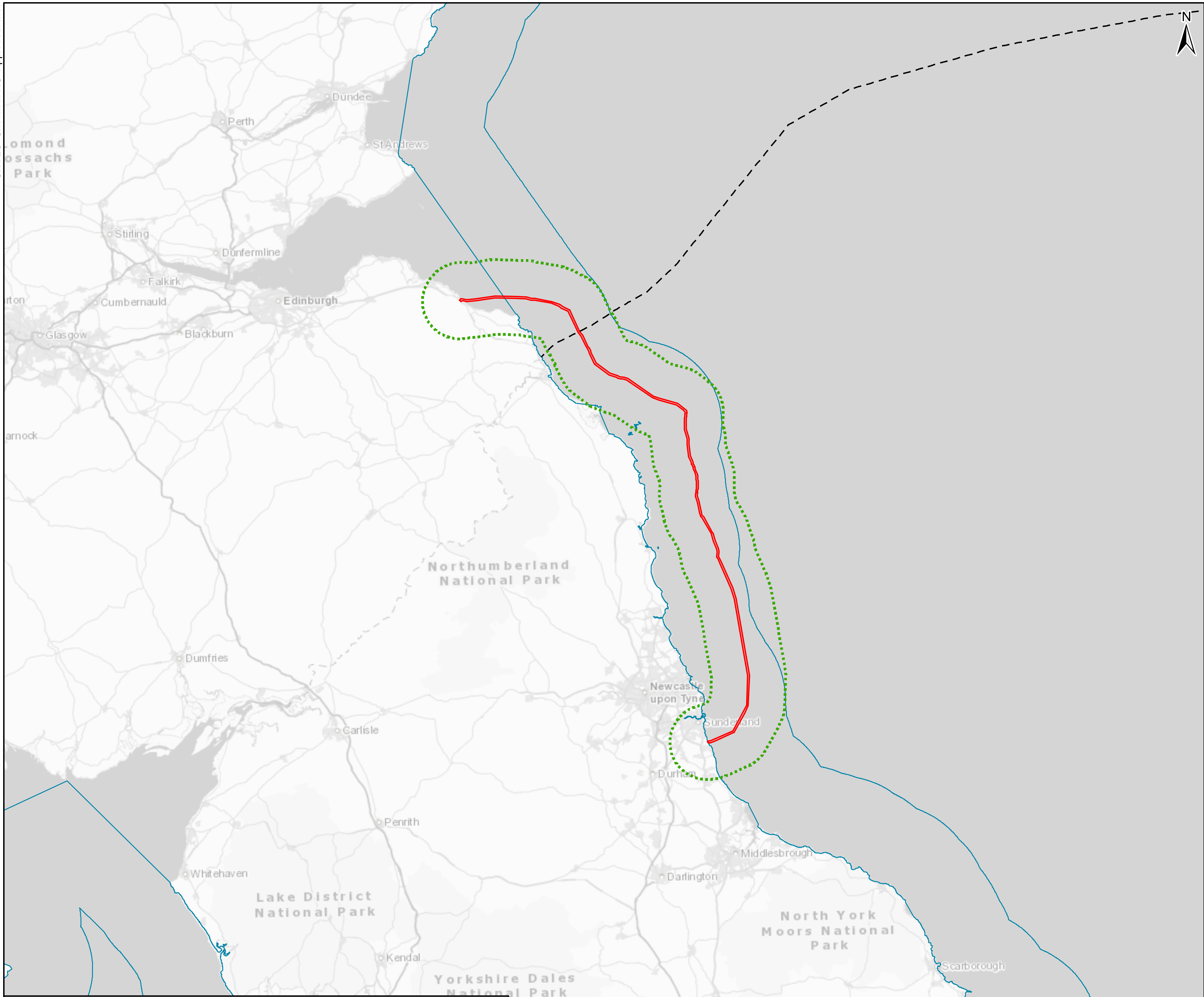

Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:1,000,000

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PROJECT

Scotland England Green Link 1 / Eastern Link 1

KEY

- Marine Installation Corridor
- UK Territorial Sea Limit - 12nm
- Scottish Adjacent Waters Boundary
- 10km Study Area

TITLE

Figure 9-1
Study Area

REFERENCE

SEGL1_M_EAR_9-1_v3_20220425

SHEET NUMBER: 1 of 1

DATE: 25/04/2022

9.4.2 Data Sources and Consultations

9.4.2.1 Data Sources

The fish and shellfish ecology baseline has been described using several data sources. This includes results of the project specific benthic survey which were used to appraise conditions in relation to fish spawning habitat (Fugro, 2021) and a wide body of available data and reports. These desk-based data sources were used to inform the understanding of the relative importance and functionality of the study area in the regional context of fish and shellfish populations in the wider central North Sea. The data sources reviewed include:

- FishBase (www.fishbase.org) for general fish ecology, distribution and biological information;
- EMODnet biological data portal (http://www.emodnet.eu/biology) for records of rarer fish and shellfish species;
- Cefas Sensitivity Maps (Coull, Johnstone, & Rogers, 1998; Ellis, Readdy, Taylor, & Brown, 2012) which provide spatial data highlighting spawning and nursery grounds in UK waters;
- Marine Scotland Sensitivity Maps (Aires, González-Irusta, & Watret, 2014) which displays sensitive areas relating to the life history of commercially important fish species in British waters;
- Cod and whiting spawning ground in the North Sea (González-Irusta & Wright, 2016) (González-Irusta & Wright, 2017) using modelled predictions;
- MarineSpace et al. (2013a; 2013b) for herring and sandeel spawning habitat classifications;
- The International Convention for the Conservation of Nature (IUCN) Red List of Threatened Species (https://www.iucnredlist.org/); and
- International Council for the Exploration of the Seas (ICES) publications and data (including 2010 – 2020 International Herring Larvae Surveys data) (https://www.ices.dk/Science/publications/Pages/Home.aspx); and
- Publicly available and relevant academic journal papers and reports.

9.4.2.2 Summary of Consultations

Following the submission of the non-statutory Scoping Report in April 2021, the MMO, MS-LOT and respective consultees and advisers had the opportunity to express their opinions and provide feedback on the proposal and EAR scope, which has been considered in this chapter.

A non-statutory scoping report was provided to MS-LOT and the MMO, who consulted with a range of stakeholders including: the Scottish Environment Protection Agency (SEPA), Nature Scot, Cefas, the Joint Nature Conservation Committee (JNCC), Natural England (NE), Environment Agency (EA), Wildlife Trusts, the National Federation of Fishermen's Organisations (NFFO), Scottish Fishermen's Federation (SFF), Fisheries Management Scotland (FMS) and Inshore Fisheries and Conservation Authorities (IFCAs) has taken place. The applicants also engaged directly with the district salmon fisheries boards.

Further details of the consultation process and associated responses are presented in Chapter 6: Consultation and Stakeholder Engagement.

Table 9-1 summarises consultation responses received from relevant statutory and non-statutory consultees in relation to fish and shellfish ecology for the Marine Scheme and outlines how and where this has been addressed in this chapter.

Table 9-1: Scoping report consultation

Consultee	Consultee response/ comment	How and where addressed
Marine Scotland Science	MSS note that there is a high intensity spawning area for sandeel present along the Marine Scheme cable route, along with high intensity nursery areas for herring, cod and whiting. It will be important to know the time of year for when the installation of the cable will take place to be able to assess the impact on spawning sandeel. The spawning period for sandeel is November to February and this is a critical time for these species. MSS advise that the applicant provides a map which overlays fish spawning areas with the proposed cable route.	Section 9.5.3 includes discussion of potential spawning grounds which occur within the study area. Figures have been provided to show these areas for the species where spawning grounds were identified. The appraisal of impacts on spawning grounds is provided in Section 9.6.
Marine Scotland Science	MSS agree that most of the existing data on fish and shellfish resources have been included; however, MSS recommend that the applicant refers to a report which provides a modelled spatial representation of the probability of the presence of 0 age group fish (fish in the first year of their life) and the probability of aggregations of 0 age group fish (Aires et al. 2014). We recommend that these data are presented visually in conjunction with the Coull et al. (1998) and Ellis et al. (2012) nursery maps, as there are certain limitations with these data. In addition to the Coull et al. (1998), Ellis et al. (2012) and Aires et al. (2014) data, new information is available regarding the spawning areas of cod, haddock and whiting (González-Irusta and Wright 2016; González-Irusta and Wright 2016; González-Irusta and Wright 2017). The whiting paper is available but the associated GIS layers are not available as yet. These three papers contain the new information, however associated data sets are not yet available on NMPi. We hope to get these data sources online shortly to enable their use. Links to the new reports are available in the references section at the bottom of this response.	Data on the presence and probability of aggregations of 0-group, as report by Aires *et al.* (2014), has been presented in Section 9.5.1. Data from Coull et al. (1998) and Ellis et al (2012) has also been presented within this section.
Marine Scotland Science	MSS agree with the potential impacts on fish and shellfish that have been scoped in and scoped out; however, MSS recommend that EMF is scoped in for both benthic invertebrates, in particular lobster, Nephrops and crab which are important commercial species for local fisheries, as well as for marine fish and elasmobranch species. MSS recommend that the applicant provides expected EMF emission levels for the cable and includes this in a model of EMF levels which will aid the assessment of potential EMF impacts on marine species. MSS agree with NatureScot in welcoming further consideration of this topic within the environmental appraisal and strategic monitoring.	The baseline conditions (Section 9.5) has considered shellfish and elasmobranch species in further detail to help the appraisal of impacts from EMF. The appraisal of the impact of EMF is provided in Section 9.6.3.1
NatureScot	We are in broad agreement with the proposed approach for this chapter providing EMF (described in table 8-1 as a potential impact) is scoped back in at this stage as suggested above.	The appraisal of the impact of EMF is provided in Section 9.6.3.1.

Consultee	Consultee response/ comment	How and where addressed
Marine Scotland Science)	There is inadequate consideration of diadromous fish in the report and there is no mention of their need to be included in HRA consideration. In 8. Fish and Shellfish Ecology, it is stated that “There is limited scope for important populations of diadromous species (i.e. those that migrate between freshwater and marine environments) to fall within the Study Area.” This is incorrect. The River Tweed is a SAC for salmon and the mouth of the river is surrounded by the cable route. Both outgoing salmon smolts and adult salmon returning to the River Tweed will likely need to cross the cable. The River Tweed has an important population of eel which will also need to migrate across it, and has important populations of sea trout and sea lamprey, many of which will migrate across it too. It is also an SAC for sea lamprey. Many adult salmon returning to the rivers Teith, Tay, South Esk and Aberdeenshire Dee, which are SACs for salmon are also likely to migrate across the cable route (see Malcolm et al. 2010). There is acknowledgement that, “However, it is possible that some individuals of protected diadromous species, such as the Atlantic salmon (Salmo salar), European eel (Anguilla Anguilla), Sea Lamprey (Petromyzon marinus) and River Lamprey (Lampetra fluviatilis) may migrate through the Marine Scheme as part of their annual life cycles.” but this is insufficient. All of these species, plus sea trout, will need full consideration of the possible impacts of the construction work and operation of the cable on them, including discussion of appropriate mitigation. The rivers Tweed, Teith, Tay, South Esk and Aberdeenshire Dee will all need consideration in the Habitats Regulations Appraisal. There is also a statement that “No sites designated for the protection of fish and shellfish have been identified within 50 km of the Marine Scheme in Scottish waters.” This is also incorrect: the River Tweed SAC is within 50 km of the Marine Scheme in Scottish waters. There will also need to be consideration of whether existing information is adequate for the environmental assessment or whether the applicant will need to carry out additional baseline studies in relation to diadromous fish in support	These rivers have been considered in further detail in Sections 9.5.1 and in EAR Volume 3 Appendix 8.2: Habitat Regulations Assessment Report.

Consultee	Consultee response/ comment	How and where addressed
	of the application and / or contribute to strategic studies. In their response, NatureScot provided no comments on diadromous fish or the need to include diadromous fish SACs in the HRA.	
Marine Scotland Science	The list of the potential impacts on fish which will need further consideration in the environmental assessment presented in Table 8-1 is also suitable for diadromous fish species, but MSS advise that EMF will need specific consideration in respect of migrating diadromous fish, which may be making use of geomagnetic cues in navigating, and whether cable EMFs might interfere with this. The recent review by Hutchison et al. (2020) includes useful references. Any high-order detonation of UXO during construction will also require detailed consideration, including in relation to suitable timing of the operations, as they are potentially highly damaging to migrating salmon and sea trout.	The appraisal of the impact of EMF, for all groups of fish including diadromous species, is provided in Section 9.6.3.1
Marine Scotland Science	The fish populations of the entire River Tweed, including the part which is in England, are dealt with by Scottish fisheries legislation, as are the salmon and sea trout fisheries in coastal waters as far south as the southern limit of the River Tweed Salmon Fishery District near Holy Island. MSS advise consultation of the Environmental Appraisal should include the River Tweed Commission, Forth District Salmon Fishery Board and Fisheries Management Scotland. The Forth District Salmon Fishery Board should also be able to advise on whether there are occupiers of coastal salmon and sea trout fishing rights at the Scottish landfall at Thorntonloch, which could be affected by the works even if they are not currently being exercised. Any occupiers of coastal fishing rights should be consulted too.	Salmon rivers data from Marine Scotland included in Sections 9.5.1 and in EAR Volume 3 Appendix 8.2: Habitat Regulations Assessment Report. No responses to consultations have been received.
Scottish Fisherman's Federation	Starting @ 2.1, in the description of the Marine Cable Route, the 5 bullet points from The Ground preparation through to decommissioning all have the potential to create huge impacts affecting particularly Nephrop & Scallop grounds. so should be assessed. Along the same lines, ref Chapter6, the SFF remains concerned about any suspended sediment being around in Nephrop & Scallop grounds, particularly at spawning time. This is also referred to in Appendix B, but is obviously not considered as essential, but the SFF would expect to see it scoped in.	*Nephrops* and scallop grounds have been discussed in Section 9.5.2.5. Commercial fisheries species are further covered in Chapter 14: Commercial Fisheries.
MMO	Fisheries: 8.1. Generally, the report has identified appropriate sources of evidence related to fisheries for use in the Environmental Appraisal. 8.2. The report has indicated the key fish species of importance in the vicinity of the cable route.	Noted, this information has been transposed from the Scoping Report and provided within Section 9.5.

Consultee	Consultee response/ comment	How and where addressed
	8.3. The report has indicated the fish spawning and nursery areas for a number of fish species along the cable route. 8.5. No fish species or groups of fish that have been scoped out of the Environmental Appraisal, which the MMO support.	
MMO	Fisheries: 8.4. The report has scoped out of further assessment the potential impact of thermal emissions from operational cables on the basis that 'pelagic or demersal fish and shellfish species or life stages which remain in direct contact with the overlying water column are not predicted to be at risk of thermal effects from the buried cables as any heat would be instantly dissipated by currents. Consequently, there is considered to be no interaction between this impact and any fish and shellfish receptors.' The proposed cable route transects high intensity sandeel grounds, which are species that are known to have a close affiliation with the seabed (i.e., a burrowing species) and lay their eggs on the seabed. Therefore, the MMO do not support the reports statement above as there is insufficient evidence presented within the scoping report to support their conclusion. The impact of thermal emissions should be scoped into the subsequent assessment in the Environmental Appraisal and present a discussion of the known tolerance of sandeel eggs to heat and specify the predicted increase in temperature on substratum sediments from operational cables.	The appraisal of the impact of thermal emissions on fish and sandeel grounds is provided in Section 9.6.3.2 Description of the sandeel grounds within the study area have been considered within Section 9.5.1.
MMO	Fisheries: 8.6. The dates of the proposed cable installation and therefore the potential for works to coincide with the sandeel spawning season should be considered.	The appraisal of the impact of cable installation works on sandeel spawning is provided in Section 9.5.3.2
MMO	Shellfish: 9.1. All expected potential impacts in relation to shellfish have been identified in the report. 9.2. Evidence from previous surveys and existing data will be used to inform baseline characteristics. This is appropriate in instances where sufficient existing timely data are available. Landing statistics provide a reliable current baseline for commercial species present. 9.3. The MMO agree with the decision to scope out thermal emissions from operational cables in relation to shellfish for subsequent assessments.	Noted, this information has been transposed from the Scoping Report and provided within Section 9.5.
MMO	Shellfish: 9.4. It should be noted that the proposed cable route does run through known grounds where Nephrops are often targeted.	*Nephrop* and scallop grounds have been discussed in detail in Chapter 14: Commercial Fisheries and have been considered within Section 9.5.2.5.

9.4.3 Data Gaps and Limitations

For many species, understanding of spawning and nursery grounds is largely derived from the information published by Coull et al. (1998) and Ellis et al. (2012) which remain key data sources for UK waters. However, it is important to recognise the principal limitations of these sources in the context of the Marine Scheme. Firstly, although for many pelagic and demersal fish species, the underlying data sets provide good coverage of the study area, for others, notably elasmobranchs, insufficient data has precluded the delineation of spawning grounds. Secondly, it is acknowledged that more recent and localised trends in fish abundance, distribution and behaviours may not be fully represented by the maps due to the historic and widescale nature of the supporting data sets.

Noting these limitations, a high-level site-specific appraisal of habitat suitability has been undertaken in accordance with the habitat assessment criteria outlined in MarineSpace et al. (2013a) for herring and sandeel (Fugro, 2021), which owing to their life history strategies may be vulnerable to effects from the Marine Scheme. Finally, the durations of the spawning seasons reported by Coull et al. (1998) and Ellis et al. (2012) represent the maximum seasons. The timing and duration of spawning are for many species' dependant on a range of factors (e.g. stock, water temperature) and so in reality, variations may occur within the indicative windows provided.

Fish, being mobile species, exhibit varying spatial and temporal patterns. Survey data often only provides a seasonal specific description of the composition, abundance and distribution of fish and shellfish communities; with these a number of factors are expected to vary both within and between years.

Despite a review of literature, there remains a paucity of information related to migratory fish species, particularly for those life stages which occur fully in marine environments. In the absence of robust data, the precautionary principle has been applied and the migratory routes of these species has been considered over larger distances, beyond an initial screening distance of 50 km.

The high biophysical connectivity and dynamic nature of marine environments mean that, although the baseline described and characterised is considered to be relatively stable, it will continue to change in response to global trends both in climate change and anthropogenic activities (e.g. ocean acidification, fisheries, eutrophication, offshore development) (Teal, 2011).

While acknowledging these limitations, every effort has been made to obtain data concerning the existing environment and to accurately predict the likely environmental effect of the proposed development. It is considered that the baseline information collected and used for this appraisal is representative of the study area.

9.5 Baseline Conditions

This section describes the fish and shellfish ecology baseline for the Marine Scheme, with respect to general fish and shellfish communities, spawning and nursery grounds, relevant designated sites and species, commercial fisheries (from an ecological perspective) and species-specific information.

9.5.1 Protected Species and Designated Sites

9.5.1.1 Protected Species

There are several fish species known to be present in the study area which are protected under national and international conservation legislation (Table 9-2). All species listed are also considered to be of wider ecological value as well as commercial value within the study area except for sandeel and the diadromous fish species. The basking shark is also protected under the Wildlife and Countryside Act 1981. There are no shellfish species which are afforded conservation protection known to be present in the study area.

Table 9-2: Summary of relevant fish and shellfish species protected by national and international legislation or policy

Common names	Latin names	Habitats Directive Annex II and IV species	OSPAR list of threatened and/or declining species	Bonn Convention Appendix I and II species	Bern Convention Appendix II and III species	UK Post 2010 Biodiversity Framework Species of Principal Importance	Features of Conservation Interest (FOCI)	IUCN Red List*	Priority Marine Features #
Atlantic salmon	*Salmo salar*	✓	✓			✓	✓	LC (-)	✓[2]
Sea trout	*Salmo trutta*					✓		LC (?)	✓[2]
European eel	*Anguilla anguilla*		✓	✓		✓	✓	CR (↓)	✓[2]
Sea lamprey	*Petromyzon marinus*	✓	✓		✓	✓	✓	LC (↔)	✓[2]
River lamprey	*Lampetra fluviatilis*	✓				✓	✓	LC (?)	
Herring	*Clupea harengus*					✓	✓	LC (↑)	
Mackerel	*Scomber scombrus*					✓	✓	LC (↓)	
Haddock	*Melanogrammus aeglefinus*							VU (-)	
Cod	*Gadus morhua*		✓			✓	✓	VU (-)	✓[3]
Whiting	*Merlangius merlangus*					✓	✓	LC (?)	✓[3]
Dover sole	*Solea solea*					✓	✓	DD (↔)	
Plaice	*Pleuronectes platessa*					✓	✓	LC (↑)	
Sandeel	*Ammodytidae*					✓[1]	✓[1]	LC (?)[1]	✓[3**]
Basking shark	*Cetorhinus maximus*					✓		EN (↓)	✓[3]
Thornback ray	*Raja clavata*		✓					LC (?)	
Spotted ray	*Raja montagui*		✓					LC (↔)	

* IUCN Red List Status defined as 'CR' = Critically Endangered, 'EN' = Endangered, 'VU' = Vulnerable, 'NT' = Near Threatened, 'LC' = Least Concern and 'DD' = Data Deficient. Population trends are also shown in brackets ('↑' = increasing, '↓' = decreasing, '↔' = stable, '?' = unknown and '-' = unspecified)

** Only *A. marinus* occurs offshore in sandeel species

✓[1] = Offshore waters; ✓[2] = Territorial waters; ✓[3] = Both

9.5.1.2 Designated Sites

The Marine Scheme overlaps with a number of designated sites (outlined below), which form part of the UK's national site network of SAC and Marine Conservation Zones (MCZ) (Figure 9-2).

No sites designated for the protection of fish and shellfish have been identified within 50 km of the Marine Scheme in Scottish waters. However, following consultation with MS-LOT, and given that diadromous fish species are known to migrate over large distances, consideration has also been given to the following sites:

- River Dee SAC (approximately 110 km away):
  - The Annex II fish species present as a qualifying feature is: Atlantic salmon *Salmo salar*.
- River Tay SAC (approximately 72 km away):

  - The Annex II species present as a qualifying feature are: Atlantic salmon, sea lamprey *Petromyzon marinus*, brook lamprey *Lampetra planeri* and river lamprey *Lampetra fluviatilis*.
- River Teith SAC (approximately 98 km away):
  - The Annex II species present as a qualifying feature are: sea lamprey, brook lamprey, river lamprey and Atlantic salmon.
- River South Esk SAC (approximately 82 km away):
  - The Annex II fish species present as a qualifying feature is: Atlantic salmon.

The sites designated for the protection of fish and shellfish within 50 km of the Marine Scheme in English waters are:

- Tweed Estuary SAC (approximately 12 km away):
  - The Annex II species present as qualifying features are: sea lamprey and river lamprey; and
- River Tweed SAC (approximately 9 km away):
  - The Annex II species present as qualifying features are: Atlantic salmon, sea lamprey, brook lamprey, and river lamprey.

Further detail on designated sites screened into the Marine Scheme appraisal are presented in EAR Volume 3 Appendix 8.2: Habitat Regulations Assessment Report.

9.5.2 Species Specific Information

9.5.2.1 Diadromous Species

Atlantic Salmon

Atlantic salmon is an anadromous[3] migratory species, which during its lifetime utilises both marine and freshwater habitats. Spawning of salmon typically occurs in November or December, in the upper reaches of rivers in gravelly substrate (Heessen, Daan, & Ellis, 2015; NASCO, 2012). The resultant larvae known as 'alevins' remain within the interstitial gravels. The transition from larvae to parr occurs in the first summer in southern streams (Potter & Dare, 2003) or up to a year in upland systems. Following the parr life stage, salmon physically and morphologically change into 'smolt'. This is preceding migration to the ocean following one to five years in freshwater. The migration of smolt down-river to the ocean usually occurs from spring to early summer, generally occurring earlier in the season for larger smolt with most fish gone by June (Thorstad, et al., 2012). Once salmon have spent another one to five years at sea, the adults then return to their spawning rivers, which in the UK usually peaks in June to August and October to December (Cowx & Fraser, 2003).

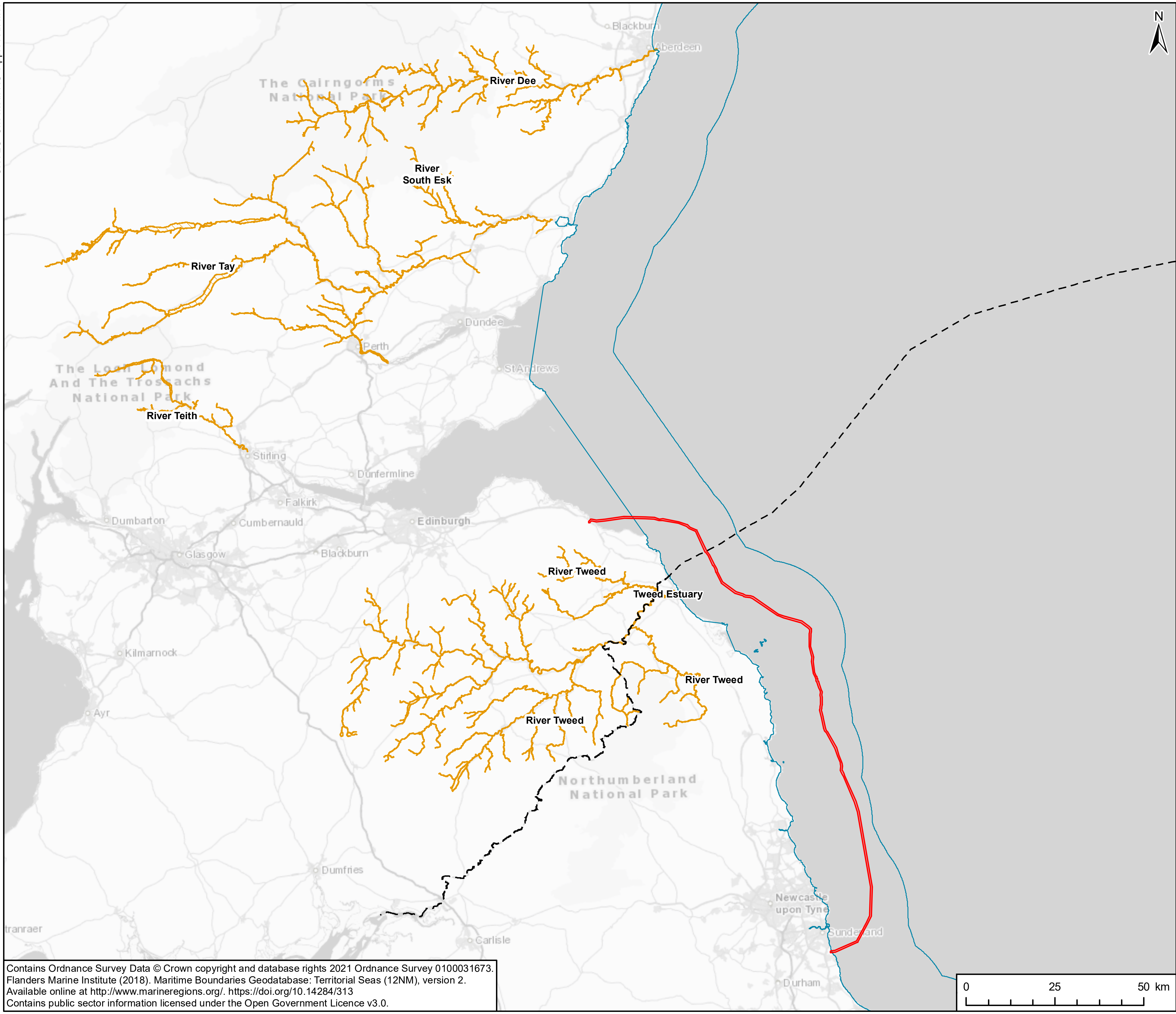
Atlantic salmon typically spend most of their time in surface waters, but often dive, sometimes to great depth (up to 280 m). It also appears that this behaviour persists late into the migration on the return to home waters. Sub-adult Scottish salmon are known to migrate to areas of water around Greenland and the Faroe Islands to feed before returning to home waters (Malcolm, Godfrey, & Youngson, 2010) suggesting that the likelihood of salmon migrating through or within 50 km of the Marine Scheme, during their travel between their natal rivers and the sea is high.

Atlantic salmon are protected as an Annex II species and are a qualifying feature of the following designated sites:

- River Dee SAC (110 km);
- River South Esk SAC (82 km);
- River Tay SAC (72 km);
- River Teith SAC (98 km); and
- River Tweed SAC (9 km).

[3] Anadromous fish are diadromous fish that migrate from the sea into freshwater for spawning. This distinguishes them from catadromous fish, such as eels which migrate in the opposite direction, moving from freshwater to spawn in the sea.

GIS: LC Checked: RG Approved: MW



Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:1,000,000

nationalgrid
SP TRANSMISSION

PROJECT

Scotland England Green Link 1 / Eastern Link 1

KEY

- Marine Installation Corridor
- UK Territorial Sea Limit - 12nm
- England/Scotland Planning Boundary
- Special Area of Conservation

TITLE

Figure 9-2
Key Sites Designated for the Protection of Fish and Shellfish within 50 km of the Project Marine Scheme

REFERENCE

SEGL1_M_EAR_9-2_v4_20220308

SHEET NUMBER: 1 of 1

DATE: 08/03/2022

The most important of these is the River Tweed SAC which supports a large population of Atlantic salmon with sub-catchments in both Scotland and England. Atlantic salmon migrate from the North Sea to the River Tweed almost all year round (Gauld, Campbell, & Lucas, 2016). The River Tweed catchment area is located within the study area and data from the National Fish Populations Database (NFPD) for the Tweed area, as reported by the Environment Agency (Environment Agency, 2020a). The NFPD provides a collection of information from fisheries monitoring work on rivers, lakes and transitional and coastal waters (TraC), recorded by the Environment Agency and third parties. A total of 695 individual salmon were recorded in the TraC surveys between 2002 to 2017 in the River Tweed. However, the majority (62%) were recorded in 2008 and there were many years (2003, 2004, 2006, 2007, 2009 and 2016) when no salmon were recorded at all.

Other Scottish rivers considered as important for salmon, which are close to the Marine Scheme include: the River Eye Water, and the River Tyne. The main salmon rivers in England which are in close proximity to the Marine Scheme (see Figure 9-3), include the river Aln, Coquet, Tyne, and Wear. These rivers (excluding the river Aln) are considered ‘Principal Salmon Rivers’ and have their own ‘Salmon Action Plans’, used to provide a strategy for the management of the fishery, and enforced by the Environment Agency.

Brown Trout (Sea Trout)

Brown or sea trout, *Salmo trutta,* displays a broad range of life history traits, with individuals that complete their lifecycle in freshwater, those that predominately inhabit estuarine waters, and those that exhibit full anadromy (Harris, 2017). Sea trout exhibit a similar life cycle to Atlantic salmon though the adult marine stage of sea trout is shortened both spatially and temporally, with some migration back to freshwater environments after only a very short period of time feeding at sea, whilst ‘maidens’ only return to freshwater after a minimum of a year at sea (Gargan, Roche, Forde, & Ferguson, 2006). Adult sea trout returning to freshwater to spawn are more likely to stray from natal rivers compared to salmon. Spawning usually takes place in autumn or winter, on stone and gravel bottoms.

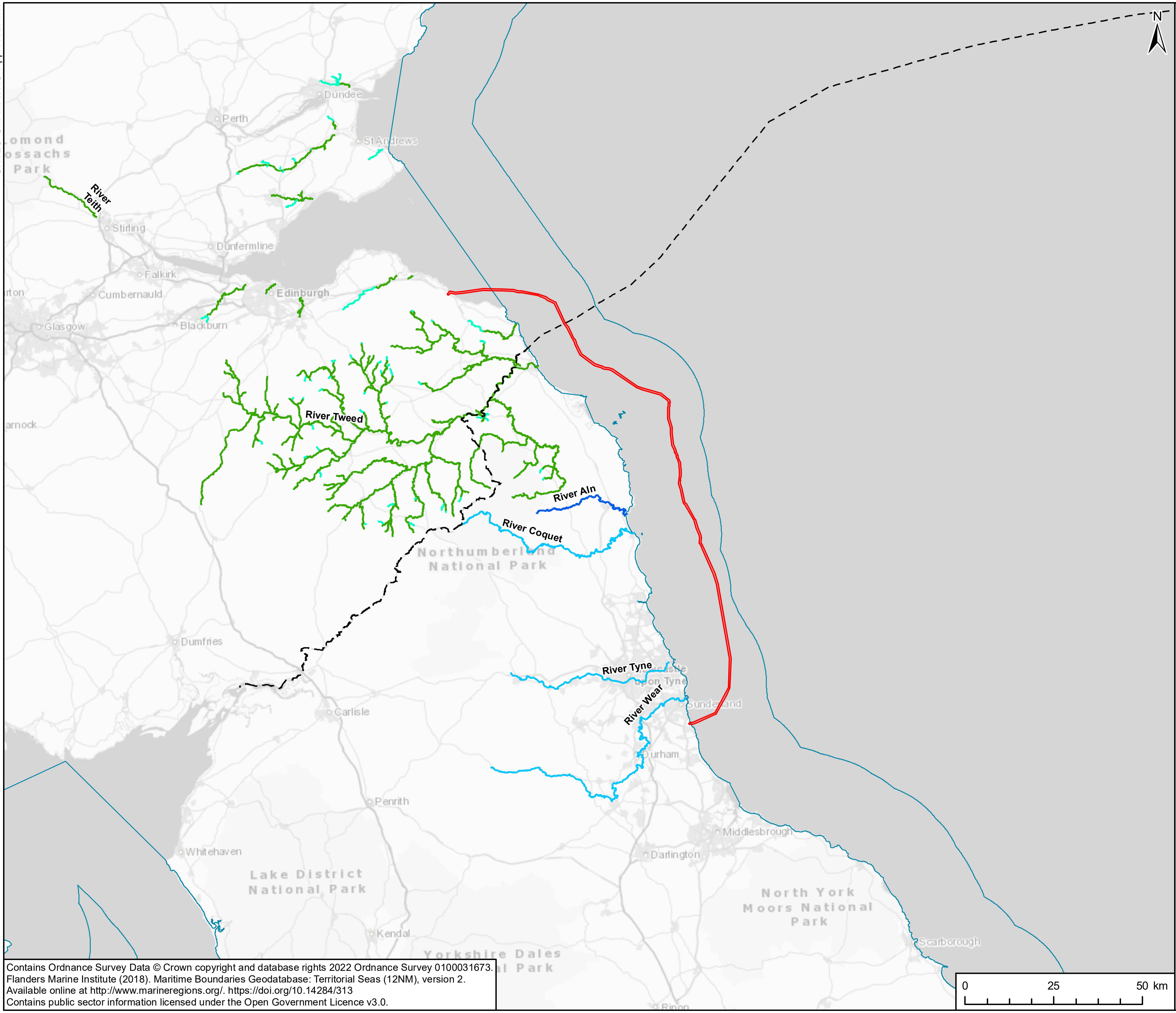
Studies on sea trout movements in Scottish waters have largely been confined to the west coast of Scotland. Malcom et al. (2010) concluded that sea trout post-smolts on the west coast display relatively local movement for the first couple of months at sea, often remaining within local fjords or sea lochs. However, due to the absence of detailed studies, the movement of sea trout on the east coast of Scotland remains unclear and no reliable conclusions can be drawn as to the marine distribution of adult sea trout. There is limited information on swimming depths for adult sea trout though available data suggest during the marine mitigation phase, they have a generally shallow swimming depth (approximately 0-3 m) and make occasional deep dives (Kristensen, Righton, del Villar-Guerra, Baktoft, & Aarestrup, 2018). However, a detailed study carried out by Gauld and Campbell (2016) on sea trout and salmon in the River Tweed, found that the peak entry time of the sea trout in the Tweed estuary is in June and July.

Sea and River Lamprey

Sea lamprey and river lamprey are both anadromous migratory species. After spending several years in the marine environment, adults return to freshwater to spawn in spring and early summer (Laughton & Burns, 2003).

Sea lamprey are widely dispersed in the open sea as they are solitary feeders, being rarely found in coastal and estuarine waters (Moore, Hartel, Craddock, & Galbraith, 2003). When returning to freshwater, sea lamprey generally choose larger rivers compared to river lamprey, although they can be found in tributaries of all sizes (Heessen, Daan, & Ellis, 2015). As a parasitic species the distribution of sea lamprey is chiefly defined by its host, often other fish (Waldman, Grunwald, & Wirgin, 2008) and they are often found at considerable depths in deeper offshore waters (Moore, Hartel, Craddock, & Galbraith, 2003).

In contrast, river lamprey are usually found in coastal water, estuaries and accessible rivers and juveniles are often found in large congregations (Maitland, 2003). Distribution in the UK appears to be mainly in Wales, Northern Ireland and southern Scotland (Figure 9-4). River lamprey generally spend one to two years in estuaries, then move upstream in the autumn, between October and December (Zancolli, Foote, Seymour, & Creer, 2018).



Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:1,000,000

nationalgrid
SP TRANSMISSION

PROJECT

Scotland England Green Link 1 / Eastern Link 1

KEY

- Marine Installation Corridor
- UK Territorial Sea Limit - 12nm
- England/Scotland Planning Boundary

Main Salmon Rivers in Scotland

- Salmon Present
- Salmon Likely Present

Main Salmon Rivers in England

- River
- Principal Salmon River

TITLE

Figure 9-3
Rivers of Known Importance to Migratory Salmon within 50km

REFERENCE

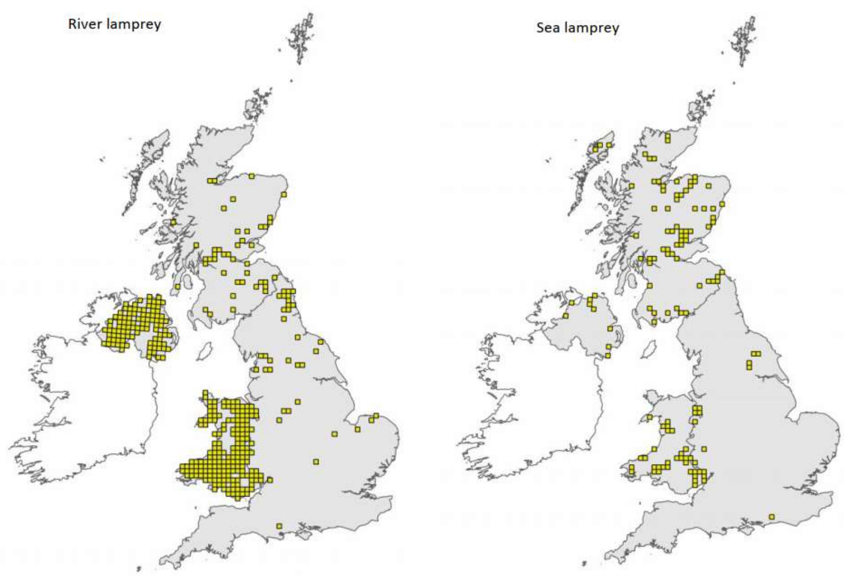
SEGL1_M_EAR_9-23_v6_20220425

SHEET NUMBER	DATE
1 of 1	25/04/2022

Sea lamprey spawn when the water temperature reaches at least 15°C and normally migrate into freshwater from April to June, spawning from late May to June (Zancolli, Foote, Seymour, & Creer, 2018). Migration to sea can vary from river to river, although the metamorphosis of larvae into adults, occurs in July to September (Maitland, 2003).

While sea lamprey population sizes in Scotland appear small, the trend for adult sea lamprey abundance in the UK appears to show a general increase in spawning migrants, which may be a result of ongoing water quality improvements and access to spawning habitat (Hume, 2017).

Sea lamprey and river lamprey are protected as Annex II species and are qualifying feature of the following relevant designated sites, the Tweed Estuary SAC, River Tweed SAC and River Teith SAC. These lampreys are the primary reason for the site selection in the River Teith SAC located approximately 99.3 km of the Marine Scheme.



Data source: **(JNCC, 2018a; JNCC, 2018b)**

Figure 9-4: Distribution of river and sea lamprey in UK rivers

European Eel

The European eel *Anguilla anguilla* is a catadromous[4] migratory species, undertaking an extensive migration to spawn in the Sargasso Sea. The larvae are transported to the continental shelf of the North Atlantic by the prevailing currents of the Gulf Stream, where they metamorphose into the life stage of glass eel and subsequently, in freshwater and coastal waters become pigmented 'elvers' (Aerestrup, et al., 2009; Potter & Dare, 2003).

Glass eels travel across shelf seas, using tidal stream transport, rising in the water column when the tide travels inwards, and settling to the bottom as the tide returns (Heessen, Daan, & Ellis, 2015). Eels migrate upstream into freshwater predominately during spring but may continue to do so until early Autumn.

Once in freshwater eels remain for five to 15 years, transforming into yellow eels and then finally to silver eels before beginning their downstream migration through rivers and estuaries and to spawning grounds, predominately between August and December (Behrmann-Godel & Eckmann, 2003; Tesch, 2003; Chadwick, Knights, J, & Bark, 2007). Spawning occurs mainly in spring (Righton, et al., 2016). Some eels do not migrate into freshwater but instead inhabit estuaries as 'elvers' and yellow eels before returning to spawning grounds.

[4] A diadromous species that migrates from freshwater to seawater to spawn.

The River Tweed has an important population of European eel (Tweed Foundation, 2014). Most abundant are those up to 300 mm in length, with abundance decreasing considerably in eels of longer lengths. The lower reaches of the Tweed, near the sea, have higher abundances compared to the upper reaches.

9.5.2.2 Pelagic Species

Herring

Herring *Clupea harengus* is an important commercial species and represents a significant prey species for many predators, including large gadoids (such as cod), dogfish, sharks, marine mammals and birds (ICES, 2006a). Herring is a pelagic fish and is found mostly in continental shelf areas to depths of 200 m (Whitehead, 1986). Juveniles are generally distributed separately from adults, being found in shallower water, migrating into deeper waters to join the adult stock after two years. In the North Sea 1-group[5] herring are restricted within the 100 m depth contour and are most abundant in the south-east, Kattegat and along the British east coast (ICES, 2006a).

Herring are demersal spawners, which means when spawning occurs, large numbers of eggs are released (~50,000 per female) near the seafloor, which sink and attach to gravel, stones and shell where they form a dense mat. Herring spawning takes place in areas of well-mixed waters in open seas, coastal waters, and embayments (Heessen, Daan, & Ellis, 2015). In September, herring larvae are present in high numbers in the North Sea (IMARES, 2014). Once developed into juvenile fish, herring aggregate into shoals which migrate into estuaries and shallow waters where they remain for six months to a year (Dipper, 2001). After their first year, herring move offshore, joining the adult populations as they reach maturity (Heessen, Daan, & Ellis, 2015).

Ellis et al. (Ellis, Readdy, Taylor, & Brown, 2012) recognised the study area i as a high intensity nursery ground for herring.

Sprat

Sprat *Sprattus sprattus* is a short-lived, small-bodied pelagic schooling species that is relatively abundant in shallow waters. Sprat is an important food resource for a number of commercially important predatory fish, seabirds and marine mammals.

Sprat are thought to be intermediate, multiple batch spawners, batches of eggs released repeatedly throughout the spawning period (Heessen, Daan, & Ellis, 2015). Spawning occurs in coastal waters up to 100 km offshore, and in deep basins (Whitehead, 1986; Nissling, Muller, & Hinrichsen, 2003). Once released, the eggs and larvae, which are pelagic, move into coastal nursery areas by larval drift (Hinrichsen, Kraus, Voss, Stepputtis, & Baumann, 2005; Nissling, Muller, & Hinrichsen, 2003). The study area is recognised by Coull et al. (1998) as being a nursery ground for sprat (Table 9-4), with spawning grounds located nearby. Spawning of sprat is thought to occur from May to August, peaking in May to June (Coull, Johnstone, & Rogers, 1998).

Mackerel

Atlantic mackerel *Scomber scombrus* is a widely distributed migratory fish and is one of the most abundant fish species in the North Atlantic (ICES, 2011). Mackerel spend their entire life in the pelagic environment and are an important food source for sharks, tuna and dolphins (Tappin, et al., 2011). This species is also exploited by commercial fisheries, which in the past has caused the collapse of abundant stocks in the North Sea (ICES, 2006c).

Mackerel in the eastern Atlantic are divided into three spawning components, the North Sea being one of these (ICES, 2011). The main spawning period for mackerel occurs in mid-May to late June, taking place particularly in the central North Sea (Jansen & Gislason, 2011). After this period, mackerel redistribute in the North Sea or migrate into surrounding waters. Mackerel are batch spawners (Murua & Saborido-Rey, 2003), reported as having a fecundity of between 130,000 and 1,100,000 eggs in the North East Atlantic (Macer, 1976).

Ellis et al. (2012) recognised the study area as a low intensity nursery ground for mackerel (Table 9-4).

[5] Fish in the second year of their lives, which are identified as having a winter (hyaline) otolith ring

9.5.2.3 Demersal Species

Sandeel

Five sandeel species occur in the North Sea, including Raitt's sandeel *Ammodytes marinus* which is the most common although the lesser sandeel *Ammodytes tobianus* and great sandeel *Hyperoplus lanceolatus* are also prevalent. Sandeel are an important element of the food chain in the North Atlantic and are prey for other fish species, sea birds and marine mammals (Dipper, 2001). In the northern and central North Sea (ICES Divisions 4.a and 4.b) sandeel fisheries have been divided into 'Sandeel Areas', Sandeel Area 4, in the northern and central North Sea (ICES divisions 4.a and 4.b), overlaps with the study area (ICES, 2021d).

Sandeel spend a large proportion of the year buried in the sediment, only emerging into the water column to spawn briefly in winter (November to February), and for an extended feeding period during the spring and summer months (Van der Kooij, Scott, & Mackinson, 2008). The distribution of sandeel (referring to all species within the genus *Ammodytes*) is highly patchy due to their preference for sandy habitats in well oxygenated waters, favouring coarse sand with fine to medium gravel and a low silt content (Holland, Greenstreet, Gibb, Fraser, & Robertson, 2005); (Greenstreet, et al., 2010). Populations are also associated with seabed morphological features such as subtidal sandbanks as stated in MarineSpace et al. (2013a). Sandeel are demersal spawners; the presence of spawning grounds in the study area is considered in Section 9.5.3.

Great sandeel spawn from late spring to summer, Raitt's sandeel from November to February, whilst the lesser sandeel may spawn both in spring and autumn (Heessen, Daan, & Ellis, 2015). Once hatched, the larvae are pelagic, spending their time in the water column (undertaking vertical migrations that are influenced by light) until they develop into juveniles in the winter when they burrow into the sediment (Limpenny, et al., 1966).

Ellis et al. (2012) did not identify the study area as a high intensity spawning or nursery ground for sandeel, although a high-intensity nursery ground was identified to the north of the marine installation corridor (Table 9-3 and Table 9-4).

Haddock

Haddock *Melanogrammus aeglefinus* is a commercially important (Ellis, Milligan, Readdy, Taylor, & Brown, 2012) and widespread species occurring in deep waters of the eastern, northern and north western Atlantic. They are important prey items for larger fish and seals (ICES, 2006d).

Whilst the most popular spawning ground for haddock in the North Sea is between the Norwegian Deep and the Shetland Islands (UK Government, 2004) modelling has indicated haddock at spawning stage are concentrated offshore around the east coast of Scotland (González-Irusta & Wright, 2016). The distribution of spawning has shown some variability between 2009-2015 but the east coast of Scotland has remained the most concentrated spawning area of the North Sea (González-Irusta & Wright, 2016). Haddock are broadcast spawners, releasing eggs directly to the water column.

There are nursery grounds identified within the Marine Scheme study area (Coull, Johnstone, & Rogers, 1998) (Table 9-4).

Cod

Cod *Gadus morhua* is widely distributed throughout the North Sea, found in shallow coastal waters to the shelf edge (200 m depth). From late winter to early spring, adult cod migrate to offshore spawning grounds, typically at depths of 20 m to 100 m in the North Sea (Dipper, 2001). Cod is classified as a determinate multiple spawner (McEvoy & McEvoy, 1992) with experiments reporting between eight and 22 batches of pelagic eggs spawned per season (Kjesbu, Kryvi, Sundby, & Solemdal, 1992).

The Marine Scheme does not fall within cod spawning grounds identified by either Ellis et al. (2012) or Coull et al. (1998). González-Irusta and Wright (2016) used the abundance of spawning fish to model spawning habitat within the North Sea, indicating cod is widespread, and associated with coarse sand and low tidal flow. Cod spawn in the winter and autumn months (depending on the area). The Marine Scheme falls within an extensive area of occasional spawning including areas to the east of Scotland and of northern England.

The eggs and larvae of cod remain in the water column, developing into juvenile fish for approximately six months. Juveniles then move to the seabed, often between July and August, where they become demersal (Heessen & Daan, 1994). Juvenile cod move into coastal nursery areas once the spawning season is over, with young cod often found in estuaries and shallow waters.

The study area is a high intensity nursery ground for cod Ellis et al. (2012) (Table 9-4).

Whiting

Whiting *Merlangius merlangus* is a bentho-pelagic species, found in association with a variety of seabed types including sediment and rocky areas (Barnes, 2008). The spatial distribution of whiting, particularly in the northern North Sea, appears to be affected by sea surface temperature (Zheng, Pierce, Reid, & Jolliffe, 2002). Overall, whiting do not make long-distance migrations from their spawning site (Heessen, Daan, & Ellis, 2015).

Spawning of whiting takes place from February to June (Coull, Johnstone, & Rogers, 1998), peaking in spring in shallow waters (Wheeler, 1978). Most whiting spawning occurs in water depths <100 m (Heessen, Daan, & Ellis, 2015). González-Irusta and Wright (2017) states that whiting shows a high plasticity in spawning ground selection, with extensive areas of spawning occurring across the North Sea.

Ellis et al. (2012) recognised the study area as a low intensity spawning ground for whiting (Table 9-3).

Whiting was identified as aggregating to spawn, but often across large areas, with the highest aggregations occurring in the English Channel, the southern North Sea, and the east of Scotland, away from the study area. Whiting typically reach maturity after two years and often spawn during this year. Eggs are pelagic.

The study area is within high intensity nursery ground for whiting (Ellis, Readdy, Taylor, & Brown, 2012) (Table 9-4).

Dover Sole

Dover sole *Solea solea* is a southern species whose northern limit is in the North Sea. It favours sandy and sandy muddy substrates, which they can bury into, in waters of up to 50 m depth. The spatial distribution of Dover sole varies between life stages, with juveniles favouring coastal nursery grounds whilst older and larger individuals occupying deeper offshore waters (Teal, 2011).

Spawning in the North Sea typically occurs in March to June and peaks in April (Tappin, et al., 2011). Spawning takes place inshore, generally in estuaries, where high numbers of eggs are released. The eggs then drift into high productivity shallow sandy nursery grounds which provide a good feeding ground for juveniles (Dipper, 2001).

The study area is not recognised by Ellis et al. (2012) or Coull et al. (1998) as being a Dover sole nursery ground or spawning area.

Plaice

Plaice *Pleuronectes platessa* isfound on all UK coasts, normally on sandy substrata, as well as gravel and mud (Tappin, et al., 2011). Plaice generally spawn between January and April, at depths of between 20 m and 40 m, releasing high numbers of pelagic eggs. Coastal and inshore waters of the North Sea represent important nursery areas (Kuipers, 1977). Following spawning, plaice reach their peak densities in May, and in June and July older fish tend to migrate offshore, whilst juveniles remain in the intertidal zone until autumn (Kuipers, 1977).

The study area is within an area recognised by Ellis et al. (2012) as a low intensity nursery ground for plaice (Table 9-4).

9.5.2.4 Elasmobranchs

Basking Shark

The basking shark *Cetorhinus maximus* is a large pelagic migratory species, listed under Schedule 5 of the Wildlife and Countryside Act 1981, with a distribution concentrated around the north and south west coasts of the UK (Witt et al., (2012). Basking shark is present in the North Sea but observations are relatively rare (Witt et al., (2012). There have been some sightings around the east coast of Scotland, close to the Scottish landfall, and some close to the English landfall, indicating very occasional presence of basking shark in the study area.

Although, the North Sea was not previously considered to be an aggregation hotspot for this species, however, a habitat suitability modelling study suggests that several areas in the North Sea, including around both landfall locations, have suitable habitat for basking sharks. These areas may become populated in the future as the north-east Atlantic population recovers following previous exploitation of this species across the northern extent of its range (Austin, et al., 2019). Data do not currently suggest a change in distribution.

Skates and Rays

The thornback ray *Raja clavata*, spotted ray *Raja montagui* and blonde ray *Raja brachyura* are oviparous demersal spawners, laying successive batches of eggs typically at inshore areas characterised by sandy/muddy substrates (Heessen, Daan, & Ellis, 2015). The spawning season for these species is between February and September with peak spawning for thornback ray in May/June and occurring slightly later in the year for the other ray species. There is insufficient information in the literature to delineate spawning grounds for these species.

Spotted ray and blonde ray are distributed throughout the north-east Atlantic and known to be present within the North Sea but with generally low abundance.

Dogfish and Small Elasmobranchs

Lesser-spotted dogfish is one of the most abundant sharks in the North Sea (Heessen, Daan, & Ellis, 2015). Other species known to be present but in lesser abundance include spurdog S*qualus acanthias*, tope *Galeorhinus galeus*, smooth hound *Mustelus mustelus* and starry smooth hound *Mustelus asterias*. Dogfish and smooth hounds, which are all predominately coastal species.

The lesser-spotted dogfish is an oviparous demersal spawner, laying successive batches of eggs, anchoring them to macroalgae and other sessile features on the seabed. This species exhibits a protracted spawning period (November to July), peaking in June/July (Heessen, Daan, & Ellis, 2015). The spawning grounds of lesser-spotted dogfish are difficult to identify due to insufficient information in the literature, but these are anticipated to overlap with low intensity nursey areas within the southern North Sea (Ellis, Readdy, Taylor, & Brown, 2012).

Spurdog, tope, smooth hound and starry smooth hound are all ovoviviparous or viviparous species (i.e., rear eggs or young within the body) and are therefore not affiliated with any particular habitats. Spawning grounds for these species are not well-defined although tope is thought to utilise inshore areas as nursery grounds (Ellis, Readdy, Taylor, & Brown, 2012).

9.5.2.5 Shellfish

Scallops

In the North Sea, the king scallop *Pecten maximus* favours clean firm sand, fine or sandy gravel and depressions in the seabed but are occasionally found on muddy sand. They are active, epibenthic suspension feeders that occur at depths of between 10 – 110 m particularly in sheltered areas close to faster currents (Marshall, 2008).

Scallop spawning times vary from spring to autumn with some populations exhibiting two spawning peaks during this time. Larvae are planktonic for 30 days and may disperse long distances before settling onto hydrozoans and/or bryozoans until they reach a size of approximately 1 – 5 mm. They then detach and settle onto the seabed (CEFAS, 2021a).

Scallops are an important commercial species in the study area. Further detail is presented in Chapter 14: Commercial Fisheries.

Norway Lobster

The Norway lobster *Nephrops norvegicus,* is distributed according to the extent of cohesive muddy sediments, in which they construct their burrows. The type of sediment also dictates the structure of the *Nephrops* populations, with areas of sandy mud having higher population densities.

The study area falls within important spawning and nursery ground for this species (Coull, Johnstone, & Rogers, 1998). Further detail on this species is presented in Chapter 14: Commercial Fisheries.

European Lobster

The European lobster, *Homarus gammarus* is generally found from the intertidal zone to depths of 60 m and therefore has the potential to be found in coarse habitats within the study area. This species exhibits site fidelity although home extents can range between 2 km and 10 km (Bannister, Addison, & Lovewell, 1994). Lobsters are solitary animals and inhabit holes and tunnels that they build below rocks and boulders (Wilson, 2008). Females can spawn annually or following a bi-annual pattern, with reproduction taking place during the summer (Atema, 1986). They do not make extensive migrations when berried (carrying eggs attached to its tail or exterior part) and hatching takes place in spring and early summer on the same grounds (Pawson, 1995).

Crabs

The edible crab *Cancer pagurus*, is found in waters between 25 m and 300 m in the North Sea, with a preference for bedrock, mixed course grounds, and offshore in muddy sands (Neal & Wilson, 2008). This species therefore has the potential to be present with the study area. Edible crabs copulate in the spring and summer, the female crabs becoming gravid, carrying their eggs under the abdomen. In the North Sea, brooding females migrate offshore to release the larvae, which once hatched remain in the water column for between 60 and 90 days before settling. Tagging surveys off the coast of Norfolk, have shown that mature females undertake long-distance northerly migrations to the Yorkshire coast, although more recent studies suggested this may be a discrete population of edible crabs (Eaton, Brown, Addison, Milligan, & Fernand, 2003).

Velvet swimming crab, *Necora puber*, prefers rocky substates from shallow subtidal habitats at around 70 m (Hearn, 2004). Their main spawning season is between February and March (Hearn, 2004). In contrast to edible crabs, there is no evidence that velvet swimming crab undertake extensive migrations. Their movements are thought to be restricted to a few hundred metres (Hearn, 2004).

9.5.3 Spawning and Nursery Grounds

The occurrence, distribution and abundance of many fish and shellfish within the study area is determined by their propensity to aggregate within specific areas to spawn (lay or release their eggs). ‘Spawning grounds’ are defined either by the species behaviour and therefore may cover a wide area, or by specific habitat preferences (e.g. gravel), which may restrict spatial extent. Fish exhibit several modes of reproduction, the most common being broadcast spawning, where eggs and sperm are released into the water column (Ellis, Readdy, Taylor, & Brown, 2012). Other species deposit egg-cases (e.g. dogfish and whelk) or egg mats onto the seafloor (e.g. herring), making them particularly vulnerable to seabed disturbance.

Fisheries sensitivity maps (Coull, Johnstone, & Rogers, 1998; Ellis, Readdy, Taylor, & Brown, 2012) provide information on spawning grounds (the location where eggs are laid) and nursery areas (the location where juveniles are common) for selected fish and shellfish species prevalent in the study area (see Table 9-3 and Table 9-4). This data indicates that the Marine Scheme is located within important spawning grounds for herring, whiting, sandeels, plaice, and *Nephrops*. High-intensity nursery grounds of herring, cod, and whiting were also identified within the study area, as were important grounds of sandeel, plaice, sprat, and *Nephrops*. Juvenile horse mackerel appear to be widespread exhibiting no spatially discrete nursery grounds within the study area. The spawning and nursery grounds of these species, as detailed by Coull et al. (1998) and Ellis et al. (2012), are presented in the context of the Marine Scheme in Figure 9-5 and Figure 9-6. Cod, whiting and plaice are broadcast spawners. As such eggs, once spawned, are pelagic and distributed through the water column and will therefore be carried by ocean currents, potentially distant from the project and so are unlikely to be at risk of impacts. On this basis, only sandeel and herring have been taken forward for detailed appraisal in Sections 9.5.3.1 and 9.5.3.2 (Table 9-5).

Defining spawning and nursery grounds is useful in identifying sensitive areas for particular species. However, it is also important to consider aggregations of 0 group fish[6] and or larvae of key commercial species and sensitivity maps have been updated with this information (Aires, González-Irusta, & Watret, 2014). These data have corroborated the Coull et al. (1998) and Ellis et al. (2012) sensitivity maps for cod, haddock, whiting, herring found in the wider Marine Scheme.

Table 9-3: Spawning grounds within study area

Species	Ellis et al., 2012	Coull et al., 1998
Herring	Insufficient data	Yes
Sandeel	Low intensity (High intensity also found nearby)	Yes
Sprat	n/a	No
Mackerel	Insufficient data	No
Haddock	n/a	No
Cod	No	No
Whiting	Low intensity	Yes
Dover sole	Insufficient data	No
Plaice	Low intensity	Yes
Norway lobster *(Nephrops)*	n/a	Yes

Table 9-4: Nursery grounds within study area

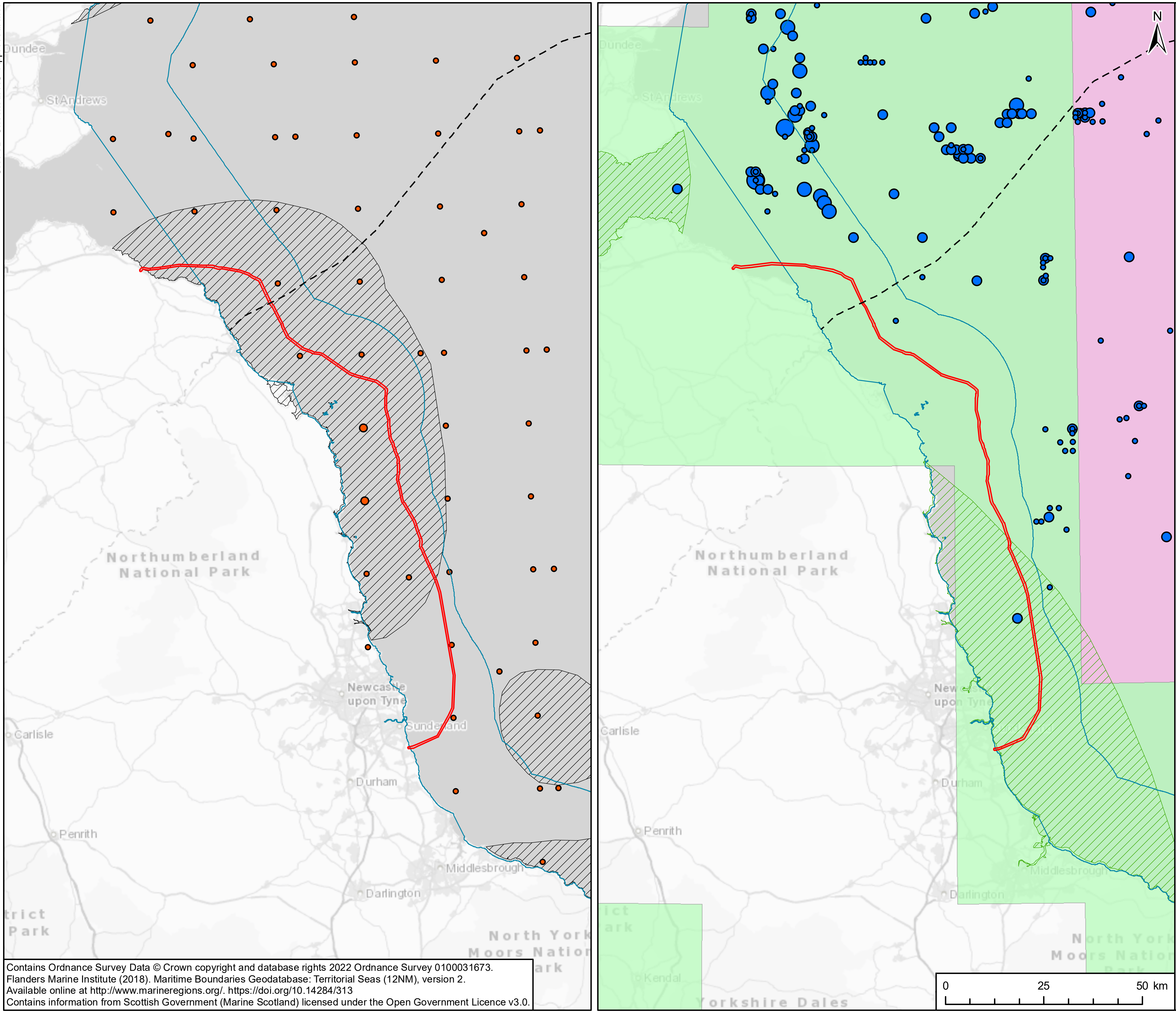
Species	Ellis et al., 2012	Coull et al., 1998
Herring	High intensity	Yes
Sandeel	Low intensity	Yes
Sprat	n/a	Yes
Mackerel	Low intensity	No
Haddock	n/a	Yes
Cod	High intensity	Yes
Whiting	High intensity	Yes
Dover sole	Insufficient data	No
Plaice	Low intensity	Yes
Norway lobster (*Nephrops*)	n/a	Yes
Thornback ray	No	n/a
Spotted ray	No	n/a
European hake	Low intensity	n/a
Horse mackerel	Widespread	n/a

Table 9-5: Spawning times for sensitive demersal spawners in the study area

Fish species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Herring (Buchan)												
Herring (Central)												
Sandeel												

[6] 0 group fish are defined as juvenile fish in the first year of their lives, who do not yet possess a winter (hyaline) otolith ring. Aggregations refers to areas containing large abundances of these individuals

GIS: SB Checked: RG Approved: MW



Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:900,000

nationalgrid
SP TRANSMISSION

PROJECT

Scotland England Green Link 1 / Eastern Link 1

KEY

- Marine Installation Corridor
- UK Territorial Sea Limit - 12nm
- Scottish Adjacent Waters Boundary

Herring Larvae

- 0 - 254
- 254 - 1140
- 1140 - 3458
- 3458 - 8351
- 8351 - 26914
- Herring Spawning Grounds (1998)

Herring Maximum Catch Rate

- 0 - 17916
- 17916 - 66105
- 66105 - 176310
- 176310 - 418093
- 418093 - 986520
- Herring Nursery Grounds (1998)

Herring Nursery Grounds (2010)

- High Intensity
- Low Intensity

TITLE

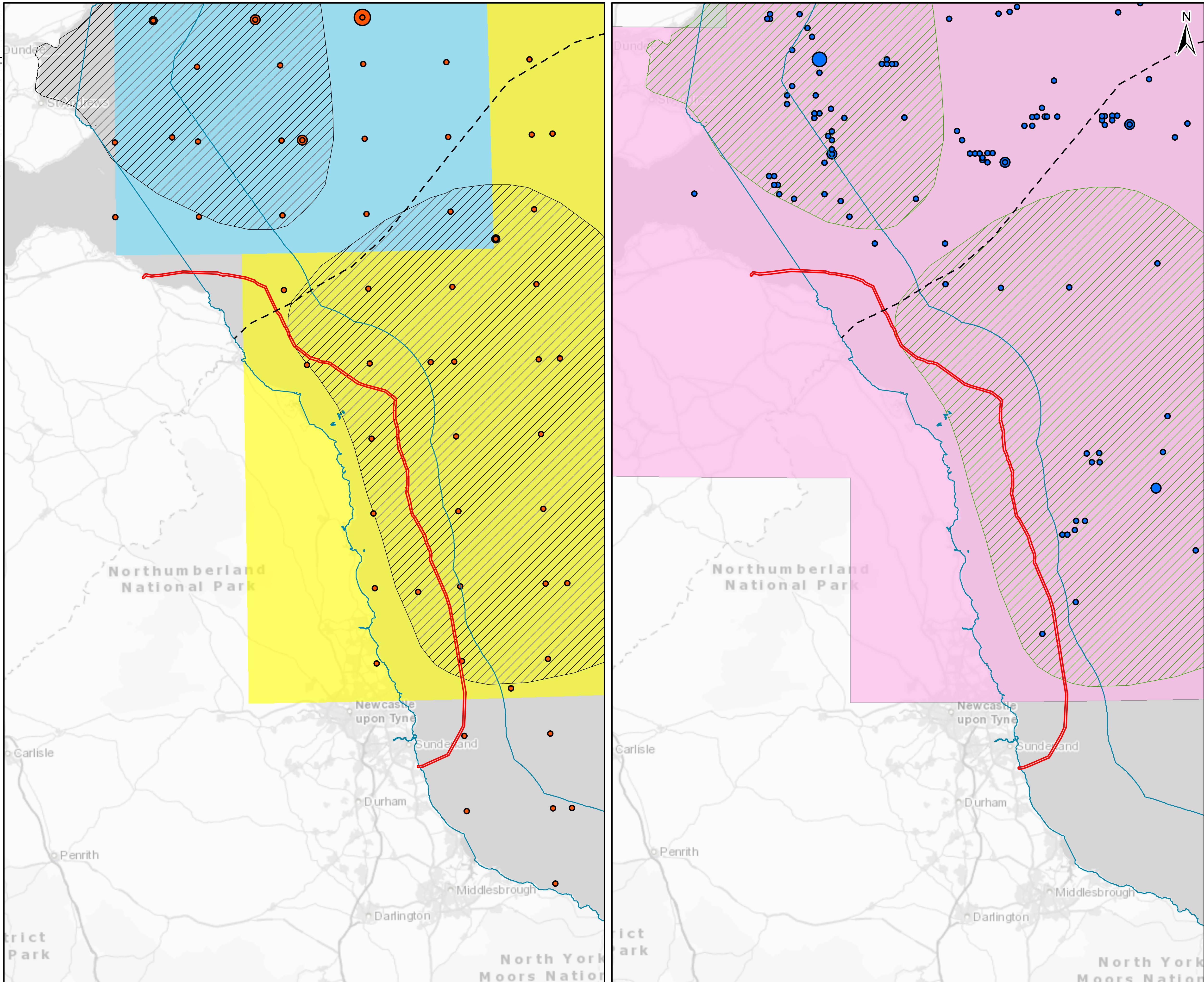
Figure 9-5
Herring Spawning and Nursery Grounds

REFERENCE

SEGL1_M_EAR_9-5_v2_20220425

SHEET NUMBER	DATE
1 of 1	25/04/2022

GIS: SB Checked: RG Approved: MW



Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:900,000

nationalgrid
SP TRANSMISSION

PROJECT

Scotland England Green Link 1 / Eastern Link 1

KEY

- Marine Installation Corridor
- UK Territorial Sea Limit - 12nm
- Scottish Adjacent Waters Boundary
- Sandeel Spawning Grounds (1998)

Sandeel Spawning Grounds (2010)

- High Intensity
- Low Intensity

Sandeel Larvae

- 0 - 20
- 20 - 70
- 70 - 167
- 167 - 418
- 418 - 1912

Sandeel Maximum Catch Rate

- 0 - 230
- 230 - 937
- 937 - 3160
- 3160 - 10621
- 10621 - 20223

- Sandeel Nursery Grounds (1998)

Sandeel Nursery Grounds (2010)

- High Intensity
- Low Intensity

TITLE

Figure 9-6
Sandeel Spawning and Nursery Grounds

REFERENCE

SEGL1_M_EAR_9-6_v2_20220425

SHEET NUMBER 1 of 1

DATE 25/04/2022

9.5.3.1 Herring Spawning Grounds

Spawning grounds for herring are located on gravel and similar habitats (such as coarse sand, maerl, and shell) where the water is well-oxygenated and there is a low proportion of fine sediment (Ellis, Readdy, Taylor, & Brown, 2012). There are several geographically distinct stocks of herring in UK waters (Tappin, et al., 2011), with three major populations, each with different spawning times. The major population associated with the study area is the Banks population, located in the Central North Sea and off the English coast, with spawning occurring from August to October (Ellis, Readdy, Taylor, & Brown, 2012).

The location of the Banks stock is evident from the abundance of larvae and eggs sampled as part of the International Herring Larvae Surveys (IHLS) in the North Sea (Figure 9-7). The IHLS are undertaken annually and provide information on the larvae hatching success and larvae abundance of the main spawning grounds of the North Sea autumn spawning herring (ICES, 2020e). The larvae which are recorded measure <11 mm in the North Sea, representing recently hatched larvae. This information, supplemented with IHLS egg counts, provides a useful indication of important herring spawning in the North Sea.

The 2018-2020 IHLS hauls within the study area recorded a limited number of herring larvae in close proximity to the Marine Scheme. Where herring were recorded, they were found in smaller numbers compared to sampling further north and south within the North Sea. During the 2010 to 2017 IHLS, egg and larvae were sampled close to the cable route but were present in smaller numbers compared to other areas surveyed (further north and south) with a number of samples not recording any herring larvae or eggs. Overall, although the Marine Scheme falls within an important area for herring spawning for the Banks population, this only represents a small section of a wider area where herring larvae and eggs are recorded in greater numbers.

The subtidal benthic habitats identified along the marine installation corridor are generally dominated by areas of mud, sand and coarse sediments[9]. A variety of other habitats are distributed throughout the length of the Marine Scheme, with a greater diversity of benthic habitats in the higher energy, coastal areas of the route. A total of 16 EUNIS biotope complexes were recorded across the subtidal area of the Marine Scheme during a benthic characterisation survey undertaken by Fugro (2021) (for more information see Chapter 8: Benthic Ecology).

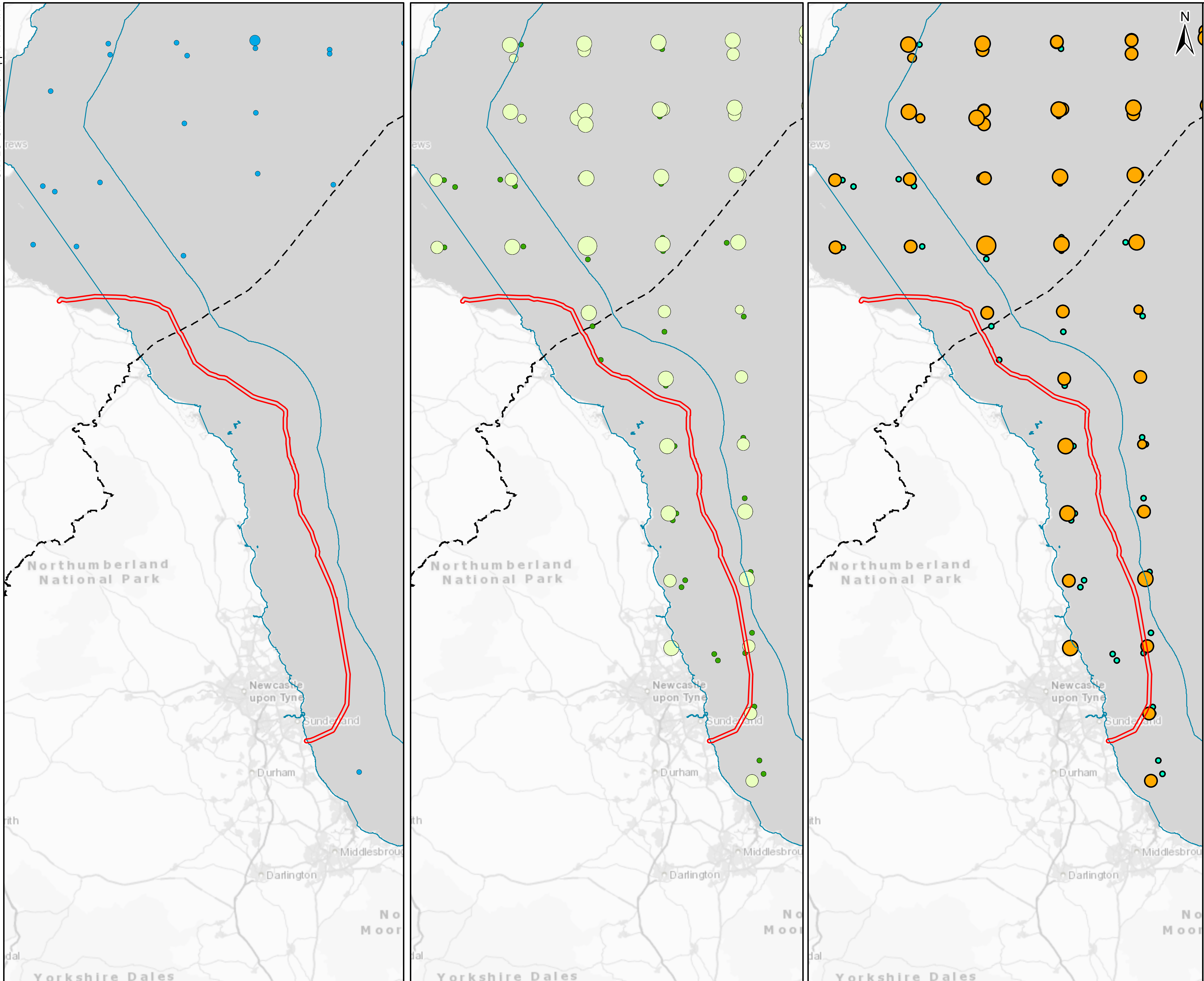
A total of 46 sampling locations were sampled by Fugro (2021) within the subtidal marine installation corridor during the benthic characterisation survey. The results of a potential herring spawning habitat study undertaken on the sampled sites are presented in Table 9-6. Within the marine installation corridor, only one station (ST38) (where the sediment was described as ‘sandy gravel’: 72.48% gravel, 25.80% sand and 1.72% mud) was classified as ‘Preferred’ habitat for herring spawning. Two stations (ST01 and ST20) were described as ‘Marginal’. The remaining sampling locations were described as ‘Unsuitable’. These results suggest limited potential for herring spawning within the marine installation corridor.

Table 9-6: Potential herring spawning habitat along the Marine Scheme

Station	KP	Modified Folk	Habitat Sediment Preference
ST01	2.3 km (AC3)	Gravelly sand (gS)	Marginal, Suitable
ST20	90.9 km (AC43)	Gravelly sand (gS)	Marginal, Suitable
ST38	162.4 km (AC75)	Gravel (G) / Sandy gravel (sG)	Preferred, Prime

[9] EMODnet seabed habitat mapping. Available online: https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/?zoom=3&center=-15.000,51.600&layerIds=3&baseLayerId=-3&activeFilters=

GIS: LC Checked: RG Approved: MW



Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:1,000,000

nationalgrid
SP TRANSMISSION

PROJECT

Scotland England Green Link 1 / Eastern Link 1

KEY

- Marine Scheme Scoping Boundary
- Territorial Sea Limit - 12nm
- England/Scotland Planning Boundary

Average Number of Larvae Per Haul 2018-2020 (ICES)

- 1- 5
- 5 - 10
- 10 - 20
- 20 - 30

Total Larvae Caught Per Haul 2010-2017 (ICES)

- 0
- 1 - 10
- 10 - 100
- 100 - 1000
- 1000 - 10000
- 10000 - 100000

Number of Eggs Per Haul 2010-2017 (ICES)

- 0
- 1 - 10
- 10 - 100
- 100 - 1000
- 1000 - 10000
- 10000 - 100000

TITLE

Figure 9-7
North Sea Herring Larvae and Egg Abundance

REFERENCE

SEGL1_M_EAR_9-7_v2_20220518

SHEET NUMBER 1 of 1

DATE 18/05/2022

9.5.3.2 Sandeel Spawning Grounds

Sandbanks and other sandy areas are known to be important habitat for sandeel, which typically prefer depths between 30 m and 70 m but are known to occur at depths of 15 m and 120 m burrow into these sandy habitats and use interstitial water to ventilate their gills. Fine sediment has the potential to clog their gills and therefore, sand eels have a very specific habitat requirement, meaning their distribution is often patchy (Holland, Greenstreet, Gibb, Fraser, & Robertson, 2005); (Jensen, Rindorf, Wright, & Mosegaard, 2011). Sandeels remain buried between September and February, except to emerge between December and February to spawn their demersal eggs onto sand from which larvae hatch between February and April.

Broadscale mapping of sandeel spawning grounds, based on the regular presence of larvae in the water column (Coull et al., 1998; Ellis et al., 2012), indicates there are potential spawning grounds along most of the marine installation corridor. All data indicates these are low intensity spawning grounds.

To determine the presence of suitable sandeel habitat at a scale local to the project, i.e. within the marine installation corridor, the sediment type determined from grab samples was assessed against the specific habitat requirements of this species (Fugro, 2021).

Along the Marine Scheme, of the 46 sampling locations within the subtidal survey areas, 8 were described as ‘Preferred’, and one as ‘Marginal’, with the remaining stations classified as ‘Unsuitable’ (Table 9-7). No sandeel were collected in grab samples, as is often the case in areas of seabed of particular importance for sandeel. Low intensity spawning grounds appear to be subject to local patchiness and the data indicate the seabed of the marine installation corridor is not of high importance.

Table 9-7: Potential suitable habitat for sandeel along the Marine Scheme

Station	KP	Coarse Sand (%)	Fine Sand and Silt (%)	Habitat Sediment Preference
Nearshore Subtidal				
TOR_ST01	0.87	27.53	71.94	Preferred
TOR_ST02	0.87	27.79	71.93	Preferred
Offshore Subtidal				
ST01	2.26	77.31	12.48	Preferred
ST12	47.50	63.24	36.69	Preferred
ST20	90.94	68.79	26.06	Preferred
ST21	95.97	77.87	21.68	Preferred
ST38	162.40	24.24	3.28	Marginal
ST41	168.38	3.93	96.06	Preferred
ST42	168.38	14.23	85.48	Preferred

9.5.4 Commercial Fisheries

Species of commercial importance vary along the marine installation corridor depending on location. The most important species by landings weight, for the period 2016 to 2020, were king scallop, crabs, herring, sandeel, lobster and *Nephrops* (MMO, 2021). Detail on commercial fisheries within the study area, including information on ports and fishing fleet characteristics, has been provided within Chapter 14: Commercial Fisheries.

9.5.5 Summary of Receptors

Fish and shellfish receptors taken forward for appraisal have been determined based upon potential activity / receptor interactions (source – pathway -receptor). Those species considered to have greatest sensitivity to a particular impact have been appraised at the species level, whereas those species with lower sensitivity have been appraised either at a high taxonomic level (e.g. elasmobranchs) or by functional group (e.g. demersal, pelagic and migratory) as appropriate (Table 9-8).

Table 9-8: Fish and shellfish ecology receptors considered in this EA Report and their assigned value

Receptor group	Species	Rationale	Value
Pelagic fish species	Herring	• National conservation importance • Presence of spawning and nursery grounds • Sensitive to habitat disturbance and underwater sound • Commercially and ecologically (prey species) important	Medium
	European sprat	• Presence of spawning and nursery grounds • Sensitive to underwater sound • Commercially and ecologically (prey species) important	Low
	Mackerel	• Low intensity nursery grounds • Commercially and ecologically (prey species) important	Medium
Demersal fish species	Sandeel	• National conservation importance (lesser sandeel a PMF) • Low intensity spawning and nursery areas • Sensitive to increased SSC, smothering and habitat disturbance and/or loss • Commercially and ecologically (prey species) important)	Medium
	Atlantic cod, haddock, whiting, European plaice, Dover sole	• International and/or national conservation importance • Presence of spawning and nursery grounds • Sensitive to increased SSC, smothering and underwater sound • Valuable economically (commercial species)	Low / Medium
Elasmobranchs		• Some species of international and national conservation importance • Low intensity nursery ground for thornback ray and spurdog • Sensitive to increased SSC, smothering, habitat loss and EMF • Some species valuable economically (commercial species)	Medium
Migratory species	European eel, Atlantic salmon, sea and river lamprey, and brown (sea) trout	• Species of international or national conservation importance • European eel listed as ‘critically endangered’ on the IUCN Red List • Atlantic salmon and river and sea lamprey are qualifying features of designated SACs • Species sensitive to underwater sound disturbance and EMF • Some species valuable economically (commercial species)	High
Shellfish		• Spawning and nursery grounds for *Nephrops* • Some species and life stages are epibenthic or demersal and therefore sensitive to increased turbidity and smothering • Norway lobster, European lobster, crabs and scallops valuable economically (commercial species)	Medium
General fish and shellfish communities		• Common and widespread distribution • Some species and life stages are demersal and therefore considered sensitive to increased turbidity and smothering • Considered to have a high tolerance to change given their distribution and abundance	Low

9.6 Appraisal of Potential Impacts

This section describes the potential impacts of the Marine Scheme on the fish and shellfish receptors during installation, operation (including maintenance and repair), and decommissioning phases of the Marine Scheme as presented in Chapter 2: Project Description. The appraisal has been undertaken in accordance with the methodology presented in Chapter 4: Approach to Environmental Appraisal. The following pathways detailed in Table 9-9 have been scoped into the appraisal.

Table 9-9: Summary of impacts pathways and ZOIs

Potential impact	Zone of influence (ZOI)
Route preparation and cable installation	
Temporary physical disturbance to fish and shellfish	Maximum disturbance footprints are 50 m for pre-installation and 30 m for installation
Permanent loss of fish and shellfish due to placement of hard substrates on the seabed	Rock berm width a maximum of 7 m
Temporary increase in suspended sediment concentrations (SSC) sediment deposition leading to contaminant mobilisation, turbidity and smothering effects on fish and shellfish	1.4 km from the point of disturbance within the marine installation corridor is the maximum distance to which an increase in fine sediment (silts and muds) is predicted.
Underwater sound effects on fish and shellfish	Behavioural disturbance from continuous sound sources generated by project activities to a maximum estimated distance of 1 km (based on Popper et al., 2014 thresholds)
Changes to marine water quality effects from the use of HDD drilling fluids and accidental leaks and spills from vessels, including loss of fuel oils	Footprint of the proposed works plus 1.4 km buffer; based on professional judgement and consideration of worst-case for fine particulates
Cable operation and maintenance	
Disturbance to fish and shellfish due to subsea cable thermal emissions	Approximately 1 m from the cable, dependent upon the heat carrying capacity of particular sediments.
Disturbance to fish and shellfish due to subsea cable electromagnetic field (EMF) emissions	For the separated cables, the magnetic field resulted in a combined field slightly above the background level at 20 m from the cable.
Maintenance the same as route preparation and cable installation	As above
Decommissioning	
Potential effects the same as route preparation and cable installation	As above

9.6.1 Embedded Mitigation

The following embedded mitigation has been built into the Marine Scheme (Chapter 2: Project Description), to avoid and/or minimise impacts to fish and shellfish ecology receptors and is presented in Table 9-10:

Table 9-10: Fish and Shellfish Ecology Embedded Mitigation

Measure	Description
Pre-installation	
Micro-routeing	Detailed route development and micro-routeing to be undertaken within the marine installation corridor to avoid or minimise localised engineering and environmental constraints.
CEMP	A CEMP, including an Emergency Spill Response Plan, Waste Management Plan, Marine Mammal Protection Plan, Fisheries Liaison and Co-existence Plan and Fisheries Management and Mitigation Strategy will be developed prior to commencement of works.

Measure	Description
Vessels	All vessels will follow the International Regulations for Preventing Collisions at Sea 1972 (COLREGS) and International Convention for the Safety of Life at Sea 1974 (SOLAS);
	All vessel wastes will be managed in accordance with the requirements set out within the International Convention for the Prevention of Pollution from Ships (MARPOL);
Route preparation works	Route preparation works would be carried out as locally as possible to minimise disturbance to sensitive habitats potentially suitable for marine ecological receptors.
Installation Phase	
Biodegradable drilling fluids	Drilling fluids used will be biologically inert and will be selected from the Centre from Environment, Fisheries, and Aquaculture Science (Cefas) approved list of drilling fluids, and the OSPAR List of Substances/Preparations Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR). During drilling, drilling fluids will be recycled, treated, and reused, and any waste drilling fluid will be transported offsite for treatment and disposal.

9.6.2 Installation Phase

9.6.2.1 Temporary physical disturbance to fish and shellfish

There are a number of installation activities that will disturb seabed habitats, resulting in short term (approximately 12 months) physical disturbance to, and temporary loss of, seabed habitats, with potential damage to less mobile receptors (e.g. eggs, larvae, some shellfish).

Sensitivity to effects of habitat disturbance varies between receptors; mobile species and life stages are considered to have greater capacity to accommodate such changes through movement to undisturbed areas, while sessile or less mobile species/life stages are considered far less tolerant of such disturbance.

Migratory fish are not considered to have functional associations with seabed habitats due to their life history strategies and will have a transient presence within the marine installation corridor, therefore potential effects of habitat disturbance on this receptor group are not considered further.

Pelagic spawners (including sprat, mackerel, cod, whiting and plaice) are considered to have low sensitivity to disturbance during installation, as recruitment of these species would be largely unaffected by direct disturbance of the seabed. No distinguishable change from baseline conditions is predicted expected and they are not considered further.

Landfall Activities

Installation activities at the landfall location, which have potential to cause disturbance and / or loss of benthic habitats and species, include:

- **HDD** – completed boreholes will breakout within the marine installation corridor at water depth of between 4 and 10 m below lowest astronomical tide (LAT). There may be up to six breakouts at each landfall location;
- **Temporary Breakout Protection** – up to 20 concrete mattresses may be used at borehole breakouts to protect the breakout from damage before cable installation. Each mattress will cover an area of up to 18 m^2, be up to 0.3 m thick, and weigh up to 9.1 tonnes. The area affected at each landfall may be up to 360 m^2; and
- **Cable installation at the breakout** – several vessels including a cable lay barge (CLB) and a jack-up barge (JUB) may install the cable at the breakouts. Depending on seabed conditions, appropriate burial method(s) could include Mass Flow Excavation (MFE), backhoe digger or diver operated jetting.

The habitat type at the breakout at both landfall is *Sublittoral sand (*A5.2), with patches of *Atlantic and Mediterranean high energy infralittoral rock* (A3.1). No important or high intensity nursery grounds for cod, whiting, or plaice occur at the HDD breakout locations (Coull et al., 1998; Ellis et al., 2012).

Analysis of sediment Particle Size Analysis (PSA) data at the Scottish landfall location (TOR_ST01 and TOR_ST02) (Fugro, 2021) identified this area as being the 'preferred' spawning habitat type for sandeel, however, this location is not identified as being important for sandeel spawning or nursery grounds by Coull et al. (1998) or Ellis et al. (2012). Coull et al. (1998) identifies the Scottish landfall as potentially important for herring spawning, however, sediment PSA data shows the location to be 'unsuitable' habitat for herring spawning.

Both HDD breakout locations are characterised by sandy subtidal sediment, which is found extensively along the coastline, meaning temporary displacement of mobile species due to physical disturbance is appraised as having a **negligible** effect on the wider distribution and abundance of fish and shellfish species within the study area. Also, the temporary protective mattresses required at the HDD breakout points represent the largest area of temporary disturbance but are still considered small in extent (up to 360 m^2 at each location). Following removal of these structures, given the highly dynamic nature of subtidal sand habitats, particularly in shallow waters, sediments would be expected to recover from penetration, abrasion and disturbance, returning to baseline conditions within a short period of time (i.e. <1 year) (Dernie, Kaiser, & Warwick, 2003).

There is potential for shellfish, such as scallops (which favour clean fine sand), to be present at the HDD breakout locations. However, these locations are not considered to be particularly important grounds for this species, with limited to no scallop dredging known to occur in these areas (see Chapter 14: Commercial Fisheries).

Therefore, whilst fish and shellfish may be present, and some temporary avoidance of the affected area around the HDD breakout is expected, disturbance will be temporary (total period for HDD operations and nearshore cable installation is estimated to be six months per landfall location), short-term and limited in spatial extent. Thus, the impact of physical disturbance to and/or temporary loss of habitat is predicted to be of low magnitude. Combined with the low to medium value and sensitivity of all fish and shellfish receptors, the significance of effect is predicted to be **minor adverse** and therefore **not significant**.

Route Preparation and Cable Installation

The activities associated with route preparation and cable installation for the offshore elements of the Marine Scheme, that have the potential to result in temporary physical disturbance to fish and shellfish, include:

- **Cable route clearance** – prior to installation obstructions (e.g. big boulders, abandoned fishing equipment etc.) may need to be removed from the marine installation corridor. This will be achieved using one or more clearance methods, which may include a selection of methods including pre-lay grapnel across a 3m swath, a plough towed across the seabed to push boulders aside, with a swathe of 10 – 15 m, and / or a grab to clear boulders across a swathe of 10 - 25 m per cable (a total assumed disturbance width of 50 m);
- **Burial trials** – in areas of very hard or very soft seabed, it may be necessary to include trials of pre-trenching using a displacement plough and / or a mechanical trencher to determine what burial depth can be achieved; and
- **Cable installation** – cable installation will be either simultaneous cable lay and burial or surface lay followed by post-lay burial of the cable system. Post-lay burial has the potential to have a marginally greater effect because it involves two separate periods of disturbance for each activity, with mobile species returning to the area following the initial disturbance associated with cable laying. There are three generic types of equipment for burying cables into the seabed: cable burial ploughs, jetting trenchers, and tracked mechanical trenchers. The most appropriate methodology is dependent on sediment type and is therefore likely to vary along the length of the marine installation corridor.

Demersal species (e.g., cod, whiting, dover sole, plaice and sandeel) and demersal life stages (e.g., eggs, larvae, juveniles) are the most sensitive to effects from physical disturbance to and/or temporary loss of seabed habitat.

Displacement is considered the most likely effect to adult life stages of demersal species although some physiological damage and/or mortality of less mobile shellfish species and demersal life stages such as eggs and, to a lesser extent larva of some species which exhibit high site fidelity, is probable.

Temporary disturbance as a result of installation activities will occur along the entire marine installation corridor (176 km in length). Where cable burial cannot be achieved, rock placement and / or cable mattresses will be required (Chapter 2: Project Description). At these locations, there will be permanent habitat loss, which has been appraised in further detail as a separate impact pathway (Section 9.6.2.2).

The dominant habitat type along the marine installation corridor is sand, accounting for 70% of the total habitat, dominating the shallower areas from KP8 to KP65 and from KP101 to KP168. The deeper water region between KP66 and KP100 is characterised by a mosaic of mixed and coarse sediments with a small number of stations categorised as medium resemblance stony reef.

Displacement ploughs would result in the widest disturbance swathe per cable trench, at 10 - 25 m; although the disturbed seabed footprint due to ploughing would 2 - 5 m (remainder of the disturbed area is due to the action of plough skids and berms to either side of the ploughed seabed). Assuming a worst-case scenario of a disturbance swathe of up to 25 m wide per trench (which would also include any disturbance effects from cable route clearance) the total area of temporary disturbance along the whole of the marine installation corridor would be a maximum of 8.8 km^2 (10 % of marine installation corridor) for two non-bundled cables which, in comparison to the surface area of the North Sea (750,000 km^2), equates to <0.001 %.

Herring

Herring and sandeel are potentially sensitive to removal and degradation of spawning habitat because of their specific sediment requirements. Furthermore, the high site fidelity exhibited by sandeel also increases its potential sensitivity to benthic habitat loss at sub-population levels (Jensen, Rindorf, Wright, & Mosegaard, 2011). For detailed baseline information on these species see Section 9.5.2.

The potential for cable preparation and installation related impacts to result in the loss of herring spawning grounds along the marine installation corridor is limited given the small number of locations in which suitable herring habitat was identified (Fugro, 2021). If these activities do occur within potential herring grounds, loss and disturbance will be highly localised and temporary, which is unlikely to have a significant effect on overall herring abundance given the wider availability of important spawning within this area. Thus, the impact of physical disturbance to and/or temporary loss of herring spawning habitat is predicted to be of low magnitude. Combined with the medium value and sensitivity of this receptor, the effect is predicted to be **minor adverse** and therefore **not significant**.

Sandeel

The Marine Scheme is located within an extensive area identified as low intensity sandeel spawning ground (Ellis, Readdy, Taylor, & Brown, 2012). A high intensity nursery ground was identified to the north of the Marine Scheme, but this is several kilometres from the marine installation corridor and outwith any project ZOIs. Results of the sediment PSA along the marine installation corridor (where rock placement and cable mattresses are not required), assessed using the methodology outlined in Latto et al (2013) indicated a small number of locations were described as ‘Preferred’ and one sampling location was described as ‘Marginal’ grounds. The remaining sampling locations were described as ‘Unsuitable’ (Fugro, 2021) and the marine installation corridor has not been identified as an area of key importance for sandeel spawning.

Overall, the spatial extent of temporary disturbance to sandeel grounds is considered negligible in the context of alternative available habitat surrounding the Marine Scheme and the wider North Sea. The areas identified as prime sandeel habitat within the marine installation corridor were limited to a small number of locations. Any physical disturbance along the marine installation corridor is thought to be temporary, with the recovery of any sandeel populations and habitat function expected following cable burial, despite the high site fidelity exhibited by this species. A degree of recovery would be expected over the medium term (1 – 5 years) with individuals recolonising suitable substrates following completion of cable installation. However, on the basis of survey data the areas of importance for sandeel within the marine installation corridor are sporadic and limited in extent. Consequently, the overall impact of disturbance to and/or loss of sandeel grounds is predicted to be of low magnitude.

Combined within the medium value and sensitivity of this receptor, the effect is predicted to be **minor adverse** and therefore **not significant**.

Other Marine Fish and Shellfish

The marine installation corridor is not within a Dover sole nursery ground or spawning area but overlaps with high intensity nursery grounds for whiting as well as low intensity nursery grounds for plaice (Ellis, Readdy, Taylor, & Brown, 2012). The presence of juvenile fish is therefore considered likely. However, the area disturbed is very small, the nursery grounds large, and so the overall impact of disturbance to and/or loss of the nursery grounds is predicted to be of low magnitude. Combined within the medium value and sensitivity of this receptor, the effect is predicted to be **minor** and therefore not **significant.**

Little is known about the spawning habitat requirements of elasmobranchs and so no comparative exercise has been undertaken for this receptor in relation to the marine installation corridor or at broader scales. Species common to the area such as thornback ray and lesser spotted- dogfish are known to associate with a variety of substrates including mud, sand, shingle and gravel. Owing to the prevalence of these habitats along the marine installation corridor and within the wider area, potential effects on spawning are likely to be limited in spatial extent and scale.

Considering the broad spawning habitat requirements of elasmobranchs and the small spatial extent of the marine installation corridor relative to the availability of suitable substrates within the central North Sea, temporary disturbance to spawning habitat is considered unlikely to result in a detectable change from baseline conditions. Thus, physical disturbance and/or temporary loss of spawning of elasmobranchs is predicted to be of negligible magnitude. Combined with the medium value and sensitivity of this receptor, the significance of the effect is predicted to be **negligible** and therefore **not significant**.

Shellfish species are more limited in their mobility than fish and in turn are often less able to avoid or move away from areas where habitat disturbance and/or loss is occurring. Some species such as king scallop, mussel, native oyster and cockle are able to move over very short distances, while others are sessile. Due to these physiological constraints to dispersal, shellfish at all life stages are considered to have a medium to high sensitivity to physical damage associated with the route preparation and cable installation works (Tyler-Walters, 2007); (Neal & Wilson, 2008); (Perry & Jackson, 2017). Due to the temporary and localised nature of installation activities and the small-scale installation footprint, the physical disturbance and/or temporary loss of shellfish habitat is predicted to be of low magnitude. Combined with the medium and sensitivity value of shellfish of commercial and/or conservation importance, the effect is predicted to be **minor adverse** and therefore **not significant**.

9.6.2.2 Permanent loss of fish and shellfish due to placement of hard substrates on the seabed

Migratory fish are not considered to have functional associations with seabed habitats due to their life history strategies and transient presence within the Marine Scheme. Therefore, the potential effects of permeant habitat disturbance and/or loss are not considered for this receptor group.

As part of the cable installation, rock protection and/or concrete mattresses will be used within the subtidal (including nearshore and offshore zones) marine installation corridor to protect cable crossings and cable joints and in locations where the target burial depth cannot be achieved (Chapter 2: Project Description) as follows:

- **Crossings** – seven cable crossings have been identified that will require cable protection. No other infrastructure has been identified that needs to be crossed. Of the seven identified crossings, four are currently installed and two are planned. Of the two planned crossings, the crossing of Havingsten S2 is located at KP 141.4; the exact locations of the crossing of power cables for the Berwick Bank Offshore Windfarm is currently unknown.
- **Rock placement** – rock berms will be added to some areas of the seabed where a safe burial depth cannot be achieved. The size (grade) of rock needed for a dynamically stable rock berm decreases with increasing water depths.

Hard substrates will permanently change areas of seabed including fine to coarse mobile substrates. This may lead to the permanent loss or disturbance to benthic habitats and species.

Crossing of third-party assets

Crossing protection is required for seven crossings. Crossing protection for each cable is expected to be on average 7 m wide, 1 km length and 1 m high for two non-bundled cables resulting in a maximum area of 49,000 m^2.

The scale of permanent habitat loss associated with cable and pipeline crossings is dependent not only on the number of crossings but also:

- The type of crossing structure;
- The burial depth of the asset which is to be crossed;
- The water depth (which dictates the size of the outer rock placement); and
- The distance from the crossing point where trenching has to stop or can start again.

Generally, the cables will cross over other infrastructure on a ‘bridge’ comprised of either a rock berm or concrete mattresses. In addition to the seven planned cable crossings, artificial hard substrates may also be added to the seabed to stabilise out-of-service cables and cable joints. The size of each concrete mattress is expected to be 18 m^2, with a maximum of up to 300 rock mattresses required within the marine installation corridor, resulting in a maximum area of 5,400 m^2. The total area of both rock berms and concrete mattresses required to protect cables and cover out of service cables and cable joints is 54,400 m^2.

Rock placement

Rock protection and concrete mattressing will be required in specific locations to protect the cable where the target burial depth cannot be achieved. A total of 52.17 km of the route has been identified as requiring rock protection. A further 7 km of protection will be required for crossings per cable and an additional 1.8 km of additional remediation. The height and width of these berms will be kept to a practical and safe minimum, typically, a height of 0.5 m to 0.8 m, with a width of 6 to 7 m. The maximum size of the rock placement berms has been assumed to be 7 m wide and 1 m high (see Chapter 2: Project Description).

The actual level of rock placement varies depending on seabed conditions and not all of the identified areas will need full coverage by rock. Categories 2, 3, 4 and 5 (25%, 50%, 75% and 100% coverage respectively) have been used to distinguish different levels of rock protection required at each location (Chapter 2: Project Description). When considering these percentages, 34.5 km of rock berm is anticipated to be required for the protection of the each of the cables. However, this appraisal of rock placement impacts on fish and shellfish assumes 100% rock cover as a worst-case situation.

Deep circalittoral mixed sediments (A5.45) is the habitat estimated to have the highest amount of rock placement (0.270 km^2). The width of the rock placement berm, for each of the two cables, is assumed to be up to 7 m and the rock placement methodology, using fall pipe technology, will ensure accurate placement of material on the seabed (Chapter 8: Benthic Ecology – Table 8-7).

Rock structures have the capacity to function as an artificial rocky reef allowing species dependant on hard substrate, such as wrasse, lumpsucker *Cycloplerus lumpus* and eel pout *Zoarces viviparous,* to colonise areas which might have been previously unsuitable. Although this phenomenon has been shown to benefit biodiversity, increasing the abundance and diversity of fish species (Inger, et al., 2009; Petersen & Malm, 2006), a decrease in the populations of sandy-bottom fish populations, such as plaice, and suitable habitat for demersal spawners may be also observed. In addition, artificial reefs have the potential to facilitate the introduction and spread of invasive non-native species (INNS) which can harm fish and shellfish receptors via changes in the availability of prey resources (Inger, et al., 2009).

There are several demersal and pelagic species for which cable crossings will occur within high and low intensity nursery grounds, and low intensity spawning grounds. However, most of the demersal and pelagic fish species known, or likely, to be present in the Zone of Influence (ZoI) are highly mobile, with wide distributions and broad habitat requirements meaning they have capacity to exhibit avoidance behaviour and move into alternative available habitats nearby. Thus, this group of species is considered to have low sensitivity to permanent physical disturbance to and/or loss of habitat due to placement of hard substrates on the seabed.

The fish species which are deemed to be highly sensitive to permanent habitat loss include herring and sandeel as these are demersal spawners and exhibit specific habitat requirements for spawning (i.e. gravelly sediments for herring and sandy sediments for sandeel). Adult sandeel is also sensitive owing to the co-location of spawning and adult habitats and sediment requirements for burrowing.

Herring

Data from IHLS surveys taken between 2018-2020 show that the abundance of herring larvae around the marine installation corridor is sparse. Herring nursery grounds identified by Coull et al. (1998) overlap with cable crossing locations. However, the cable crossing locations do not overlap with 'suitable' herring spawning grounds, as identified by sediment PSA (Fugro, 2021). The potential for Marine Scheme related impacts to result in the loss of potential herring spawning habitat is limited given the small number of locations in which suitable herring habitat was identified and the wider available habitat in an area of known importance for herring spawning. Habitat loss at cable crossings will be highly localised and unlikely to have a significant impact on overall herring abundance.

Spawning grounds (undefined intensity) (Coull et al., 1998) and high intensity nursery grounds for herring (Ellis et al., 2012) are also located within areas of proposed rock replacement for areas along the marine installation corridor requiring additional cable protection. The area requiring rock protection (excluding contingency) that falls within spawning grounds (undefined intensity) is 0.68 km^2 with areas in high intensity herring nursery grounds 0.74 km^2.

Sediment PSA for these locations shows that there were no stations within these areas of rock placement which represented 'prime' habitat for herring spawning. High intensity nursery grounds cover a wide area of the North Sea, suggesting that rock replacement will only cause the loss of a small amount of herring habitat. As such, the permanent placement of hard substrates on the seabed leading to impacts on herring spawning is predicted to be of low magnitude. Combined with the medium value and sensitivity of this receptor, the effect is predicted to be **minor adverse** and therefore **not significant**.

Sandeel

Low intensity spawning and nursery grounds for sandeel (Ellis et al., 2012) are known to occur along the cable route, which overlaps at all five known locations of cable crossings. However, 'preferred' and 'marginal' sand eel habitat, identified using sediment PSA, has only been identified at a limited number of KPs along the cable route, none of which overlap with cable crossing locations. Therefore, although some spawning and nursery habitat may be lost by cable crossing rock placement, it is not thought to impact the areas of most importance to sandeel.

Similarly, low intensity spawning and nursery grounds for sandeel (Ellis et al., 2012) overlap with areas of multiple rock replacement locations. The area requiring protection (excluding contingency) that falls within low intensity sandeel spawning grounds and nursery grounds is 0.58 km^2 and 0.68 km^2 respectively.

Sediment PSA identified only four stations which represented 'preferred' sandeel grounds (ST02 - KP2.263; ST12 - KP47.495, ST20 - KP90.938, ST21 - KP95.965). Given the wider availability of low intensity sandeel grounds surrounding the Marine Scheme and in the Central North Sea, it is thought that the small area of sandeel habitat lost by rock replacement is negligible in comparison to the widespread use of habitat across the North Sea. Therefore, the permanent placement of hard substrates on the seabed leading to impacts on sandeel spawning is predicted to be of low magnitude. Combined with the medium value and sensitivity of this receptor, the effect is predicted to be **minor adverse** and therefore **not significant**.

Other Marine Fish and Shellfish

Studies have shown that some fish and shellfish species (for example gobies, crab and lobster) which occupy rocky habitats may benefit from the additional of artificial substrates, most likely due to the increase in habitat complexity (i.e., refuge) and increased epifaunal communities which provide food resource (Wilhelmsson, Malm, & Ohman, 2006a) (Wilhelmsson, Yahya, & Ohman, 2006b). This is particularly relevant to the marine installation corridor given that the majority of rock placement will occur in deep circalittoral sand and mixed sediments. These fish species are therefore considered to have low sensitivity to habitat loss associated with the placement of rock or mattressing as subsequent habitat and food resource may be available on the structures themselves.

According to the Marine Evidence based Sensitivity Assessment (MarESA), commercially important shellfish such as brown crab and scallop are considered to be moderately sensitive to habitat loss (Neal & Wilson, 2008; Marshall, 2008). Some crustaceans (for example crab and lobster) may benefit from the addition of artificial hard substrates, providing additional refuge and new potential sources of food. Post-installation monitoring surveys at the Horns Rev offshore wind farm found artificial hard substrates were used as a hatchery or nursery grounds for several shellfish species, notably brown crab (Vattenfall, 2006). Thus, the overall sensitivity of shellfish of commercial and/or conservation importance is considered to be low. Potential impacts associated with introduction of hard substrates on commercial fisheries receptors are considered separately within Chapter 14: Commercial Fisheries.

For flatfish such as Dover sole and plaice, which exhibit a preference for sandy substrates, a proportion of habitat would be lost under the footprint of the permanent cable protection at crossings. Rock placement is proposed to occur within low intensity spawning and nursery grounds for plaice, as identified by Ellis et al. (2012). In addition to this, only low intensity plaice spawning and nursery grounds, as identified by Ellis et al. (2012), are present within cable crossing locations. Spawning and nursery grounds for sole are also present within the cable crossing locations, as identified by Coull et al. (1998). However, the extent and scale of the impact is considered to be small when considering the wider availability of suitable habitats within the Central North Sea and given there are only seven known locations for cable crossings. No benefit from any reef effect is expected for these species. Thus, the permanent placement of hard substrates on the seabed leading to effects to flatfish such as Dover sole and plaice is predicted to be of low magnitude. Combined with the low to medium value and sensitivity of these receptors, the effect is predicted to be **minor adverse** and therefore **not significant**.

Although a small proportion of shellfish habitat would be lost under the footprint of the permanent cable protection, there would be no overlap with known or designated shellfish beds and therefore the impact of cable protection on associated shellfish populations would be of low magnitude. The introduction of hard artificial structures on the seabed also has the capacity to function as rocky reef habitat and therefore may benefit several mobile crustaceans such as lobsters and crabs, providing additional habitat, refuge, and potential food resources. Given the medium value of shellfish species and low sensitivity of commercial and/or of conservation importance, the overall effect is predicted to be **minor adverse** and therefore **not significant**.

Indirect effects on prey resources for fish and shellfish

The appraisal of the effect of the Marine Scheme on benthic ecology (see Chapter 8: Benthic Ecology) has determined that the permanent placement of cable protection would not result in a significant impact on benthic ecology receptors, including seabed species on which fish may feed. Therefore, the permanent placement of hard substrates on the seabed leading to indirect impacts such as a loss of prey items on fish and shellfish is also predicted to be of negligible magnitude; the extent of the impact is local and minor in comparison to the wide distribution and availability of suitable foraging grounds for fish. Combined with the low to medium value of all fish and shellfish receptors, the effect is predicted to be **negligible** and therefore **not significant**.

9.6.2.3 Temporary increase in suspended sediment concentrations (SSC) sediment deposition leading to contaminant mobilisation, turbidity and smothering effects on fish and shellfish

The following installation activities associated with the preparation and installation of the Marine Scheme will result in physical disturbance to the seabed:

- **Cable route clearing** – in specific identified regions, a swathe of between 10 m and 25 m width will be cleared of surface boulders, using a plough or grabs. There will also be a pre-lay grapnel run to remove any debris along the cable route;
- **Pre-installation trenching** – this is required only at the landfall locations, in a section of up to 200 m in length and up to 30 m wide from the breakout point; and
- **Cable installation** – the method will vary along the route, depending on seabed conditions, and so will involve a mixture of ploughing, jet trenching and mechanical trenching.

There were no sand waves substantial enough to require clearing/sweeping prior to installation and so no requirement for pre-sweep dredging has been identified for the Marine Scheme.

Seabed disturbance has the potential to increase suspended sediment concentrations (SSC) and turbidity, creating a sediment plume in the water column that can travel away from the marine installation corridor before the sediment is deposited on the seabed. There are several potential effects in fish and shellfish associated with increased SSC and sediment deposition. These include the clogging of respiratory apparatus such as gills, reduced feeding success of visual predators due to decreased visibility, the clogging of feeding apparatus, the mortality of eggs and larvae which are less tolerant to turbid conditions, and effects related to toxic conditions if sediments in suspension are contaminated. The movement and migration of fish could also be impacted by SSC.

Increased SSC and sediment deposition

The largest sediment plumes and highest levels of SSC will be associated with disturbance of sediments with a high proportion of fine particulate material, such as muds and clays, that will remain in suspension longest and settle to the seabed more slowly.

The sediment type at the breakout and trenching location at both landfall locations, where pre-installation trenching will be required, is sublittoral sand (EUNIS code A5.2) (Fugro, 2021). There are some small patches of potential stony reef in the nearshore areas, but these are outside the immediate breakout locations. The sand to be disturbed during installation is a sediment type that will fairly rapidly settle to the seabed and so any effect of an increase in SSC or the extent of a sediment plume will be short-lived and local. There are no areas of particular importance or sensitivity in relation to fish, including spawning areas at the landfall locations. The magnitude of this impacts is considered to be negligible. Therefore, combined with the medium value of this receptor and low sensitivity the effect of this impact is **negligible** and therefore **not significant**.

The Marine Scheme is characterised by a range of different seabed types but is dominated by long stretches of sublittoral sand (KP 8 to KP 65 and KP 101 to KP 168) with the deeper water region (between KP 66 and KP 100) a mosaic of mixed and coarse sediments (Fugro, 2021). Coarse material such as gravel is expected to settle quickly i.e. within a few hours of disturbance, with the sediment plume extending to only tens of metres from the source. Finer sediments such as fine sand, silt and clay are expected to produce a more persistent plume lasting up to a few days depending on the duration of disturbance. Mean PSA across stations sampled across the marine installation corridor recorded an average of 16.82 ± 14.63 % silt compared to 73.51 ± 19.12 % sand (Fugro, 2021), suggesting the majority of the sediment particles are larger and will therefore settle to the seabed within hours.

Calculations have been undertaken to estimate the extent of sediment dispersion before deposition as a result of trenching activities. The method for these calculations, and the results, are reported in further detail in Chapter 7: Physical Environment.

The distance travelled by suspended coarse sand, typical of the majority of the sediments affected, before deposition, is expected to be around 200 m. Fine sands, silts and clay may, however, be transported beyond the marine installation corridor with any fine sand settling on the seabed up to 1.4 km from the point where it is mobilised. Based on the calculated settling velocities silt-sized material could remain in suspension for several days and may therefore travel significant distances. However, given the small proportion of fine sediment, primarily located between KP 120 – 162, and that dispersion processes will also act to dilute the concentration of silt carried in suspension, elevated concentration levels at 1.4 km from the source will be negligible. It is considered that there will be no significant elevated concentration levels beyond the travel distance calculated for fine sand which corresponds to a maximum 1.4 km from the point of mobilisation within the marine installation corridor.

Based on these calculations, any measurable change in suspended sediment concentrations will be temporary and localised, i.e. mostly within the bottom 5 m of the water column. The finer fractions that are transported further also be rapidly diluted so that the suspended sediment concentration will be low and the deposition thickness on the seabed, where the sediment will settle, will be negligible.

The potential effects on each of the fish and shellfish that have been identified within or have the potential to occur within the marine installation corridor, are considered separately below.

Herring

The sensitivity of fish species to increased SSC varies depending on whether they are demersal or pelagic, and their life stage. Most fish species occupying the subtidal and offshore waters along the cable route are pelagic and/or of low sensitivity, with either low intensity or no spawning and nursery grounds present. However, herring and sandeel are demersal spawners and are regarded as being moderately sensitive to smothering effects from SSC, which can have implications on spawning success and recruitment (Kjelland, Woodley, Swannack, & Smith, 2015).

Herring larvae and eggs have been identified as very tolerant to high levels of SSC and deposition (Kiørboe, Frantsen, Jensen, & Sørensen, 1981). As seen in Section 9.5.2.2 of the baseline, the abundance of herring larvae in the study area was much lower in the 2018-2020 IHLS survey compared to the 2010-2017 survey, suggesting there has been a decrease in larvae abundance in recent years. Consequently, any impact from SSC is expected to be small and highly localised. Larvae were not identified in the intertidal areas of the cable route in the latest survey.

Spawning adults and juvenile herring are highly adaptable to disturbance and will return to their habitats following completion of the cable installation, meaning recoverability of the herring spawning and nursery areas under the cable route is expected to be high. Due to their tolerance and high recoverability, the increased SSC and turbidity levels associated with cable installation activities are not expected to cause major direct or indirect impacts to herring. The magnitude of this impact is negligible. Although this receptor is considered to be of medium value, the low sensitivity of this species has determined the effect as **negligible** and therefore **not significant**.

Sandeel

Increased SSC could potentially cause physiological damage and mortality to sandeel eggs in the vicinity of the sediment plume. Sediment plumes may also block filter-feeding organs used to consume plankton from the water column. However, sandeel prefer habitats of coarse sediment (Holland, Greenstreet, Gibb, Fraser, & Robertson, 2005) which are expected to disperse and settle rapidly. The species also spend most of the year burrowing (Van der Kooij, Scott, & Mackinson, 2008), indicating smothering effects will not be of concern.

Although the cable route passes through both nursery and spawning ground for sandeel, there are only a couple of sites along the cable route which have been determined as preferred sandeel habitat, mostly located near the landfalls where natural variations of SSC will not be exceeded. Although sandeel exhibit site fidelity, the effects of increased SSC to sandeel due to the cable installation are expected to be short-term and localised, making recoverability high. This receptor has been valued as medium with a sensitivity also as medium, but the magnitude of impact is considered low. Therefore, the significance of increased SSC to sandeel is predicted to be **minor adverse** and therefore **not significant.**

Diadromous fish

The cable route passes offshore of several estuaries and rivers used by migratory fish, including salmon and river lamprey (Section 9.5.2). Salmonids can be sensitive to increased SSC through reduced vision of prey (Abbotsford, 2021). However, effects to migratory fish from increased SSC and turbidity are thought to occur in response to long-term changes.

The increase in SSC, turbidity and deposition associated with cable installation is expected to be localised and short-term. As a result, this is unlikely to affect fish spawning grounds in the rivers identified in Section 9.5.2.1. Due to the short-term nature of any increase in SSC and the associated deposition and smothering risks occurring during installation of the cable, it is also unlikely to act as a barrier to migrating fish between marine and freshwater environments. These species are considered to be of low sensitivity, but of high value. The magnitude of impacts of increased SSC, turbidity and smothering is predicted to be negligible. Therefore, the effect on migratory fish species is predicted to be **negligible** and therefore **not significant.**

Shellfish

Many crustacean species, including the edible crab and *Nephrops* are known to be tolerant of, and have low sensitivity to, short-term increases in turbidity and SSC. Increased turbidity can affect shellfish, for example crabs spend more time searching for prey due to decreased visual acuity (Wang N. , 2021).

This can lead to them exhibiting avoidance behaviour when conditions become unfavourable to increase feeding success (Neal & Wilson, 2008). Berried crustacean species including the edible crab and European lobster remain sedentary during egg-bearing, meaning they may be more sensitive to increased SSC and turbidity. During egg-bearing, avoidance of sediment disturbance may be more difficult. The eggs that are laid also require sufficient regular aeration, meaning a high level of deposition and smothering may have implications, making them likely to be highly sensitive to substantial levels of sediment deposition.

Mobile shellfish including crabs, scallops and lobsters are thought to tolerate a smothering depth of 5 cm over a month (Neal & Wilson, 2008). They can exhibit avoidance behaviour when conditions become unfavourable by moving away from the affected area. Due to their mobility, adults are considered to have low sensitivity to increased SSC and its associated impacts.

The impact of sediment deposition and turbidity will decrease with distance from the source of disturbance. The greatest impact is expected within a few hundred metres from the cable. In line with the receptors considered in this appraisal, the overall magnitude of impacts to shellfish of commercial/conservation importance created by an increase in SSC and deposition is considered to be low. Shellfish are a medium value receptor with medium sensitivity, which when combined with the magnitude, determines the effect to be **minor adverse** and therefore **not significant.**

Other Marine Fish

The effects to all remaining fish and shellfish species including general communities caused by increased SSC is predicted to be of negligible magnitude for the cable installation. Combined with the low to medium value of fish and shellfish and low sensitivity, the duration of temporary increased suspended sediment concentrations, and subsequent settlement of sediment, the effect is predicted to be **negligible** and therefore **not significant.**

Mobilisation of contaminants

Sediment contaminants, such as heavy metals and polycyclic aromatic hydrocarbons (PAHs), present in concentrations above thresholds of concern could have detrimental impacts on fish and shellfish when resuspended with sediment plumes or redeposited to the seabed. For example, PAHs can result in cell apoptosis in fish immune systems (Reynaud & Deschaux, 2006).

Project specific sediment chemistry analysis found all heavy metals and hydrocarbons to be present in low concentrations, with the exception of a small number of stations where some thresholds for one or more of the following metals – arsenic, nickel, chromium and lead – exceeded the Cefas Action Level 1 threshold or the Canadian TEL threshold (Fugro, 2021). No heavy metal concentrations exceeded Cefas Action Level 2 though there were two stations where the concentration of arsenic was above the Canadian PEL threshold. However, metal concentrations were within background levels reported from a Marine Scotland monitoring station in the Firth of Forth and a Clean Safe Seas Environmental Monitoring Programme (CSEMP) station at Tyne/Tees (Fugro, 2021) indicating that these levels of contamination are typical for North Sea sediments. Previous research has shown that arsenic has been shown to alter the behaviour of fish, inducing erratic swimming and skin lesions (Verma & Prakesh, 2019) but only if exposed to sufficient in-water concentrations.

There were no stations with levels of hydrocarbons above quality standards but there were a number of Canadian PEL thresholds exceeded for PAHs, though this was limited to a single station (ST37) at KP162. The concentration of the heavy metals' arsenic, chromium, nickel and lead were also elevated at this station but were below Cefas Action Level 1.

Contaminants will be associated with finer material such as silts and clays, which are limited within the mostly coarse sediments within the marine installation corridor. Where finer sediments do occur, the potential for mobilisation of contaminants is limited, in the same way as the mobilisation of the sediments themselves will be limited in extent and also dilution of suspended particulate matter, is anticipated to occur rapidly. Thus, the concentration of contaminants is not expected to exceed the background levels reported from the Firth of Forth and the Tyne/Tees monitoring stations. In addition, natural disturbance to the sediment, such as during storm events and periods of strong wave action, will mobilise contaminants and subject fish to only low level, temporary and localised changes in water quality.

As a result, fish and shellfish at all life stages are expected to have a high tolerance to minor changes in the surrounding water due to mobilisation of sediment-bound contaminants. These factors mean that the resulting magnitude of impact will be negligible. Irrespective of the value and sensitivity of fish and shellfish, it can therefore be concluded that the effect on fish and shellfish receptors from the disturbance of sediment-bound contaminants is also **negligible** and therefore **not significant**.

9.6.2.4 Changes to marine water quality from release of HDD drilling fluids

The discharge of drilling fluids from HDD works in the shallow subtidal zone of the marine environment has the potential to alter water quality and affect fish and shellfish at each of the landfall locations.

During HDD works the estimated discharge to the sea per borehole is up to 2,000 m^3 of fluid and up to 80 m^3 of solids giving an estimated maximum of 12,000 m^3 of fluid and 480 m^3 of solid discharged from the six drills at each landfall. These will be located at a water depth of between 4 m and 10 m below chart datum at both HDD breakout locations (see Chapter 2: Project Description). The drilling fluid discharges from the Marine Scheme's HDD operations will be single events over a short period of time and rapidly dispersed in the shallow, open sea coastal environment.

Drilling fluids will be selected from the OSPAR List of Substances/Preparations Used and Discharged Offshore which are Considered to Pose Little or No Risk to the Environment (PLONOR). Industry standard drilling fluids and additives required during the HDD operations will also be biodegradable. For example, the most widely used fluid, bentonite, consists predominately of clay minerals. This PLONOR substance is generally considered to be an inert, and generally non-polluting substance. Bentonite is also not listed under the Environmental Quality Standards Directive.

Embedded mitigation measures will be implemented to minimise the release of drilling fluid leaks from the end of the ducts and any associated impacts (Section 9.6.1). The discharged drilling fluids will also be subject to immediate dilution and rapid dispersal within the marine environment, particularly as the release will be in the shallow nearshore area where there is likely to be significant wave and tidal water movement.

The sensitivity of fish and shellfish receptors will vary depending on factors including species, life history strategy and life stage. Pelagic early life stages (e.g. egg and larvae) are particularly sensitive to toxicity in the water column, whereas juvenile and adult fish are highly mobile and are therefore likely to be subject to displacement from polluted areas. There are a number of fish species of conservation value in the study area for the Marine Scheme, but no important spawning, nursery or fishing grounds have been identified within the ZoI for HDD discharges at either of the landfall locations. Additionally, many potentially sensitive species are mobile and can avoid areas of disturbance, and there are no rivers for migratory species such as salmon, trout and lamprey in the vicinity of the breakout locations.

The drilling fluid discharges from the Marine Scheme's HDD operations will be a small number of single events over a short period of time and rapidly dispersed in an open sea coastal environment. Only receptors in the immediate vicinity of the HDD breakouts are likely to be in contact with drilling fluids, which pose little risk to the environment. Overall, the magnitude of impact to all fish and shellfish receptors from HDD fluids is predicted to be negligible. Combined with the low to high value of receptors and medium sensitivity, the effect is predicted to be **negligible** and therefore **not significant**.

9.6.2.5 Underwater sound effects on fish and shellfish

A number of activities undertaken during the construction phase of the Marine Scheme will generate underwater sound. Sound can be either impulsive in nature, such as that created by some high-resolution seabed imaging sources such as MBES and seismic, impact piling or explosions. Non-impulsive, or continuous sound sources, include dredging and drilling type activities and sound from vessel movements including with the use of dynamic positioning (DP). The effect of man-made sounds on marine receptors depends on the intensity of the sound source (i.e. the amplitude of the sound pressure wave), the duration of the sound, frequency, the surrounding environment (e.g. water depth) and the sensitivity of the receiving fauna.

For underwater sound impact appraisals, the metrics are sound pressure level (SPL) and sound exposure levels (SEL). The SPL is a measure of the amplitude or intensity of a sound and, for impulsive sound sources, is typically measured as a peak or rms (root-mean-square) value. In contrast, the SEL is a time-integrated measurement of the sound energy, which takes account of the level of sound as well as the duration over which the sound is present in the acoustic environment.

The sound characteristics of the Marine Scheme activities have been determined on the basis of a significant body of knowledge of many common sound generating activities, for which there is an extensive range of values in the literature (Table 9-11). Where a range of sound source levels was found in the literature a reasonable but realistic worst-case level has been assumed.

Table 9-11: Characteristics of underwater sound sources generated by the Marine Scheme construction phase

Activity	Operating Frequency (kHz)	Sound Pressure Level# (dB re 1µP a@1m)	Reference
Swathe or multi-beam echo sounder (MBES)	170 - 450	221 235 (peak)	(Genesis Oil and Gas Consultants Ltd, 2011)
Side scan sonar (SSS) (e.g. EdgeTech 4200 Series)	300 - 600	210 - 226	(Genesis Oil and Gas Consultants Ltd, 2011) and equipment specification sheet
Sub-bottom profiling (SBP) (e.g. Innomar SES-2000, Edgetech Chirp & Applied Acoustics 201 boomer)	0.5 – 12	238	Equipment specification sheets
Ultra-Short Base Line(USBL) (e.g. Kongsberg HiPAP 502)	21 - 31	207	Equipment specification sheet
Cable installation (jetting, trenching	1 - 15	178	(Nedwell, Langworthy, & D., 2003); (EGS Survey Group, 2018)
Rock placement	n/a	< Vessel sound level	(Nedwell, Brooker, & Barham, 2012)
HDD (break-out)	n/a	129.5	(Nedwell, Brooker, & Barham, 2012)
Cable lay vessel (~ 140 m in length operating with DP)	0.005 - 3.2	180 – 197	(AT&T, 2008); (Ross, 1993)
Project support vessels including medium (50-100 m) and small (<50) boats	Low to high frequency	160 – 180 dB	(Genesis Oil and Gas Consultants Ltd, 2011) (Richardson, Greene, Malme, & Thomson, 1995) OSPAR commission (2009)
UXO explosions – assumed 55 kg and 100 kg charge weight as worst case scenario	-	289 (peak)	(Soloway & Dahl, 2014)

Sound Pressure Level metrics in rms unless indicated.

A number of the above sound sources can be either scoped out of the appraisal or have low sound source intensity such that it is masked by other elements of the installation operations that are appraised:

- **MBES** – in shallow water (less than 200 m) MBES operates at high frequencies that fall outside the hearing range of fish and the sounds produced will also attenuate quickly. Thus, any significant effect from shallow water MBES is considered unlikely and this is reflected in the absence of any recommended mitigation measures for this activity;
- **SSS –** also operates at high frequency, producing sound that is outside the range of hearing of all fish and so this activity can be scoped out of the appraisal;
- **Rock placement –** in four studies of rock placement rock dumping it was possible to faintly hear rocks falling through a tube to the seabed but the underwater sound from the operations was dominated by the sound of the dynamic thrusters of the vessel (Nedwell et a., 2012). Thus, the effect of rock placement operations is included within the envelope of the appraisal of the effect of vessel operations during the installation process and not appraised as a separate activity;
- **HDD** – sound measurements made during a generic HDD operation, in shallow riverine water, recorded, in the absence of vessel noise, a maximum unweighted Sound Pressure Level (SPL), of 129.5 dB re. 1µPa (Nedwell et al., 2012). The Marine Scheme HDD breakout points will also be in shallow water where sound rapidly attenuates. Thus, underwater sound generated by HDD will be very low, undetectable in the presence of operational vessels, and so this sound source is not considered further in this appraisal;
- **Ploughing, jetting and trenching cable installation** - the primary source dominating underwater sound from measurements made during cable installation operations is vessel propulsion noise, particularly from the dynamic positioning systems used by these vessels. Therefore, the appraisal of the impact of the sound generated during all cable lay activities is based on the sound source levels known to be generated by the cable lay and associated support vessels; and
- **Detonation of UXO** – whilst there is potential for UXO to be present within the marine installation corridor, a full and detailed pre-installation UXO survey has not yet been undertaken. Therefore, as the nature of any UXO that may require detonation is not yet known, an impact appraisal and associated licence applications, such as the requirement for an EPS licence, will be undertaken if UXO is identified prior to installation. No further consideration of UXO is included in this appraisal.

Thus, the appraisal addresses the remaining sound sources: impulsive sound from the operation of the SBP and USBL during the pre-installation geophysical survey and the installation works, and the continuous sound sources from the movement of two broad groups of cable installation vessels: large cable lay vessels operating with DP and a range of smaller support vessels.

Hearing and impacts of underwater sound in fish

Sound plays a major role in the lives of fish including for communication, locating prey and avoiding predators (Fay & Popper, 2000). Sound is perceived by fish through the ears and the lateral line (the acoustico-lateralis system) which is sensitive to vibration. In addition, some species of teleost or bony fish have a gas filled sack called a swim bladder that can also be used for sound detection (Hawkins, 1993). A species sensitivity to sound varies according to the sound frequency. The response to sound depends on the presence and levels of noise within the range of frequencies to which an animal is sensitive. For most fish, sound above 1 kHz is not audible.

The potential impacts of sound on fish are, to a large extent, determined by the physiology of fish, particularly the presence or absence of a swim bladder and the potential for the swim bladder to improve the hearing sensitivity and range of hearing (Popper, et al., 2014). These morphological features have been used to develop categories of fish depending on how they might be affected by sounds and these can be used when appraising impacts. Fish have been grouped into the following three categories of hearing sensitivity to underwater sound as described below:

- **High hearing sensitivity fish** – species in which hearing involves a swim bladder or other gas volume (e.g. Atlantic cod, herring and relatives). These species are susceptible to barotrauma and detect sound pressure as well as particle motion and includes Atlantic cod, herring and other species of the Clupidae family;
- **Medium hearing sensitivity fish** – species with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g. Atlantic salmon, sea trout and European eel). These species are susceptible to barotrauma although hearing only involves particle motion, not sound pressure. Atlantic salmon, sea trout and European eel are included in this category;

- **Low hearing sensitivity fish** – species with no swim bladder or other gas chamber are less susceptible to barotrauma detecting particle motion rather than sound pressure. This group includes flatfish and elasmobranchs.

There are fish species from all hearing groups found within the Marine Scheme Study Area. These include herring which have very high hearing sensitivity and for which spawning grounds are found in the vicinity of the Project Marine Corridor, protected diadromous fish species such as salmon and trout, and a wide range of commercially important pelagic fish in the medium hearing sensitivity group.

Potential effects of underwater sound vary with the level and character of the sound produced and the distance of receptor from source and can be broadly categorised as follows:

- **Physical or physiological effects** – this includes mortality, non-recoverable and recoverable injury. Only in extreme cases, such as where fish are in close proximity to very high sound pressure levels, such as UXO detonations, is underwater sound likely to cause physical injury, including barotrauma such as rupturing of the swim bladder and subsequent death. Recoverable injuries such as haematomas, capillary dilation, and loss of sensory hair cells may still lead to death if they decrease fitness and the animal is subject to predation or disease. Sudden changes in pressure are more likely to result in damage than are gradual changes (Popper et al., 2014);
- **Auditory damage** – high intensity underwater sound can cause physical damage to the auditory system structures such as the inner ear, sensory hair cells and otoliths (Parvin, J.R., & R., 2006). this can be either a temporary threshold shift (TTS) which is a reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range; or permanent threshold shift (PTS) which is an irreversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range);
- **Masking -** caused by interference with ecologically significant sounds and relates to behavioural responses. Some fish are known to use auditory cues, such as juvenile fish selecting healthy reef habitats on the basis of their sound signature but the consequences of masking for fish are still not well understood; and
- **Behavioural responses** – includes changes in movements, swimming direction, migration, feeding, breeding and displacement.

Pre – installation geophysical parameters

For most fish species, sensitivity to sound occurs from below 100 Hz to several hundred hertz, or several thousand hertz in a few species (Popper, et al., 2014); (Mann, Higgs, Tavolga, Souza, & Popper, 2001). Those with a swim bladder, such as Atlantic cod are sound pressure sensitive at the higher frequencies and some species of herring like fishes, but not the Atlantic herring can detect sounds above 20 kHz (ultrasound) (Popper, et al., 2014).

As the geophysical survey activities use very high frequency acoustic signals, beyond the hearing range of any fish in the study area, there are no likely effects on fish and so the impact of underwater sound on all fish, including migratory species, and fish spawning and nursery areas can be scoped out of the appraisal.

Underwater sound from vessel movements much lower frequency. They can be detected and cause avoidance behaviour in fish. The impact of geophysical vessel movements is encompassed by the appraisal below of underwater sounds from cable lay vessels, as these are likely to produce higher intensity underwater sounds.

Cable installation and associated works

The underwater sound from the cable installation activities of HDD drilling, ploughing, jetting and trenching, rock placement and the overarching vessel sound are all non-impulsive or continuous sound sources. With the exception of two quantitative thresholds for recoverable injury and TTS in high hearing sensitivity fish, which includes herring and cod, all the thresholds (Popper, et al., 2014) are provided as a relative risk rating (Table 9-12). Relative risk is given as High, Moderate or Low at three distances from sound source. Whilst the distance groupings do not have associated absolute values near (N) can be considered to be within tens of meters of the sound source; intermediate (I) within hundreds of meters and far (F) within thousands of meters.

Table 9-12: Shipping and continuous sound pressure criteria (Popper et al., 2014)

Receptor	Mortality and potential mortal injury	Recoverable injury	Temporary Threshold Shift (TTS)	Behavioural response
Low hearing sensitivity - fish with no swim bladder (particle motion detection) – elasmobranchs, lamprey and flatfish	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Medium hearing sensitivity - fish with swim bladder not involved in hearing (particle motion detection) – Atlantic salmon	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
High hearing sensitivity - fish with swim bladder involved in hearing (particle motion detection) = herring, cod	(N) Low (I) Low (F) Low	170 dB rms for 48 h	158 dB rms for 12 h	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low

* rms sound pressure levels dB re 1 μPa

The thresholds in Table 9-12 indicate that the key impacts for all fish receptors from continuous sound sources anticipated during construction relate to behavioural responses rather than physical injury or physiological effects. With the exception of high hearing sensitivity fish, the risk of mortality, injury and recoverable injury from continuous sounds sources is low, even for animals in close proximity (N-near) to the sound source. However, there remains some potential for recoverable injury and TTS in high hearing sensitive species (e.g. herring, sprat and migratory species) if subject to the sound pressure levels outlined in Table 9-12 for a period of 48 hours and 12 hours, respectively and a moderate risk of TTS for the other hearing groups.

During installation the cable lay vessel (CLV) is expected to progress at a rate of between 0.5 km and 5 km per day (Chapter 2: Project Description). Thus, the potential for the underwater sound produced by installation activities to remain in one location for the 12 hours or 48 hours is highly unlikely. Thus, injury or TTS in any fish, including eggs and larvae, along the route during offshore cable lay is not anticipated.

At both landfall locations a cable lay vessel will remain on location, with DP operational, as the cable pull operations occur. Thus, continuous sound will be produced over an extended period, potentially up to a week (based on 24 hour working depending on weather) at each landfall location. The CLV sound source intensity (SPL_{rms}) is estimated to be up to 180 dB re 1μPa@1m[11] and over this extended period the underwater sound has the potential to exceed the quantitative threshold for TTS for the most sensitive fish and increase the risk rating for species with lower hearing sensitivity. However, since any fish in the local area are likely to move away from the noisy operations, they are unlikely to experience a level of exposure that could result in any temporary injury. As there were no habitats of particular importance for fish, particularly spawning grounds, identified at either of the landfall locations, such avoidance behaviour is not considered to have a noticeable effect on foraging and availability of prey as similar habitats are widely available.

[11] 1 microPascal at a distance of 1 m

Behavioural effects have the potential to occur, particularly during fish migratory periods when underwater sound may form a barrier to movement. There are a number of diadromous species that could be present in the Study Area, potentially migrating to or from natal rivers along the area of the east coast parallel to the marine installation corridor. Several rivers and sites designated for diadromous fish have been identified including the River Tweed, almost 12 km from the marine installation corridor. However, even for cable installation operations during migratory seasons the installation vessels will be moving continuously and will not present a barrier to movement towards the coast. There may be some minor avoidance behaviour but as soon as the vessel has moved away normal migration activity can resume. Thus, the impact is localised, temporary and reversible and so the magnitude is predicted to be negligible. Combined with the low to high sensitivity and value of the species, the effect is predicted to be **negligible** and therefore **not significant**.

Less mobile fish or fish life stages may be exposed to underwater sound for longer as they are less or not able to use avoidance behaviour. In particular, eggs and larvae, do not have the ability to move away and so will be subject to underwater sound as the cable installation takes place. However, as for other fish groups the potential for injury from the sound source is negligible as the vessel only remains in position for a short time. It is therefore highly unlikely that eggs and larvae at spawning grounds would be exposed to enough sound pressure levels for a long enough period to result in recoverable injury or TTS. Considering the localised, temporary and reversible nature of impacts for all receptors in the marine installation corridor, the magnitude of impact to all fish receptors is predicted to be negligible. Combined with the low to high sensitivity and value of species, the effect is predicted to be **negligible** and therefore **not significant**.

Shellfish

There has been very little research into the impact of underwater sound on marine invertebrates (including shellfish) which are believed to be sensitive to particle motion rather than to sound pressure (Popper and Hawkins, 2018). At present there are no published sensitivity thresholds for this receptor group. However, many invertebrate species do have tactile hairs or mechano-sensory systems that are thought to respond to the particle displacement components of an impinging sound field and not to the pressure component (Popper, Salmon, & Horch, 2001); (Lovell, Findlay, Moate, & Yan, 2005); (Spiga, et al., 2012).

Crustaceans for example, are thought to detect the particle motion component of sound (Lovell, Findlay, Moate, & Yan, 2005) and the prevalence of noise from aquatic crustaceans suggests it is important for communication between individuals (Spiga, et al., 2012). Whilst there are a small number of studies indicating there is some potential for injury in adult or developmental stages of individual invertebrates this has only been demonstrated for animals in very close proximity (a few metres) to high intensity sound such as that from seismic airguns.

There are areas along the marine installation corridor that support *Nephrops* fisheries but the sound from cable lay activities is of much lower intensity and unlikely to cause significant disturbance (see Chapter 14) For example, the impact of sound on a shrimp fishery in Brazil indicated that shrimp stocks were resilient to the disturbance by seismic airguns (Andriguetto-Filho, Ostrensky, Pie, Silva, & Boeger, 2005) and as a burrowing species *Nephrops* has the ability to seek refuge from any disturbance should it occur by retreating back into their burrow system. All currently available evidence suggests the other shellfish species known to be present in the MIC, such as crabs, lobsters and scallops, have a similarly low sensitivity to underwater sound sources, particularly of the type generated by the cable installation activities (Wale, Simpson, & Radford, 2013); (Spiga, et al., 2012).

Thus, accounting for the limited spatial and temporal extent of underwater sound from cable installation activities, the magnitude of impact to *Nephrops* and all other shellfish receptors is considered to be negligible. Combined with the medium value and sensitivity of species, the effect of the impact is predicted to be **negligible** and therefore **not significant.**

9.6.2.6 Accidental leaks and spills from vessels, including loss of fuel oils

The accidental release of pollutants (e.g. oil, fuels, lubricants, chemicals) could occur from any of the vessels associated with the cable lay operations and any support vessels present during cable installation. Vessels involved in cable lay operations could have cleaning fluids, oils, and hydraulic fluids onboard (as well as fuels), which could be accidentally discharged, releasing hydrocarbons and chemical pollutants into the surrounding seawater, which could then settle on the seabed with consequences for fish and shellfish.

Any waste and discharges to the marine environment or any accidental spillage of surface pollutants, such as diesel, mineral oil and chemicals from vessels and equipment during cable lay operations could alter water quality with potential effects to fish and shellfish. Effects may include behavioural disturbance such as displacement from affected areas and prevention of spawning. Chemical spills may also have sub-lethal to lethal effects dependent on the life stage, exposure level and the level of toxicity.

Both the direct and indirect effects of pollution on fish species are well studied. Contaminants can directly impact fish species via toxicity and mortality, as well as indirectly through stress responses (NOAA, 2021). Benthic and demersal species can be especially susceptible as contaminants are known to settle in benthic sediments and higher trophic levels can also be impacted through bioaccumulation of toxins and pollutants present in prey items. Shellfish are similarly susceptible as many are indiscriminate filter feeders that can easily ingest pollutants (NOAA, 2021).

Although fish and shellfish would be sensitive to the accidental release of pollutants, there is considered limited potential for accidental spills to occur. There will be relatively few large operational vessels containing considerable quantities of potential pollutants such as diesel oil involved in route preparation and cable installation works for the Marine Scheme. In addition, the vast majority of accidental oil and chemical releases in UK waters are associated with wells and hydraulic systems rather than vessels involved in cable installation (OGUK, 2019).

All effluent will be discharged in accordance with the applicable MARPOL Convention Regulations and therefore significance of waste discharges to fish and shellfish receptors is predicted to be negligible. Thus, the risk of an accidental spill occurring is very low and should an accidental spill or leak occur, it would be very small in extent and subject to immediate dilution and rapid dispersal within the marine environment. Overall, the magnitude of impact to all fish and shellfish receptors from accidental leaks and spills from vessels and equipment is predicted to be negligible and the potential effect is **negligible** which is **not significant**.

9.6.2.7 Vessel collision risk

Although records of collisions with fish are scarce, they are not unheard of. Of the few records reported, collisions with Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus* and sunfish *Mola mola* have been observed; however, the scarcity of records is likely due to the lack of reporting/observations rather than a lack of occurrence (Schoeman, Patterson-Abrolat, & Plön, 2020). The main fish species that could be susceptible to collision is probably the basking shark, which can be slow moving as they feed in surface waters. However, sightings of basking shark in the North Sea are rare and in very low numbers. Sensitivity of fish to collision has been appraised as high.

The presence of cable lay, and support vessels is not considered to increase vessel traffic considerably above baseline levels, particularly for an area of importance for fishing. Given the confines of the cable corridor, vessel presence would also be spatially limited, and the magnitude negligible. Preparation vessels move at low speeds, which are matched by any support vessels. When considering any habituation of fishes to average vessel traffic and the spatially limited nature of this operation, the likelihood of collision with fishes is very low. The effect is predicted to be **negligible** which is **not significant**.

9.6.3 Operation Phase (including Maintenance and Repair)

9.6.3.1 Potential effects due to subsea cable electromagnetic field (EMF) emissions

The design for the Marine Scheme comprises two HVDC cables laid either in two separate parallel trenches (unbundled) or else in a single trench with the cables bundled together. If the two-trench approach is used the cables will be spaced up to 30 m apart (referred to as a ‘30 m separated bipole’). For both approaches the target burial depth is 1.5 m and the minimum depth without cable protection will be 0.6 m. In a two-cable configuration the distance between the cables generates a stronger magnetic field than that generated by a bundled, single-trench configuration (Hutchison, Gill, Sigray, He, & King, 2021). Therefore, the appraisal considers the 2-trench scenario only, as the worst-case situation that will also encompass any potential effect should the cables be bundled.

Field surveys have been carried out to quantify the EMF generated by a number of HVDC subsea cables already in operation, including the Cross Sound cable and the Neptune cable (Hutchison, et al., 2018). The Cross Sound cable has a transmission capacity of 330 MW, the Neptune cable 660 MW (Hutchison, et al., 2018). The EMF generated by the Cross Sound cable ranged between 0.4 and 18.7μT, the Neptune cable between 1.3 and 20.7μT, with the variation being attributed to burial depth and transmission capacity (Hutchison, et al., 2018). The infield measurements found that the magnetic field reduced to background levels within 5 m of the Cross Sound cable and within 10 m of the Neptune cable (Hutchison, et al., 2018).

Modelling completed for the Marine Scheme provides data on the level and attenuation of the EMF emissions for both possible design options (see Chapter 2: Project Description). The modelling accounts for cable configuration, the design of HVDC cable, and the properties of electromagnetic fields in water (magnetic fields attenuate rapidly in water) with and without the influence of background geomagnetic fields. These estimates indicate that EMF from a 30 m separated bipole configuration, buried at a depth of 1 m reduces to background levels at a distance of 20 m from the cable, both vertically and horizontally.

The EMF generated by the 30 m separated bipole, at a burial depth of 1 m has been estimated to be 399.8 μT at the seabed (Table 9-13), which reflects the carrying capacity of the Marine Scheme cable operating at maximum current load. The modelling of the attenuation of the EMF around the cable has assumed a minimum burial depth of 1 m and maximum current load which reflects a worst-case estimate of EMF emissions. In many areas the cable burial depth will be greater than 1 m, and the cable will not operate at maximum current load at all times.

These estimates indicate that EMF from a 30 m separated bipole configuration reduces to a background level at a distance of between 20 m of the cable, both vertically and horizontally. In comparison, maximum magnetic field in a bundled bipole configuration is significantly lower.

Table 9-13: Calculated maximum magnetic field for separated and bundled cable designs, without and with background geomagnetic field

Maximum cable magnetic field only (μT)						
Distance above seabed	**Seabed**	**0.5 m**	**1 m**	**5 m**	**10 m**	**20 m**
Maximum cable magnetic field only (μT)						
30 m separated bipole	399.8	266.4	199.6	66.6	36.4	18.02
Bundled bipole (0.2 m)	79.2	35.4	19.95	2.22	0.66	0.18
Maximum cable and geomagnetic# field (μT)						
30 m separated bipole	404.4	273.2	212.7	102.8	82.99	66.82
Bundled bipole (0.2 m)	126.8	83.69	68.68	51.79	50.33	49.88

Assumed geomagnetic field: magnitude 49.715, dip 68.679°

The highest EMF is present immediately above the cables, but it does attenuate quickly with distance from the cables (Table 9-13). Within 20 m the EMF levels for the 30 m separated bipole configuration continue to exceed geomagnetic levels in the space between cables, but only marginally. The maximum magnetic field and geomagnetic field combined in a bundled bipole configuration is significantly lower.

Although the cable shielding will restrict the transmission of electric fields, induced electric fields (iE) may be created by the action of tidal flow through the magnetic field generated by the cables (EAR Volume 3 Appendix 2.2). The induced electric field for each cable design was calculated using the modelled magnetic fields provided in Table 9-13 and iE calculated for a range of tidal velocities at increasing vertical distances from the cables.

Analysis of tidal currents from shipboard current profiler data in the North Sea shows currents to range between 0.10 m/s and 0.68 m/s (Videnes, 2018). Conservatively, this suggests maximum induced electric fields generated by tidal currents to be 204.90 μT at the seabed (i.e. the value for a tidal current speed of 0.75 m/s), directly above the cables, but reducing to within natural geomagnetic range within 20 m. Due to the fact that magnetic fields attenuate through the water column, the area of effect will be limited to an area in close proximity to the cable. Water depth is also an important factor to consider, as in deeper water the strength of the magnetic field will decrease more quickly with distance from the cable.

The average water depth exceeds 50 m for most of the offshore cable route. However, there is shallow water as the cable route comes into the landfall locations. There is 2.5 km of the route towards the Scottish landfall, and 3.8 km towards the English, where average depths are below 20 m. Consequently, species occupying the upper layers of the water column will be exposed to weaker magnetic fields for the majority of the cable route, with marginally stronger EMF fields in shallow waters.

At the landfall locations HDD will be used to pass under the intertidal zone with the exit point in water depths of 4 – 10 m LAT (lowest astronomical tide) at both landfalls. Modelling shows that the EMF produced by the cable, buried in 1 m of sediment, is predicted to be undetectable at a distance estimated to be approximately 35 m from the cable route. However, whilst small increases above ambient EMF may be detectable effects to fish and shellfish receptors will depend on the specific sensitivity of animals to EMF and a small increase in EMF may not have an adverse effect.

Very few studies have investigated the effects of anthropologically generated EMF on fish physiology and behaviour (Nyqvist, et al., 2020; Copping, et al., 2021). Most have focussed on elasmobranchs (sharks and rays) and migratory species (i.e. salmonids and eels) that utilise magnetic cues for navigation including the effect that EMFs have on swimming behaviour and migration.

Reported effects of exposure to artificially created EMFs include a reduction in swimming speed in migrating European eel (Westerberg & Lagenfelt, 2008), attraction to cables and reduced swimming activity for several species of elasmobranchs (Gill, et al., 2009) and attraction to magnetic fields in free swimming trout larvae (Formicki, Sadowski, Tański, Korzelecka-Orkisz, & Winnicki, 2004). It has been suggested that species that use electromagnetic perception for prey detection such as elasmobranchs may experience reduced foraging efficiency as a result of exposure to EMF.

Studies investigating the physiological effect of long-term exposure to EMF on juvenile flounder (Bochert & Zettler, 2004) and embryos and larvae of rainbow trout (Fey, et al., 2019) found no effect on development or survival in these species. Salmon eggs exposed to EMF with a strength of 2 mT (i.e. 2,000 μT) exhibited greater water permeability than controls, however this did not have any detrimental effects on embryological development or survival (Sadowski, Winnicki, Formicki, Sobocinski, & Tanski, 2007) and the intensity of the experiment EMF is several orders of magnitude higher than that resulting from the Marine Scheme's buried HVDC cables.

Due to the different level of sensitivity of different species and groups of fish and shellfish the appraisal of effect of maximum EMF generated during electricity transmission is divided into the key receptor groupings (see Table 9-8).

Diadromous species

The cable route is likely to pass through the migratory routes of a number of diadromous species including, salmon, sea trout, river lamprey, and sea lamprey and for the catadromous European eel. The exact paths of migration to natal rivers for these species are not well understood, and are expected to be highly diffuse, but there are several rivers of importance along the coast where migrating fish may have to pass over the buried cable. These species are important receptors, based on a number of conservation criteria. There is abundant evidence that marine animals derive their direction, and even geographic position, from features in the main magnetic field and so cable EMF have the potential to disrupting fish movement including migration (Klimley, Putman, Keller, & Noakes, 2021).

There is evidence that EMF anomalies from cables can affect the behaviour of migratory fish. For example, studies of tagged European eel observed a reduction in the swimming speed (Westerberg & Begout-Anras, 2000); (Öhman, Sigray, & Westerberg, 2007); (Westerberg & Lagenfelt, 2008) and a change in swimming trajectories during passage over a cable (Öhman, Sigray, & Westerberg, 2007);

(Westerberg & Begout-Anras, 2000). However, a field study of behavioural responses of juvenile salmon to a subsea HVDC cable in the San Francisco Bay found no significant difference to migration success (Wyman, et al., 2018). During migration the salmon needed to cross the location of the cable in order to complete their route. Some individuals took a longer route than expected and others showed some attraction to the cables. However, no overall adverse or beneficial direct impact was observed but the increase in EMF in this study was much lower than the maximum EMF estimated from the Marine Scheme.

Biotelemetry studies of the response of migrating European eels to energised subsea cables showed they did not pose a strong barrier to the migration movements of this EMF sensitive species. Some fish did show small brief perturbations in their directional movements as they passed over the HVDC cable but these were not strong avoidance actions (Westerberg & Begout-Anras, 2000). Beyond these findings, there are large data gaps regarding fish migration in relation to EMF (Wyman, et al., 2018; Nyqvist, et al., 2020). Based on current knowledge and modelling, it can be concluded that an increase in the background EMF is restricted to a distance of up to 35 m from the cable. However, whilst the level of increase likely to cause disturbance to migratory fish is not well understood, available field evidence suggests any significant responses are expected to be limited to the immediate vicinity of the cable route.

Thus, during operation of the HVDC cable migratory species may respond by changes in swimming speed or adjustments in swimming direction. However, there are a large number of natal rivers identified in the Study Area but the effect is limited to a small localised area and the buried cable is not thought to pose a significant barrier to migration (see Table 9-13). In addition, most species, including salmon are known to use the entire depth range of the water column and so can also undertake avoidance behaviour via water depth selection. The shallow waters around the nearshore cable breakout points are very limited in extent and not anticipated to represent a barrier to any migrating species as these locations do not appear to be located in an area that is close to the entrance to a natal river.

The magnitude of the impact of EMF exposure is considered to be negligible as response may occur, but these are restricted to the locality of the cable and there is no evidence to indicate any inhibition of migration success. Combined with a low sensitivity, EMF from the cable route is considered to have an effect on diadromous fish that is **negligible** and therefore **not significant**.

Pelagic species

Several commercially important pelagic species, including herring, sprat, and mackerel, are found in the waters around the marine installation corridor, many of which are identified as species of principal importance.

The pelagic nature of these species indicates they are unlikely to come into contact with, or are able to easily avoid, any increase in EMF in a small area around the cable. Even for benthic feeding pelagic fish the zone of influence for EMF is restricted to a distance of a few tens of metres and is unlikely to limit access to prey as foraging grounds are widespread and readily available. Additionally, pelagic fish are known to swim continually, often covering several kilometres daily and so the time spent in the vicinity of the cable will be limited. Pelagic species are thought to have low sensitivity to EMF and there was no evidence found to suggest that clupeids or scombrids are able to detect EMF or are affected by it in anyway (Snyder, Bailey, Palmquist, Cotts, & Olsen, 2019). Thus, a localised increase in EMF is expected to have no detectable effect of EMF on pelagic species. The magnitude of the impact is therefore appraised to be negligible combined with a low sensitivity, effect on pelagic species is considered to be **negligible** and therefore **not significant.**

Demersal species

A number of demersal teleost fish species (i.e. excluding elasmobranchs), including cod, whiting, dover sole, plaice, and sandeel, are recorded as abundant along the cable route. Demersal fish spend the majority of their time on or above the seabed, which could bring them into contact with the area of increased EMF generated by subsea cables (Hutchison, et al., 2018).

However, the maximum EMF estimated to be generated by the Marine Scheme cables is not thought to be high enough to elicit any physiological or behavioural responses (see Table 9-13). This is based on evidence from studies exposing juvenile flounder to magnetic fields with a strength of 3700μT, with fish showing no adverse effects to long term exposure (Bochert & Zettler, 2004). It has been suggested that plaice are able to use magnetic fields as navigational cues (Metcalfe, Holford, & Arnold, 1993) however no studies have been undertaken to quantify how sensitive they are. Field data from surveys investigating the effect of an offshore windfarm in the Kattegat area of the Baltic Sea, concluded that EMF was unlikely to alter cod behaviour. This was based on observations of fish aggregating within the vicinity of cables during both active and inactive electricity transmission over several years in comparison to reference areas (Bergström, Sundqvist, & Bergström, 2013; Hammar, Wikström, & Molander, 2014).

On balance the evidence indicates that the maximum Marine Scheme emitted EMF will not result in measurable responses in demersal fish. Should some individual fish avoid the area of EMF around the cable this behavioural response is expected to be very localised as EMF effects attenuate within a very short distance from the buried cable.

The EMF emitted in close proximity to the cable is a long-term effect but as transmission strength will be variable maximum effects are not expected to occur for the entire operational phase of the Marine Scheme. In any event even maximum EMF emissions are anticipated to have little influence on demersal teleost species and the magnitude of the effect is considered to be negligible. Based on the low to medium sensitivity of the receptor species and the negligible magnitude of the impact, it is considered that EMF generated by electricity transmission will have a **negligible** effect on demersal teleost fish populations and is therefore **not significant**.

Elasmobranchs

The cable route passes through areas of suitable habitat for a range of elasmobranch species including skate and dogfish. The basking shark may be occasionally present, but the North Sea is not peak habitat for this species. Elasmobranchs are recognised as having particular sensitivity to EMF and they are known to use electro-sensory perception for the detection of prey and predator avoidance and location of mates as well as orientation and migration behaviour (e.g. see Hutchison et al., 2018).

Laboratory experiments to determine the effect that exposure to EMF had on the lesser spotted dogfish reported that individuals were attracted to EMF field strengths that corresponded to prey items but were repelled by the fields mimicking the full strength of a cable in operation (Gill & Taylor, 2001; Gill, et al., 2009). Mesocosm experiments using a cable with a conductor cross section of 16 mm^2, the ability to carry 600-1000 V and rated from 25 to 730A to assess influences on lesser spotted dogfish and thornback ray found that dogfish dispersed around the enclosure before and after the cable was active and aggregated within two meters of the sunken cable when it was active indicating an attraction (Gill, et al., 2009). However, the study found no significant difference in the distribution of thornback rays between the active and inactive periods of cable operation, suggesting different behavioural response between elasmobranch species (Gill, et al., 2009).

Field trials monitoring the behaviour of tagged little skate, *Leucoraja erinacea* (a north American ray species) reported a response to the EMF generated by the Cross Sound subsea cable (Hutchison, et al., 2018). During the experiments the cable was operating at 0MW, 100MW and 330MW capacity with the corresponding EMF generated above background levels of 0.4, 4.0 and 14μT (Hutchison, et al., 2018). Little skate exposed to EMF generated by the cable travelled between 20-90% further than those in the control enclosure, swam at lower average speeds, took a larger proportion of large turns and spent more time closer to the seabed (Hutchison, et al., 2018). It was concluded that the behavioural response was typical of exploratory behaviour and that the cable did not represent a barrier to skate movement (Hutchison, et al., 2018).

Pelagic elasmobranchs, such as basking shark, are unlikely to experience EMF effects unless in very shallow water where avoidance behaviour is possible. Benthic elasmobranchs, particularly skates and rays and smaller sharks, are more likely to encounter EMF but effects are expected to be restricted to possible re-orientation of swimming direction with normal behaviour resuming a short distance from the buried cable.

The magnitude of the impact of EMF for elasmobranchs is considered to be low; responses will only occur over a very limited area and the effects are only temporary and will not interfere with any key functional activities. Combined with the low to high value and medium sensitivity of the identified elasmobranch species cable generated EMF is predicted to have an effect of **minor adverse** and therefore is **not significant** for elasmobranchs.

Spawning, eggs, larvae, and juvenile fish

The proposed marine installation corridor passes through known and nursery grounds (Section 9.5.3) of a number of species including herring, cod, whiting, and sandeel. Any EMF disturbance from the cable has the potential to disrupt fish behaviour such as spawning and could have a direct impact on the eggs, larvae and juveniles of these species.

Laboratory studies to investigate the effect of exposure to EMF on eggs, larvae and juveniles have been carried out on a number of fish species. Bochert & Zettler (2004) reported no impact on survival in juvenile flounder exposed to magnetic fields with a strength of 3700μT for a period of four weeks and Woodruff et al. (2012) reported no significant effect on survival for Atlantic halibut larvae exposed to EMF with a strength of 3000μT for a period of 27 days. Rainbow trout eggs and larvae exposed to EMF with a strength of 10000μT for a period of 36 days did not show any significant effects on mortality, growth or development (Fey, et al., 2019). Atlantic salmon eggs exposed to EMF with a strength of 2000μT exhibited increased permeability to water, however this did not cause any adverse effects upon survival or embryological development (Sadowski, Winnicki, Formicki, Sobocinski, & Tanski, 2007).

The magnetic field strengths tested in these laboratory experiments are considerably higher (by 2 to 3 orders of magnitude) than those likely to be encountered by eggs and larvae even in the immediate vicinity of the cable. This is consistent with the findings of a recent review of available literature on the effects of marine renewable energy on marine animals (Copping, et al., 2020). The study reports that the evidence to date suggests that the levels are unlikely to keep animals away from their preferred habitats or to affect migration and there are no reports of significant effects in eggs, larvae or juvenile fish.

The magnitude of the impact is therefore considered to be negligible for all fish receptor groupings. Based on the low to medium sensitivity/value rating assigned to these life stages the effect is predicted to be **negligible** and therefore **not significant.**

Shellfish

A number of important commercial shellfish species are found along the cable route including, decapods such as *Nephrops* and common lobster, crabs and bivalve molluscs such as scallop.

Edible crab has been subject EMF exposure experiments, testing stress related parameters and behavioural response. EMF strengths of 250 μT were found to have limited physiological and behavioural impacts. At exposure of 500 μT and 1000 μT stress responses were detected in histological indicators but crabs also showed a clear attraction at these EMF levels (Scott, et al., 2021). However, this attraction has been observed to not impact overall crab movements (Love, Nishimoto, Snook, Schroeder, & Bull, 2017) and in an experiment with American lobsters only subtle behavioural responses to HDVC EMF were observed (Hutchison, et al., 2018). There were notable changes in movement and distribution within an enclosed space, but the EMF did not represent a barrier to lobster movements, and no significant impact was observed overall.

Thus, the evidence indicates that the maximum EMF strength modelled for the Marine Scheme is not high enough to illicit negative responses in crustaceans. Additionally, given the relatively narrow ZoI as EMF attenuated quickly it is reasonable to expect an insignificant proportion of the North Sea population will come into contact with EMF levels higher than the natural geomagnetic range. The effect on crab and lobster is therefore predicted to be **negligible** and therefore **not significant**.

There was no evidence of negative EMF impacts to bivalve molluscs found in the literature. Research on nudibranch molluscs has shown they are able to detect changes in geomagnetic fields, but it is not understood if or how this is interpreted outside of prey detection (Wang, Cain, & Lohman, 2004). Further research on nudibranch molluscs shows that exposure to 100 μT – 500 μT EMF improved immune response with no negative impact on physiology or behaviour (Zhang, et al., 2020). However, despite being in the same phylum, the physiology of nudibranchs is dissimilar to that of bivalves. Nudibranchs possess some adaptations bivalves do not and have evolved relative sensitivity for active foraging or hunting, as opposed to sessile filter feeding. There is also little evidence of significant concerns in relation to EMF effects on molluscs. However, any effects would likely be highly localised to the immediate vicinity of the buried cable and only expose a very small area to EMF. Thus, it is expected that EMF will have negligible impact on any bivalves in the ZoI.

The magnitude of the impact of EMF exposure is considered to be negligible**.** The overall effect of EMF from cable operation on shellfish, which range in sensitivity/value from low to high, is considered to be **negligible** which is **not significant.**

9.6.3.2 Potential effects due to subsea cable thermal emissions

Both high voltage AC and DC submarine power cables have been shown to generate and dissipate heat when active, reaching cable surface temperatures of up to 70°C (Emeana, et al., 2016). Such heat has the potential to cause sediment dwelling and demersal mobile organisms to move away from the affected area. Increased heat may also alter physico-chemical conditions and bacterial activity in surrounding sediments, contributing to altered faunal composition and localised ecological shifts (Meissner, Schabelon, Bellebaum, & Sordyl, 2008). While the full effect of temperature changes on sediment composition and related biogeochemical cycling are unknown, preliminary studies have indicated shifts in bacterial community composition with increased temperatures, with corresponding changes in NH_4 concentration and nitrogen cycling (Hicks, et al., 2018).

Sediment particle size composition has been found to influence heat transfer, with coarse silts experiencing the greatest temperature change, but to a shorter distance from the source, while fine and coarse sands had a lower temperature change but a greater affected distance (Emeana, et al., 2016).

The Marine Scheme cable design comprises two HVDC cables, installed either in a 30 m separated bipole or bundled together in a single trench. Heat dissipation modelling for bundled cables buried at a depth of 1.5 m indicates that within 50 cm of the seabed surface the increase in sediment temperature is limited to approximately 3^{o}C which has been calculated based upon a maximum seabed ambient surface sediment temperature of 15^{o}C (Chapter 2: Project Description). For unbundled cables the heat profile of each individual cable at the surface may be lower but the affected area will be around two cables, rather than one.

A range of sediment types have been classified within the Marine Scheme, with the majority classified as coarse sediment and sand. These contribute to a wide variety of habitats and biotopes, which support a range of benthic fauna, demersal, and pelagic fish species. However, whilst the sediment surrounding the cable route may be heated there is negligible capability to heat the overlying water column because of the very high heat capacity of water.

Diadromous fish, including Atlantic salmon and other species of conservation importance, are unlikely to be directly impacted by any thermal emissions from an active cable, as they are mostly pelagic upon their return to marine habitats, and any heat generated by the subsea cable will not affect the overlying water column. Similarly, pelagic fish species are highly mobile and even where swimming close to the seabed are unlikely to encounter an increase in sediment or water temperature. Thus, the only fish and shellfish species likely to be affected are those that live within the sediments or on the seabed surface, including sandeel, demersal species and fish and eggs at spawning grounds.

Demersal Fishes

Benthic and demersal fish species, particularly cod, plaice, sandeel, sole, and whiting, live in close association with the seabed. However, only those species that spend time within the sediment are expected to be within a potential zone of influence of sediment heating from buried cables. This includes sandeel, plaice and sole as they all have life stages that burrow within sediments. Although the Marine Scheme was identified as high intensity nursery and/or spawning ground for cod and whiting (Ellis, Readdy, Taylor, & Brown, 2012), any eggs laid on sediment surfaces are also unlikely to impacted as temperature changes dissipated quickly within a metre and the cable is set to be buried at 1.5 m.

Sandeel spend the better portion of the year burrowed in sediments (Van der Kooij, Scott, & Mackinson, 2008). Their distribution is patchy as they favour coarse sand, fine to medium gravel, and low silt content Populations are also typically associated with subtidal sandbanks (MarineSpace Ltd; ABPmer Ltd; ERM Ltd; Fugro EMU Ltd; Marine Ecological Surveys Ltd, 2013a), but they are distributed widely from inshore waters to the shallow sublittoral zone. When spawning, females release eggs directly onto the substrate, although their larval stage is pelagic before they begin burrowing as juveniles (Limpenny, et al., 1966).

Plaice is a flatfish typically associated with sand, gravel, and mud substrata (Tappin, et al., 2011). After spawning, plaice have a planktonic larval stage before settling and burrowing into sandy substrates to hide from predators (Heessen, Daan, & Ellis, 2015).

Sole prefer to bury into sandy and muddy substrates. After spawning, larvae will settle to the benthos, where they will inhabit this nursery ground for up to two years (Rijnsdorp, et al., 1992). Sole feed nocturnally, spending the day buried in sediments and preying upon polychaetes, small echinoderms, and small molluscs at night (Braber & Groot, 1973).

All of the fish species detailed above are shallow burrowers and so not likely to come into contact with any significant sediment heating as the temperature increase is minimal in the top layers of the seabed. Thus, such a small increase in temperature is unlikely to significantly impact any species and eggs in the vicinity of the operational cable. Whilst many organisms may have a preferred temperature range, they will experience some seasonal changes, though these are expected to be less pronounced in the sediments compared to the overlying water column, and likely to be able to tolerate minor changes. Thus, even where the cable passes through sandeel or other species spawning grounds thermal impacts are predicted to be of a negligible magnitude, combined with a medium sensitivity, predicted effect that is **negligible** and therefore **not significant**.

Shellfish

Although there are no protected shellfish species within the Marine Scheme, there are important fisheries for *Nephrops norvegicus* located in the study area (Chapter 14: Commercial Fisheries). *Nephrops* are found burrowed throughout cohesive muddy sediments which allows the excavation of an often extensive but shallow system of branching unlined burrows (Atkinson, 1974). Burrow systems are generally to a depth of 20 cm and so any increase in sediment temperature at this depth will be minimal and the burrow systems is flushed with water which is expected to increase heat dissipation.

Thermal effects would be long-term, occurring continuously for the operational lifetime of the Marine Scheme. Whilst some burrowing fish and shellfish species may be within the zone of influence for sediment heating, the temperature increase is low level, likely to be a degree of two compared to ambient, at the shallow depths at which these burrowing species are found. Thus, effects are predicted to be highly localised (i.e., within a metre or marginally more of the cables), affecting a relatively small proportion of the fish and shellfish habitats in the Study Area. The sensitivity of sandeel and *Nephrops* have been appraised to be medium. The scale of the thermal change in the sediment in which these species reside, and the water layer above the seabed, is small and likely to be within the scale of natural seasonal variability. The extent of the increase is also very limited in spatial extent and thus the magnitude of the impact is predicted to be negligible. The effect of thermal emissions from the Marine Scheme are also predicted to be **negligible** and therefore **not significant**.

9.6.3.3 Maintenance and Cable Repair Effects

Maintenance activities and cable repair where required, will be carried out using the same or similar methods as cable installation, and therefore the potential pathways for impact to fish and shellfish ecology would be the same as those identified for the cable installation phase of the Marine Scheme.

Repair works are likely to be highly localised to the area of concern and therefore the spatial extent of any impacts would be small in extent. Furthermore, any maintenance or repairs works would be anticipated to take no more than several weeks to complete meaning the duration of impact would also be short.

The only exception is where rock protection would be required as part of maintenance and cable repair works to achieve cable reburial. In the event additional placement of rock, concrete mattresses or grout bags on the seabed be required to achieve reburial of the subsea cable, further permanent physical disturbance to fish and shellfish would likely arise.

The marine installation corridor will be routed to avoid any unstable habitats and to achieve the precautionary target burial depths as much as possible. However, a detailed review of rock placement requirements has already been undertaken and the need for additional cable protection as part of maintenance and cable repair works are not predicted to fall beyond the estimated volumes during installation and the significance of permanent physical disturbance effects remains as reported for cable installation.

Maintenance and unforeseen cable repair (although unlikely) are routine, and the procedures and processes are well defined and common in the industry. Impacts of maintenance and cable repair works would be of smaller magnitude than cable installation, and the effect is predicted to be **negligible** and therefore **not significant**.

9.6.4 Decommissioning Phase

At the end of the operational life of the cable the options for decommissioning will be evaluated and taking into consideration other Project constraints (e.g. safety and liability), the least environmentally damaging option would be chosen if possible.

The principal options for decommissioning described in Chapter 2: Project Description are:

- Leave in situ, buried;
- Leave in situ and provide additional protection where exposed;
- Remove sections of the cable that present a risk; or
- Remove the entire cable.

Should full removal from the seabed be required, this would have the potential to cause similar impacts to the cable installation phase of the Marine Scheme.

Impacts during decommissioning may be of a similar magnitude to cable installation, or they may be less, depending upon the decommissioning option chosen. As a worst case, the potential effects to fish and shellfish are predicted to be **negligible** to **minor adverse** and **not significant**.

9.7 Mitigation and Monitoring

Aside from the embedded mitigation measures, as aforementioned in Section 9.6.1, no additional mitigation measures or monitoring have been recommended as a result of the impact appraisal.

9.8 Residual Impacts

Given that no significant impacts have been identified for fish and shellfish, no residual impacts have been identified as a result of Marine Scheme activities.

9.9 Cumulative and In-Combination Effects

The full cumulative and in-combination effects appraisal is presented in Chapter 16: Cumulative and In-Combination Effects.

This includes a matrix (Table 16-8 in Chapter 16) to identify potential fish and shellfish ecology impact pathway interactions between the Marine Scheme and the English and Scottish Onshore Schemes. No interaction is anticipated because there are no project activities associated with the English and Scottish Onshore Schemes in the marine environment due to the use of HDD at the landfall.

In-combination effects are where receptors could be affected by more than one environmental impact. Where a receptor has been identified as only experiencing one effect or where only one topic has identified effects on that receptor, there is no potential for in-combination effects. The receptor groups within this chapter do not interact between chapters, therefore receptors have been wholly appraised within this respective topic chapter.

9.10 Summary of Appraisal

This chapter has considered the potential effects of the Marine Scheme on fish and shellfish receptors. A summary of the effects is presented in Table 9-14. No significant effects are predicted during installation, operation (including maintenance and repair), and decommissioning of the Marine Scheme.

Table 9-14: Summary of environmental appraisal

Phase	Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Project Specific Mitigation	Significance of Residual Effect
Route preparation and cable installation	Temporary physical disturbance to fish and shellfish habitats and species during cable lay	Herring	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Sandeel	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Elasmobranchs	Medium	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Shellfish	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
	Permanent physical disturbance to and/or loss of fish and shellfish habitats and species due to placement of hard substrates on the seabed	Herring	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Sandeel	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Flatfish	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Shellfish	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
	Temporary increased suspended sediment concentrations, and subsequent settlement of sediment causing smothering of fish habitat	Herring	Low	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Sandeel	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Diadromous species	Low	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Shellfish	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Other marine fish	Low	Negligible	**Negligible**	None required	**Negligible** which is **not significant**

Phase	Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Project Specific Mitigation	Significance of Residual Effect
	Underwater sound effects on fish and shellfish	Fish	Low to high	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Shellfish	Medium	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
	Changes to marine water quality from the use of HDD drilling fluids and the release of waste from vessels	Fish and shellfish	Low to high	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
	Changes to marine water quality from accidental leaks and spills from vessels, including loss of fuel oils	Fish and shellfish	Low to high	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
	Vessel collision risk	Fish and shellfish	Low to high	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
Cable operation (including maintenance and repair)	Effects of Electromagnetic field (EMF) emissions from buried cable	Diadromous species	Low	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Pelagic species	Low	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Demersal species	Low to medium	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Elasmobranchs	Medium	Low	**Minor adverse**	None required	**Minor adverse** which is **not significant**
		Spawning fish, eggs, larvae and juvenile fish	Low to medium	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
		Shellfish	Medium to high	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
	Effects of thermal emissions from buried cable	Demersal species	Low	Negligible	**Negligible**	None required	**Negligible** which is **not significant**

Phase	Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Project Specific Mitigation	Significance of Residual Effect
		Shellfish	Medium to high	Negligible	**Negligible**	None required	**Negligible** which is **not significant**
	Maintenance potential effects the same as route preparation and cable installation						
Decommissioning	Potential effects of decommissioning the same as route preparation and cable installation						

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