



Eastern Green Link 2 - Marine Scheme

Environmental Appraisal Report Volume 2

Chapter 9 - Fish and Shellfish Ecology

nationalgrid



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9. Fish and Shellfish Ecology

9.1 Introduction

This chapter of the Environmental Appraisal Report (EAR) presents an appraisal of the potential interaction of the Marine Scheme with fish and shellfish ecology.

A description of the works anticipated to be undertaken during Installation, Operation and Maintenance and Decommissioning Phases of the Marine Scheme 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 for any identified adverse effects that may result (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 in detail 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 due to the predator-prey relationships that exist between these groups. Consideration of the socio-economic aspects of commercial fishing, including vessel nationalities, home port locations, catch volume and value, and fishing methods, is discussed in Chapter 14: Commercial Fisheries. This chapter is supported by the following documents:

- Appendix 8.1: Eastern Green Link 2 Habitat Alignment Charts;
- Appendix 8.2: Eastern Green Link 2 Habitat Regulations Assessment (HRA); and
- Appendix 8.3: Eastern Green Link 2 Marine Protected Area (MPA) and Marine Conservation Zone (MCZ) Assessment.

9.2 Legislation, Policy and Guidance

This section outlines legislation, policy, and guidance relevant to the appraisal of the potential effects on fish and shellfish ecology associated with Installation, Operation and Maintenance, and Decommissioning Phases of the Marine Scheme. For further information regarding the legislative context, refer to Chapter 3: Legislative and Policy Framework and Appendix 3.2: Topic Specific Legislation.

9.2.1 International Legislation

The following international legislations concern the conservation and protection of benthic ecological receptors during the planning and execution of projects such as offshore cable developments:

- European Union Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora adopted in 1992.

9.2.2 National Legislation

The following national and devolved legislation concern the conservation and protection of fish and shellfish during the planning and execution of projects such as offshore cable development in UK waters:

9.2.2.1 UK (England and Scotland)

- The Conservation of Offshore Marine Habitats and Species Regulations 2017;
- Marine and Coastal Access Act (MCAA) 2009 (HM Government, 2009);
- Wildlife and Countryside Act 1981; and
- The Marine Strategy Regulations 2010 (HM Government, 2010).

9.2.2.2 Scotland

- Marine (Scotland) Act 2010 (Scottish Government, 2010);
- The Conservation (Natural Habitats, &c.) Regulations 1994 (Scottish Government, 1994) (as amended);
- The Conservation (Natural Habitats, &c.) (EU Exit) (Scotland) (Amendment) Regulations 2019; and
- Nature Conservation (Scotland) Act 2004 (Scottish Government, 2004).

9.2.2.3 England

- The Conservation of Habitats and Species Regulations 2017 (HM Government, 2017) (as amended);
- The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019;
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (as amended);
- European and National fisheries regulations implemented under the jurisdiction of the Marine Management Organisation (MMO) (6 nautical miles (NM) to 12 NM), local byelaws relating to fishing practices in coastal areas (0 NM to 6 NM) are enforced through the Inshore Fisheries and Conservation Authorities (IFCAs); and
- Natural Environment and Rural Communities Act 2006 (HM Government, 2006).

9.2.3 International Policy

The following international policies concerning the conservation and protection of fish and shellfish receptors during the planning and execution of projects such as offshore cable development:

Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention') adopted in 1998 and amended in 2007.

9.2.4 National Policy

The following national and devolved policies concerning the conservation and protection of fish and shellfish during the planning and execution of projects such as offshore cable development in UK waters:

9.2.4.1 UK (Scotland and England)

- UK Marine Policy Statement (MPS) (HM Government, 2011); and
- UK Post-2010 Biodiversity Framework (HM Government, 2010).

9.2.4.2 Scotland

- Scottish National Marine Plan (2015) (Scottish Government, 2015);
- Scottish Planning Policy (Scottish Government, 2020); and
- Regional Inshore Fisheries Groups (2016).

9.2.4.3 England

- North East Inshore and North East Offshore Marine Plan (HM Government, 2021);
- East Inshore and East Offshore Marine Plans (HM Government, 2021);
- National Policy Statements (NPS) (HM Government, 2014);
- Biodiversity 2020: A strategy for England's wildlife and ecosystem services (HM Government, 2011); and
- The revised National Planning Policy Framework (HM Government, 2012).

9.2.5 Guidance

In addition to the legislation and policies outlined above, the following guidance is also applicable for fish and shellfish ecology in UK waters:

- Chartered Institute for 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
- Priority Marine Features (PMF) 2014 (Scottish waters only)¹.

In the absence of Environmental Quality Standards for *in situ* sediments in the UK, the following guidance has been used to help inform a 'Weight of Evidence' (WoE) approach to determine 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). These values are 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 in dredged material below Action Level 1 are of no concern and are unlikely to influence the licensing decision. However, dredged material with contaminant levels above Action Level 2 is generally considered unsuitable for sea disposal. Dredged material with contaminant levels between Action Levels 1 and 2 requires further consideration and testing before a decision can be made. Action Levels are therefore, used as a guide in assessments of sediment contamination in non-dredging activities;
- UK Offshore Operators Association (UKOOA) sediment quality guidelines for the UK North Sea (UKOOA, 2001);
- Data from 'Clean Seas Environmental Monitoring Programme at Tyne Tees and a station at the Firth of Forth (Marine Scotland, 2020);
- OSPAR² background concentrations and background assessment concentrations and effect range low (ERL) and effect range median (ERM) concentrations for contaminants (OSPAR, 2009); and
- Canadian sediment quality guidelines (CCME, 2001) are used for a number of contaminants where there are no regional quality thresholds available.

9.3 Study Area

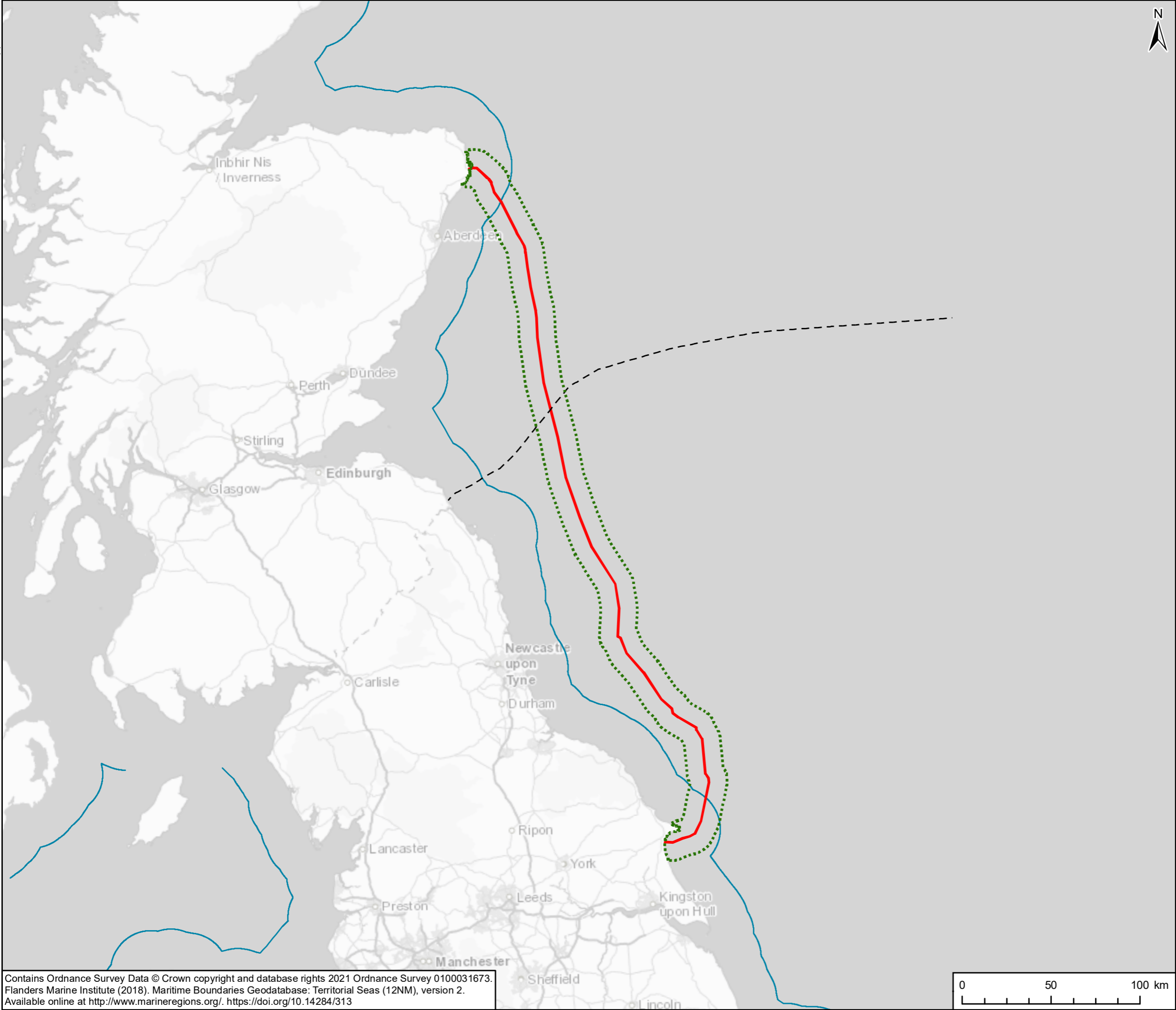
The study area was informed by stakeholder feedback and in particular, the comments raised on migratory fish. This fish and shellfish appraisal therefore covers a 10 km wide study area, 5 km either side of the centre line of the Marine Installation Corridor as illustrated in Figure 9-1. This study area has been selected to encompass all likely zones of influence (Zol) for fish and shellfish, as identified in Section 9.6.

In addition, all sites designated for migratory fish on the east coast of the UK to the Marine Scheme have been scoped into the assessment to consider the potential for an interaction between the Marine Scheme and potential migration routes of diadromous fish (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 (NEXTGeosolutions, 2022).

¹ <https://www.nature.scot/professional-advice/protected-areas-and-species/priority-marine-features-scotlands-seas>

² OSPAR is the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic



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Coordinate System: WGS1984 Zone 30N

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PROJECT
Eastern Green Link 2

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

TITLE
**Figure 9.1
Study Area**

REFERENCE
SEGL2_M_EAR_9-1_v2_20220629

SHEET NUMBER
1 of 1

DATE
29/06/2022

Scale @ A3 1:2,000,000

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 guidelines listed in Section 9.2.5.

Advice received from Marine Scotland Licensing Operations Team (MS-LOT) on 03 September 2021 and the Marine Management Organisation (MMO) on 02 November 2021 identified aspects of the Marine Scheme that have the potential to impact the fish and shellfish ecology during Installation, Operation and Maintenance and Decommissioning Phases³. Details of the advice received and how it is addressed in the appraisal are provided in Chapter 6: Consultation and Stakeholder Engagement and its associated appendices.

The design for the Marine Scheme comprises two high-voltage direct current (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 a maximum of 30 m apart (referred to as a '30 m separated bi-pole'). For both approaches, the target depth of lowering is approximately 1.5 m and the minimum depth of lowering without cable protection will be approximately 0.6 m. Therefore, the appraisal considers the two-trench scenario only, as the worst case scenario that will also encompass any potential effect should the cables be bundled.

9.4.2 Data Sources

The fish and shellfish ecology baseline has been developed using several data sources. This includes results of a project specific benthic survey which were used to assess conditions in relation to fish spawning habitat (NEXTGeosolutions, 2022) and a wide body of publicly 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 and northern 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/>);
- 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.

³ 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

9.4.3 Summary of Consultation

Advice from the MMO and MS-LOT and their respective consultees and advisers provided feedback on the Marine Scheme and EAR scope. Those consultees and advisors include NatureScot, Scottish Environment Protection Agency (SEPA), Cefas, Joint Nature Conservation Committee (JNCC), Natural England, Environment Agency and IFCA's.

Further consultation was undertaken by email on 06 December 2021 requesting relevant data to inform the characterisation of the baseline environment from the Ugie, Ythan, Deveron, Don and Dee District Salmon Fisheries Boards. No responses were received from the Salmon Fisheries Boards consulted.

Details on the consultation and how comments were addressed in relation to fish and shellfish ecology is provided in Chapter 6: Consultation and Stakeholder Engagement and its associated appendices.

9.4.4 Data Gaps and Limitations

For many species, an 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 (NEXTGeosolutions, 2022). Owing to their life history strategies these species, are likely to 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., 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, several 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 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).

Despite these limitations, every effort has been made to obtain data concerning the existing environment and to accurately predict the likely environmental effects of the Marine Scheme. It is considered that the baseline information collected and used for this appraisal is representative of the defined study area.

9.5 Baseline Conditions

This section covers the fish and shellfish ecology baseline for the Marine Scheme, with regards to the general fish and shellfish communities found near the Marine Installation Corridor, spawning and nursery grounds, commercial fish species (from an ecology perspective only), the relevant designated sites 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 international and national conservation legislation (Table 9-1). 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. There are no shellfish species which are afforded conservation protection known to be present in the study area.

Table 9-1: 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 | Wildlife and Countryside Act 1981 | UK Post-2010 Biodiversity Framework | Features of Conservation Interest (FOCI) | IUCN Red List* | Priority Marine Features (PMFs) # |
|-----------------|---------------------------------|--|---|---|---|-----------------------------------|-------------------------------------|--|---------------------|-----------------------------------|
| Atlantic salmon | <i>Salmo salar</i> | ✓ | ✓ | | | | ✓ | ✓ | LC (-) | ✓ ² |
| Sea trout | <i>Salmo trutta</i> | | | | | | ✓ | | LC (?) | ✓ ² |
| European eel | <i>Anguilla anguilla</i> | | ✓ | ✓ | | | ✓ | ✓ | CR (↓) | ✓ ² |
| Sea lamprey | <i>Petromyzon marinus</i> | ✓ | ✓ | | ✓ | | ✓ | ✓ | LC (↔) | ✓ ² |
| River lamprey | <i>Lampetra fluviatilis</i> | ✓ | | | | | ✓ | ✓ | LC (?) | |
| Herring | <i>Clupea harengus</i> | | | | | | ✓ | ✓ | LC (↑) | |
| Mackerel | <i>Scomber scombrus</i> | | | | | | ✓ | ✓ | LC (↓) | |
| Haddock | <i>Melanogrammus aeglefinus</i> | | | | | | | | VU (-) | |
| Cod | <i>Gadus morhua</i> | | ✓ | | | | ✓ | ✓ | VU (-) | ✓ ³ |
| Whiting | <i>Merlangius merlangus</i> | | | | | | ✓ | ✓ | LC (?) | ✓ ³ |
| Plaice | <i>Pleuronectes platessa</i> | | | | | | ✓ | ✓ | LC (↑) | |
| Sandeel | <i>Ammodytidae</i> | | | | | | ✓ ¹ | ✓ ¹ | LC (?) ¹ | ✓ ^{3**} |
| Basking shark | <i>Cetorhinus maximus</i> | | | | | ✓ | ✓ | | EN (↓) | ✓ ³ |
| Thornback ray | <i>Raja clavata</i> | | ✓ | | | | | | LC (?) | |
| Spotted ray | <i>Raja montagui</i> | | ✓ | | | | | | 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

Scottish Waters

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

No sites designated for the protection of fish and shellfish have been identified within 10 km of the Marine Scheme in Scottish waters. The closest site in Scottish waters is Turbot Bank MPA located 24.4 km to the east of the Marine Installation Corridor, which is designated for the protection of non-migratory fish (sandeel) which will not come within any Zol of the Marine Scheme. Therefore, it is not considered further in the assessment since there is no likely interaction between the Marine Scheme and the fish species protected by the Turbot Bank MPA.

Key sites designated for the protection of migratory fish known to migrate over large distances, have been considered:

- River Dee SAC (approximately 37.8 km away): The Annex II species present as a qualifying feature are Atlantic salmon *Salmo salar*.
- River South Esk SAC (approximately 81.1 km away): The Annex II species present as a qualifying feature are Atlantic salmon.
- River Tay SAC (approximately 103.3 km away): The Annex II species present as qualifying features are: Atlantic salmon, brook lamprey *Lampetra planeri*, sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluviatilis*.
- River Teith SAC (approximately 174.6 km away): The Annex II species present as qualifying features are: sea lamprey, brook lamprey, river lamprey and Atlantic salmon.

A number of other salmon rivers have also been considered in Section 9.5.2.1 and Section 9.6.

English Waters

One site in English waters is designated for shellfish, within 10 km of the Marine Scheme:

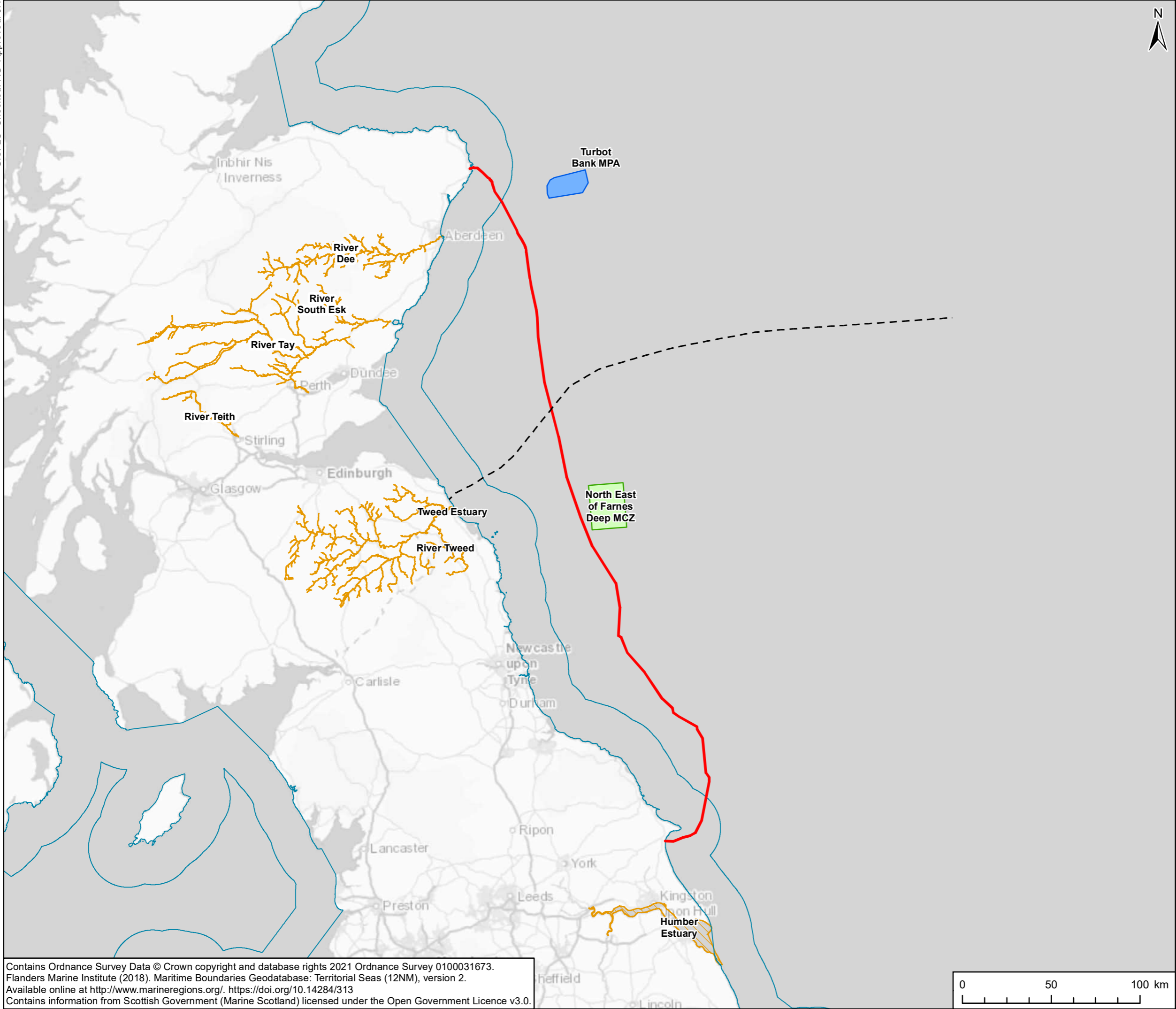
- North East of Farnes Deep MCZ (approximately 3.1 km away): The species feature of conservation in this MCZ is ocean quahog *Arctica islandica*. A detailed appraisal of impact to this species from the Marine Scheme is presented in Chapter 8: Benthic Ecology.

There are also three sites designated for migratory fish which are landward of the Marine Installation Corridor including:

- Humber Estuary SAC (approximately 34.7 km away): The Annex II species present as qualifying features are: Sea lamprey and River lamprey.
- Tweed Estuary SAC (approximately 65.0 km away): The Annex II species present as qualifying features are: Sea lamprey and River lamprey.
- River Tweed SAC (approximately 67.1 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 Appendix 8.2: Habitat Regulations Assessment and Appendix 8.3: MPA and MCZ Assessment.

Other confirmed or potential Atlantic salmon rivers are discussed in Section 9.5.2.1.



PROJECT
Eastern Green Link 2

- KEY
- Marine Installation Corridor
 - Marine Conservation Zone (MCZ)
 - UK Territorial Sea Limit - 12nm
 - Scottish Adjacent Waters Boundary
 - Special Area of Conservation (SAC)
 - Nature Conservation Marine Protected Area (MPA)



TITLE
**Figure 9-2
Relevant designated sites for the
protection of fish and shellfish**

REFERENCE
SEGL2_M_EAR_9-2_v2_20220525

SHEET NUMBER
1 of 1

DATE
25/05/2022

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Flanders Marine Institute (2018). Maritime Boundaries Geodatabase: Territorial Seas (12NM), version 2.
Available online at <http://www.marineregions.org/>. <https://doi.org/10.14284/313>
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Coordinate System: WGS1984 Zone 30N

0 50 100 km

Scale @ A3 1:2,000,000

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9.5.2 Species-Specific Information

9.5.2.1 Diadromous Fish Species

Atlantic Salmon

Atlantic salmon *Salmo salar* are an anadromous⁴ migratory species, which during their lifetime utilise 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 marine environment 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 having migrated 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 between June to August and between October to December (Cowx & Fraser, 2003).

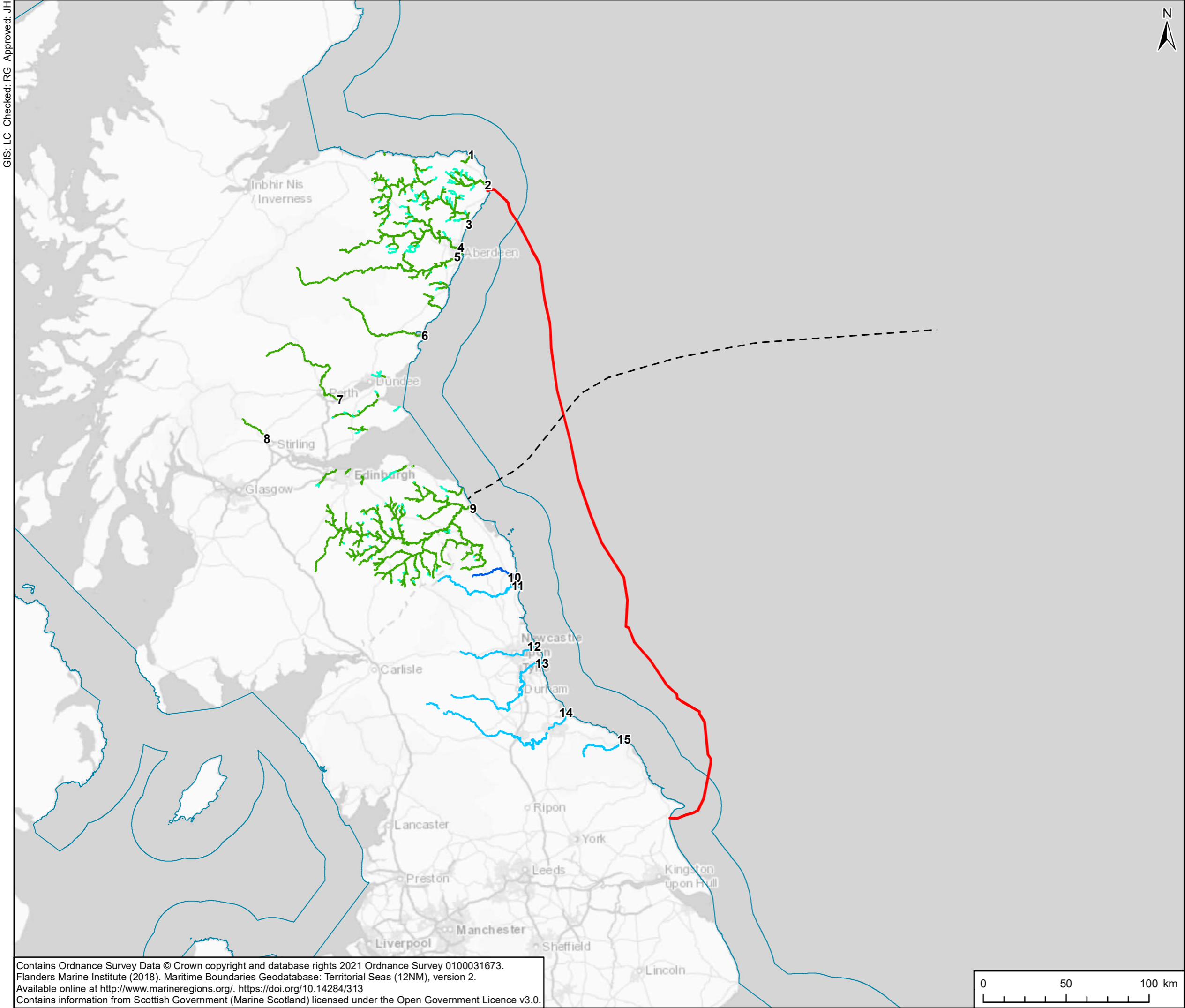
Salmon typically spend 72% to 86% of their time in surface waters (0 m to 5m), but often dive, sometimes to depths of >20 m (6% to 9% of the time). It also appears that this behaviour persists late into the migration on the return to home waters (Godfrey, Stewart, Middlemas, & Armstrong, 2014). Sub-adult Scottish salmon are known to migrate north 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 the Marine Scheme during their migration is high.

Salmon are protected as an Annex II species and are a qualifying feature (both primary and non-primary), for selection for several SACs which are listed in Section 9.5.1.2. These SACs include those in Scottish waters. There are also several rivers identified as Principal Salmon Rivers in English waters, including River Coquet, River Tyne, River Wear, River Tees and River Esk (Yorkshire) (Figure 9-3) and have their own 'Salmon Action Plans', which is used to provide a strategy for the management of the fishery, which is enforced by the Environment Agency.

The River Dee and River South Esk SACs support salmon populations and their full range of life-history types, with sub-populations of spring and summer salmon present (JNCC, 2022). Salmon spawn in the River Dee in late autumn / early winter with mid-November marking the peak of the spawning activity. The River Dees' smolts migrate to grounds off the south west Greenland coast, the Faroe Islands, into the Norwegian Sea or to waters off north west Scotland in early summer (The River Dee, 2022). The River Dee has a proposed classification of 1 under the Salmon fishing: proposed river gradings 2022 stating '*Exploitation is sustainable therefore no additional management action is currently required*'. The River South Esk has a proposed classification of 2 under the Salmon fishing: proposed river gradings 2022 stating '*Management action is necessary to reduce exploitation: catch and release should be promoted strongly in the first instance* (Scottish Government, 2021)'.

The River Tay and River Teith SACs also support high-quality salmon populations and are known to support the full range of salmon life-history types, with adult salmon entering the river throughout the year to spawn in different parts of the catchment. The River Tay has a proposed classification of 1 with the River Teith a proposed classification of 2 under the Salmon fishing: proposed river gradings 2022.

⁴ 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.



PROJECT
Eastern Green Link 2

- KEY
- Marine Installation Corridor
 - UK Territorial Sea Limit - 12nm
 - Scottish Adjacent Waters Boundary
 - Main Salmon Rivers in Scotland
 - Salmon Present
 - Salmon Likely Present
 - Main Salmon Rivers in England
 - River
 - Principal Salmon River

- ID, Name
- 1, Water of Philorth
 - 2, River Ugie
 - 3, River Ythan
 - 4, River Don
 - 5, River Dee
 - 6, River South Esk
 - 7, River Tay
 - 8, River Teith
 - 9, River Tweed
 - 10, River Aln
 - 11, River Coquet
 - 12, River Tyne
 - 13, River Wear
 - 14, River Tees
 - 15, River Esk

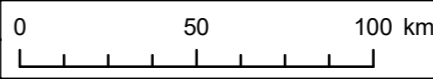


TITLE
**Figure 9-3
Rivers of Known Importance to
Migratory Salmon within 50km**

REFERENCE
SEGL2_M_EAR_9-3_v2_20220525

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Coordinate System: WGS1984 Zone 30N



Scale @ A3 1:2,141,270

In English waters, the River Tweed SAC supports a large population of salmon with sub-catchments in both Scotland and England. 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. The majority (62%) of these individuals were recorded in 2008 (434 individuals). Salmon was recorded most years; and was the highest recorded anadromous species in the River Tweed from 2002 to 2007 accounting for 63% of the total fish count of anadromous species during this time. The outcome of the conservation assessment for the Tweed for the 2022 season accords the river Category 1 status.

Other rivers in Scotland including Ugie, Ythan, Don, River Eye Water and Water of Philorth also have salmon present, with the River Ythan and River Don having salmon fishery boards in place to protect salmon stocks. Rivers in England considered as important for salmon, which are close to the Marine Scheme, include the River Tyne.

Brown Trout (Sea Trout)

Brown or sea trout *Salmo trutta*, display 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.

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 m to 3 m) and make occasional deep dives (Kristensen, Righton, del Villar-Guerra, Baktoft, & Aarestrup, 2018).

A total of 336 individuals of brown trout were recorded in Environment Agency TraC (transitional and coastal waters) surveys between 2002 to 2017 in the River Tweed (Environment Agency, 2021). The majority (51%) of these individuals were recorded in 2015 (170 individuals). Sea trout were caught almost every year during this time period, except in 2003, 2009 and 2016 where no individuals were recorded. The species accounted for 30% of the anadromous fish species caught in the River Tweed from 2002 to 2017. In the Coquet Estuary, two sea trout have been recorded in TraC surveys since the surveys began, with both individuals recorded in 2006 (Environment Agency, 2021). In the River Esk (Yorkshire), 97 sea trout were recorded, 52% of these were recorded in 2010. Nine sea trout were recorded in the Tees Estuary. In the River Tyne, a total of 783 sea trout were recorded in TraC surveys. The highest count of sea trout in the River Tyne occurred in 1987 with 146. Since then, counts in the River Tyne have varied. There were 16 individuals recorded in the River Wear.

Sea and River Lamprey

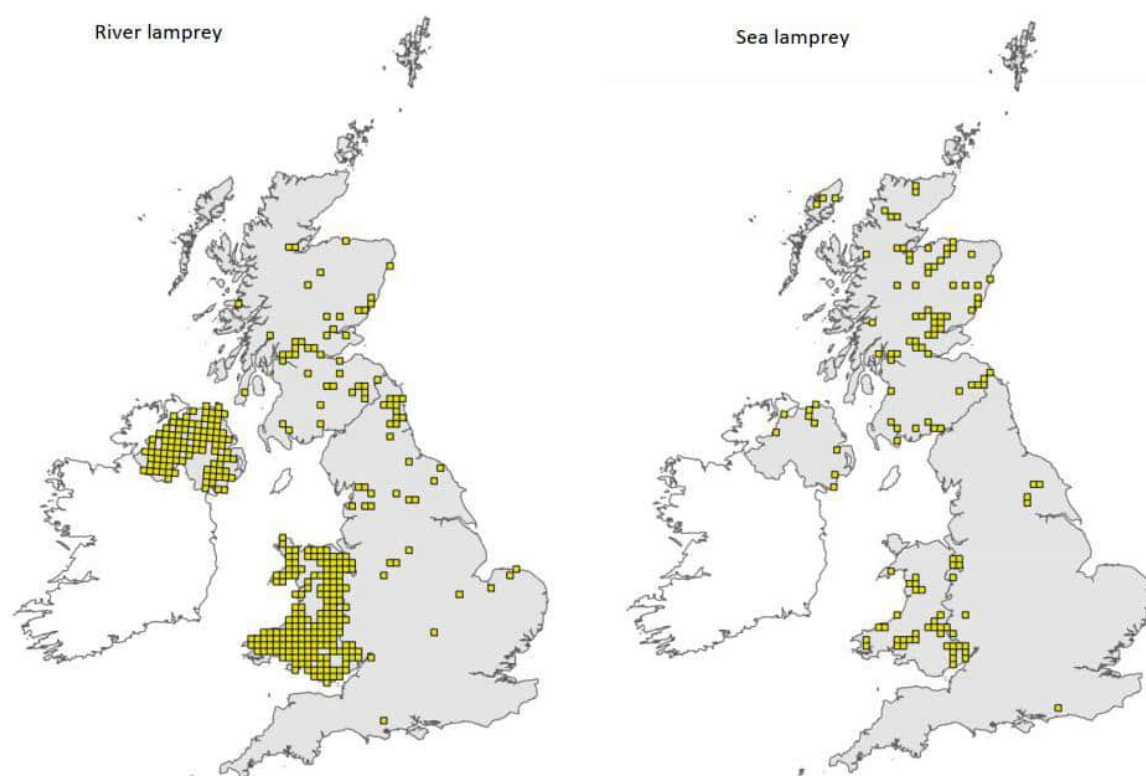
Sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluviatilis* are both anadromous migratory species. After spending several years in the marine environment, adults return to freshwater to spawn in spring and early summer (Laughton & Burns, 2003).

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). The distribution of sea lamprey is chiefly defined by their host river (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).

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

Sea lamprey and river lamprey are protected as Annex II species that are a primary reason for site selection, of the River Teith SAC. Sea lamprey and river lamprey are also qualifying features, but not a primary reason for selection, for the River Tay SAC, Tweed Estuary SAC and River Tweed SAC.



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

Figure 9-4: UK distribution of river lamprey and sea lamprey

European Eel

The European eel *Anguilla anguilla* is a catadromous⁵ migratory species, undertaking an extensive migration to spawn in the Sargasso Sea. The newly hatched larvae, known as leptocephali, 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' (Aerstrup, 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 within freshwater habitats, eels remain for five to 15 years, transforming into yellow eels and then finally to silver eels when they begin their downstream migration through rivers and estuaries towards spawning grounds, predominately between August and December (Behrmann-Godel & Eckmann, 2003; Tesch, 2003; Chadwick, Knights & Bark, 2007). Spawning occurs mainly in spring (Righton, et

⁵ A diadromous species that migrates from freshwater to seawater to spawn.

al., 2016). However, some eels do not migrate into freshwater but instead inhabit estuaries as ‘elvers’ and yellow eels before returning to spawning grounds.

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 of this species compared to the upper reaches.

9.5.2.2 Pelagic Fish 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-group⁶ 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). Herring spawning grounds have been delineated by Cefas for waters in the UK and the Marine Installation Corridor intersects some of these grounds and passes through areas of high intensity nursery grounds between KP0.7 to KP28.8 and between KP63 to KP179.9 with the remainder of the Marine Installation Corridor within an area considered to be of low intensity nursery grounds.

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, including the Scottish landfall, is located within areas that have been identified as nursery grounds for sprat, with spawning grounds located nearby (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 is divided into three spawning components, the North Sea being one of these (ICES, 2011). The main spawning period for mackerel occurs between 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 and have

⁶ Fish in the second year of their lives, which are identified as having a winter (hyaline) otolith ring

pelagic eggs and larvae (Murua & Saborido-Rey, 2003). The study area is within an area identified as being a low intensity nursery ground for mackerel (Ellis, Readdy, Taylor, & Brown, 2012).

9.5.2.3 Demersal Fish 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 (between 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 between November to February (Table 9-4), 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).

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.

The distribution of the North Sea population includes the study area for the Marine Scheme. There are nursery grounds identified within the study area (Coull, Johnstone, & Rogers, 1998). 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 and 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. The Marine Installation Corridor passes through nursery areas identified by Coull et al. (1998).

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).

González-Irusta and Wright (2016) used the abundance of spawning fish to model spawning habitat within the North Sea indicating it is widespread, associated with coarse sand and low tidal flow. Cod spawn in the winter and autumn months (depending on the area). The eggs and larvae of cod remain in the water column, developing into juvenile fish within six months. Juveniles then move to the seabed, often between July and August, when they become demersal (Heessen & Daan, 1994). Juvenile cod then move into coastal nursery areas once the spawning season is over, with young cod often found in estuaries and shallow waters.

The Marine Installation Corridor passes through an area of low intensity spawning towards the Scottish landfall and the English landfall falls within an area of high intensity nursery habitat (Coull, Johnstone, & Rogers, 1998) (Ellis, Readdy, Taylor, & Brown, 2012).

Whiting

Whiting *Merlangius merlangus* is a benthic-pelagic species, found in association with a variety of seabed types including sediment and rocky areas (Barnes, 2008). Overall, whiting do not make long-distance migrations from their spawning site (Heessen, Daan, & Ellis, 2015).

Whiting are broadcast spawners, releasing eggs to the water column from February to June (Coull, Johnstone, & Rogers, 1998), peaking in spring in shallow waters (Wheeler, 1978). Most whiting spawning occurs in water depths less than 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. The study area is located within high intensity nursery ground for whiting (Ellis, Readdy, Taylor, & Brown, 2012).

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 between March to June, peaking in April, in inshore areas such as estuaries (Tappin, et al., 2011). The pelagic eggs drift into high productivity shallow sandy nursery grounds which provide a good feeding ground for juveniles (Dipper, 2001).

Plaice

Plaice *Pleuronectes platessa* are found 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) although the study area is within a low intensity nursery ground for plaice (Ellis, Readdy, Taylor, & Brown, 2012) as mapping shows the Scottish and English landfalls to be within plaice nursery grounds (Coull, Johnstone, & Rogers, 1998). 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).

9.5.2.4 Elasmobranchs

Basking Shark

Basking shark *Cetorhinus maximus* are 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 are present in the North Sea but observations are relatively rare (Witt, et al., 2012). There have been some sightings around Aberdeenshire, 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, the results of a habitat suitability modelling study suggest that several areas of the North Sea, including around both landfall locations, has suitable habitat for basking sharks (Austin, et al., 2019). 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 but the data do not suggest a change in distribution currently.

Skates and Rays

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 and June. Peak spawning occurs slightly later in the year for the other ray species. There is insufficient information in the literature to delineate spawning grounds for these species (Ellis, Readdy, Taylor, & Brown, 2012). Spotted ray *Raja montagui* and blonde ray *Raja brachyura* 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 *Squalus 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 (between November and July), peaking in June and 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 nursery 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, scallop *Pecten maximus* favour 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 m and 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 mm to 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.

Crabs

The edible crab *Cancer pagurus* is found in water depths between 25 m and 300 m in the North Sea, with a preference for bedrock, mixed coarse 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 days 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 substrates 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).

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 North Sea is identified as a core habitat for *Nephrops* (Johnson, Lordan, & Power, 2013). The Scottish landfall is located in spawning and nursery ground for this species, with small portions of the offshore Marine Installation Corridor also passing through *Nephrops* spawning and nursery grounds (Coull et al., 1998).

However, only a single Norway lobster was observed at the camera transect conducted at KP213.3. This suggests there is very little *Nephrops* activity, and that the Marine Installation Corridor is not within key *Nephrops* habitat (NEXTGeosolutions, 2022).

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).

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. '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 or egg mats onto the seafloor making them more 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 (Table 9-2 and Table 9-3). This data indicates that the Marine Installation Corridor is located within important spawning grounds for herring, whiting, sandeels, plaice, cod and Dover sole *Solea solea*. High-intensity nursery grounds of herring, cod, and whiting were also identified within the study area.

The spawning and nursery grounds of these species, in the context of the Marine Installation Corridor are shown in Figure 9-5 to Figure 9-6. Cod, whiting, and plaice are broadcast spawners, and 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 Marine Installation Corridor 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 Section 9.5.3.1 and Section 9.5.3.2 (Table 9-4) and the assessment of potential impacts in Section 9.6.

Table 9-2: Spawning grounds within the study area

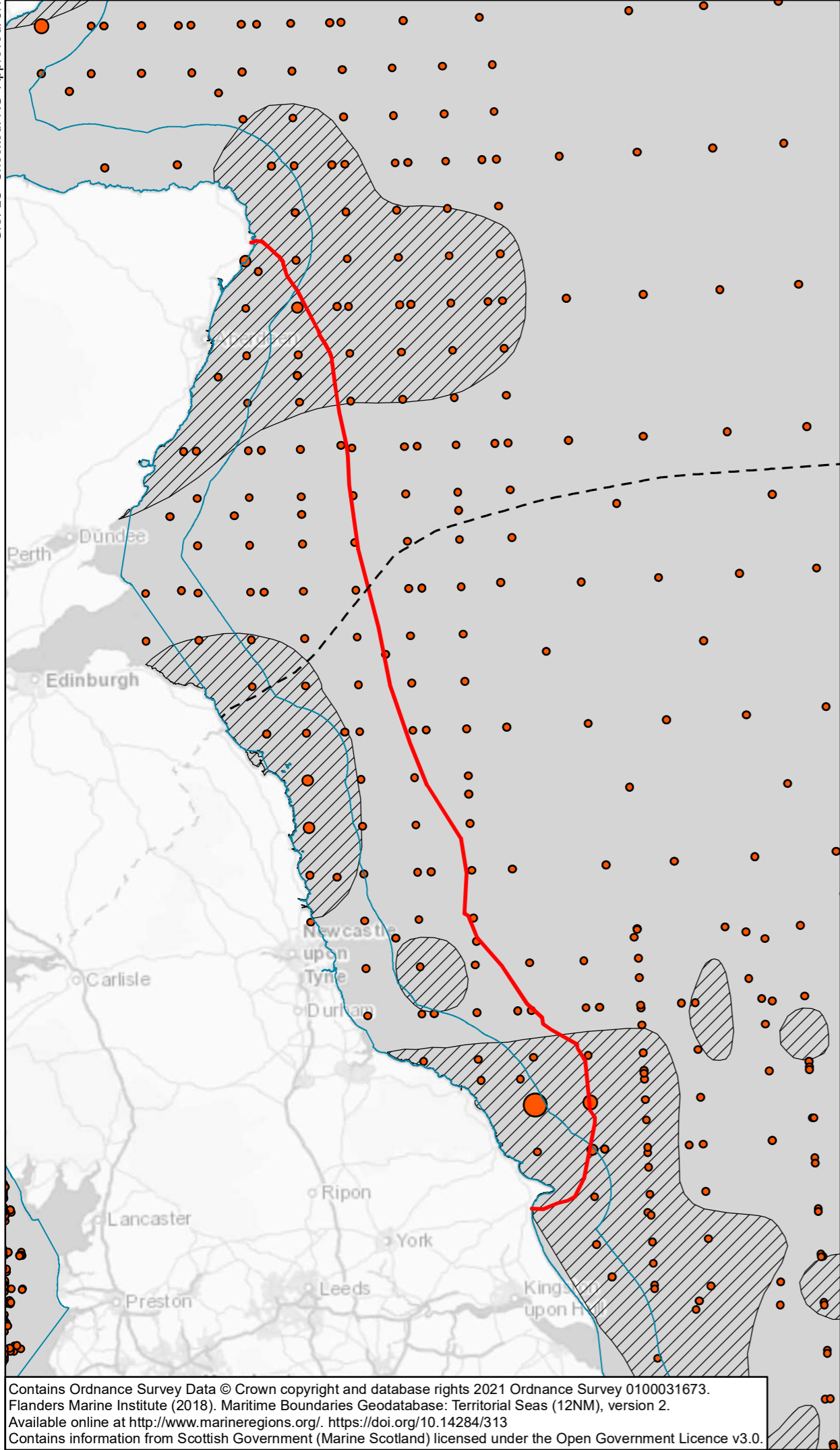
| Species | Ellis et al. (2012) | Coull et al. (1998) |
|----------------|----------------------------------|---------------------|
| Herring | Yes | Yes |
| Sandeels | Low intensity and high intensity | Yes |
| Sprat | n/a | Yes |
| Mackerel | Insufficient data | No |
| Haddock | n/a | No |
| Cod | Low intensity | Yes |
| Whiting | Low intensity | Yes |
| Plaice | Low intensity and high intensity | Yes |
| Norway lobster | n/a | Yes |
| European hake | No | n/a |
| Dover sole | Low intensity | Yes |

Table 9-3: Nursery grounds within the study area

| Species | Ellis et al. (2012) | Coull et al. (1998) |
|----------------|----------------------------------|---------------------|
| Herring | High intensity and low intensity | No |
| Sandeels | Low intensity | Yes |
| Sprat | n/a | Yes |
| Mackerel | Low intensity | No |
| Haddock | n/a | Yes |
| Cod | High intensity and low intensity | Yes |
| Whiting | High intensity and low intensity | Yes |
| Plaice | Low intensity | Yes |
| Norway lobster | n/a | Yes |
| Spotted ray | Yes | n/a |

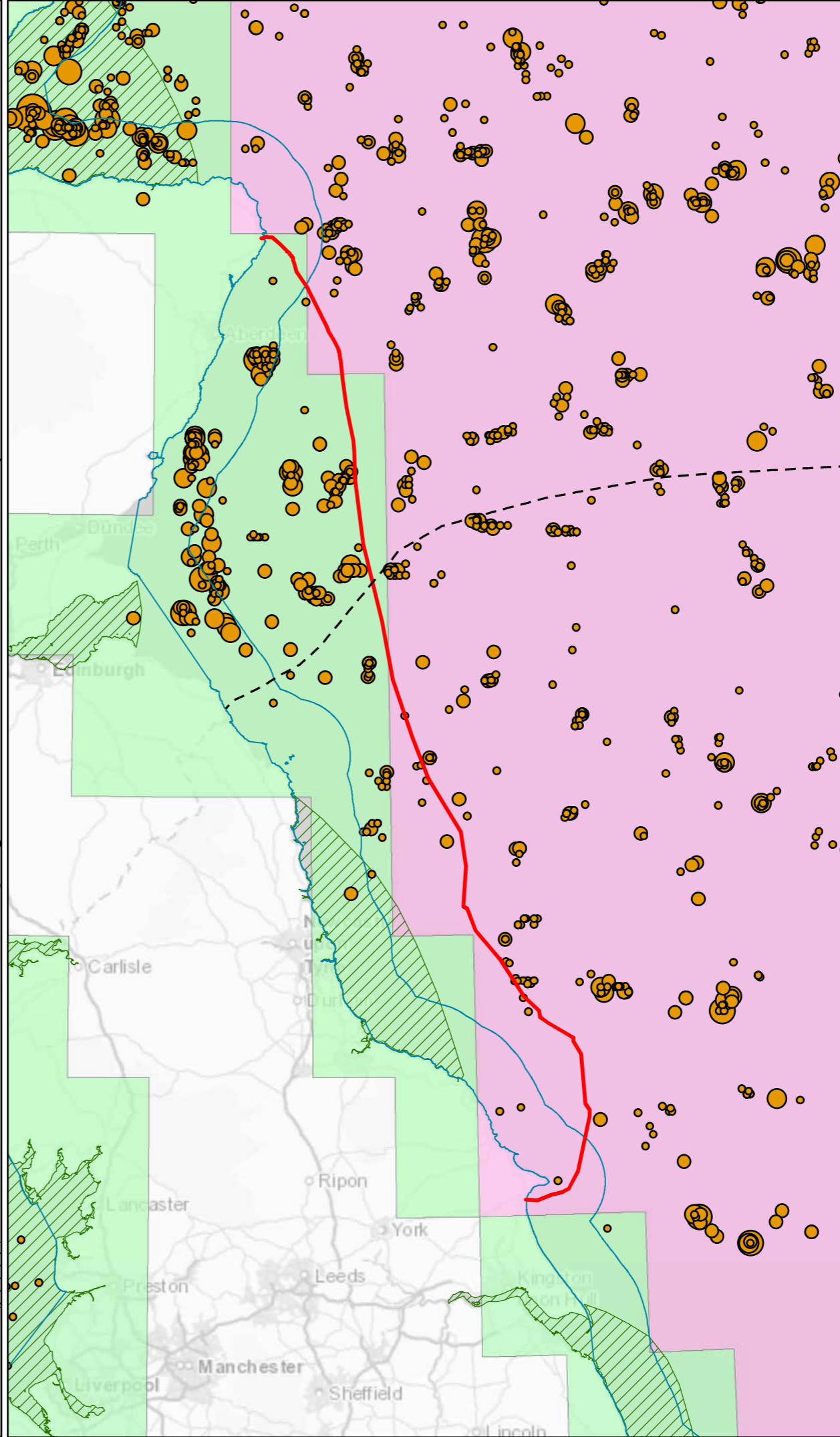
Table 9-4: Spawning times for sensitive demersal spawners in the study area

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



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Coordinate System: WGS1984 Zone 30N



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PROJECT
Eastern Green Link 2

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

Herring Nursery Grounds (2010)

- High Intensity
- Low Intensity

Herring Larvae

- 0 - 254
- 254 - 1140
- 1140 - 3458
- 3458 - 8351
- 8351 - 26914

Herring Maximum Catch Rate

- 0 - 17916
- 17916 - 66105
- 66105 - 176310
- 176310 - 418093
- 418093 - 986520



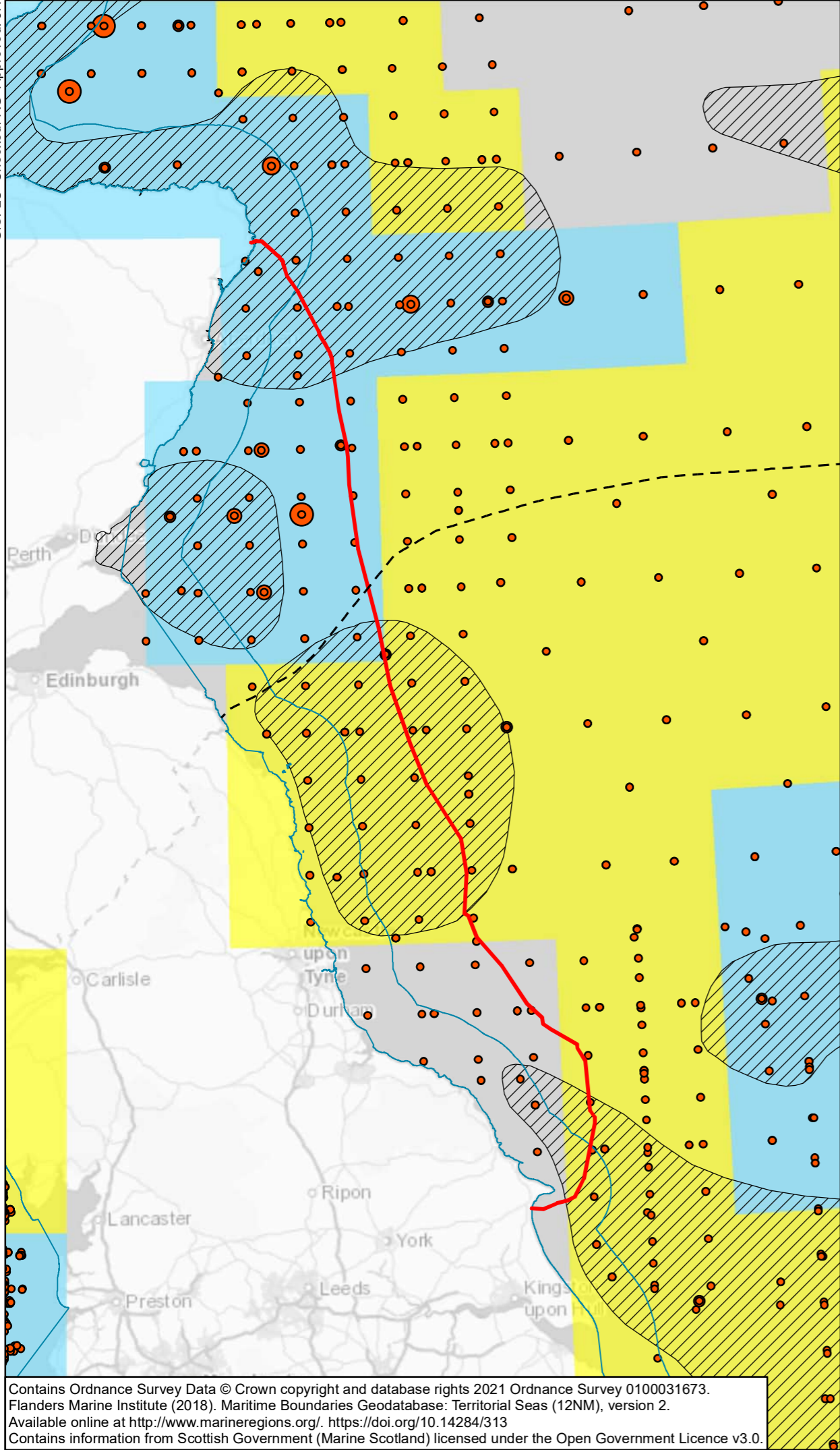
TITLE
**Figure 9-5
Herring Larvae Spawning and Nursery
Grounds**

REFERENCE
SEGL2_M_EAR_9-5_v1_20220525

SHEET NUMBER
1 of 1

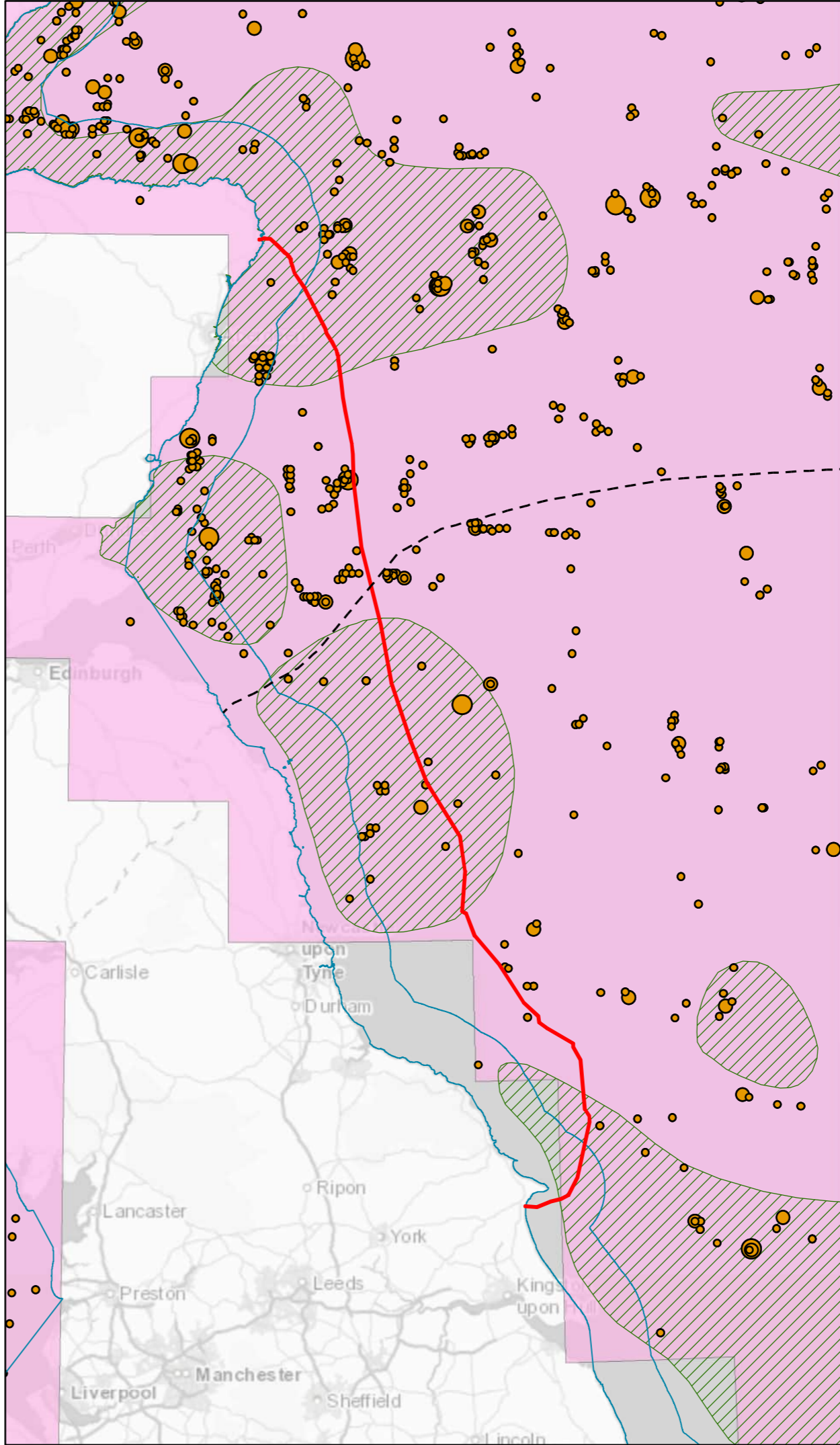
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Coordinate System: WGS1984 Zone 30N



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PROJECT
Eastern Green Link 2

- KEY
- Marine Installation Corridor
 - Scottish Adjacent Waters
 - UK Territorial Sea Limit - 12nm
 - Sandeel Spawning Grounds (1998)
 - Sandeel Nursery Grounds (1998)
 - Sandeel Spawning Grounds (2010)**
 - High Intensity
 - Low Intensity
 - Sandeel Nursery 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



TITLE
**Figure 9-6
Sandeel Larvae, Spawning and Nursery
Grounds**

REFERENCE
SEGL2_M_EAR_9-6_v1_20220525

SHEET NUMBER
1 of 1

DATE
25/05/2022

Scale @ A3 1:2,000,000

9.5.3.1 Herring Spawning Grounds

Herring spawn on the seabed in specific habitat types and their eggs are demersal and remaining on the seabed. They are therefore sensitive to potential seabed impacts. 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 herring stocks in UK waters (Tappin, et al., 2011), with three major populations, each with different spawning times. The major populations associated with the study area are the Buchan population in Scotland and the Banks population off the coast of England in the central North Sea (ICES, 2020a). Spawning on the Buchan grounds takes place between August to September and the Banks grounds from August to October (ICES, 2006a; Ellis, et al., 2012). Tows taken between 2012 and 2016 show a high density of larvae less than 10 mm offshore from the Scottish landfall (Marine Scotland, 2018). After spawning occurs in the Banks and Buchan populations, larvae often drift into nursery areas in the central and southern North Sea (Marine Scotland, 2018).

The location of the Buchan and Banks stocks is evident from the higher abundance of larvae and eggs in these areas, 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 less than 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.

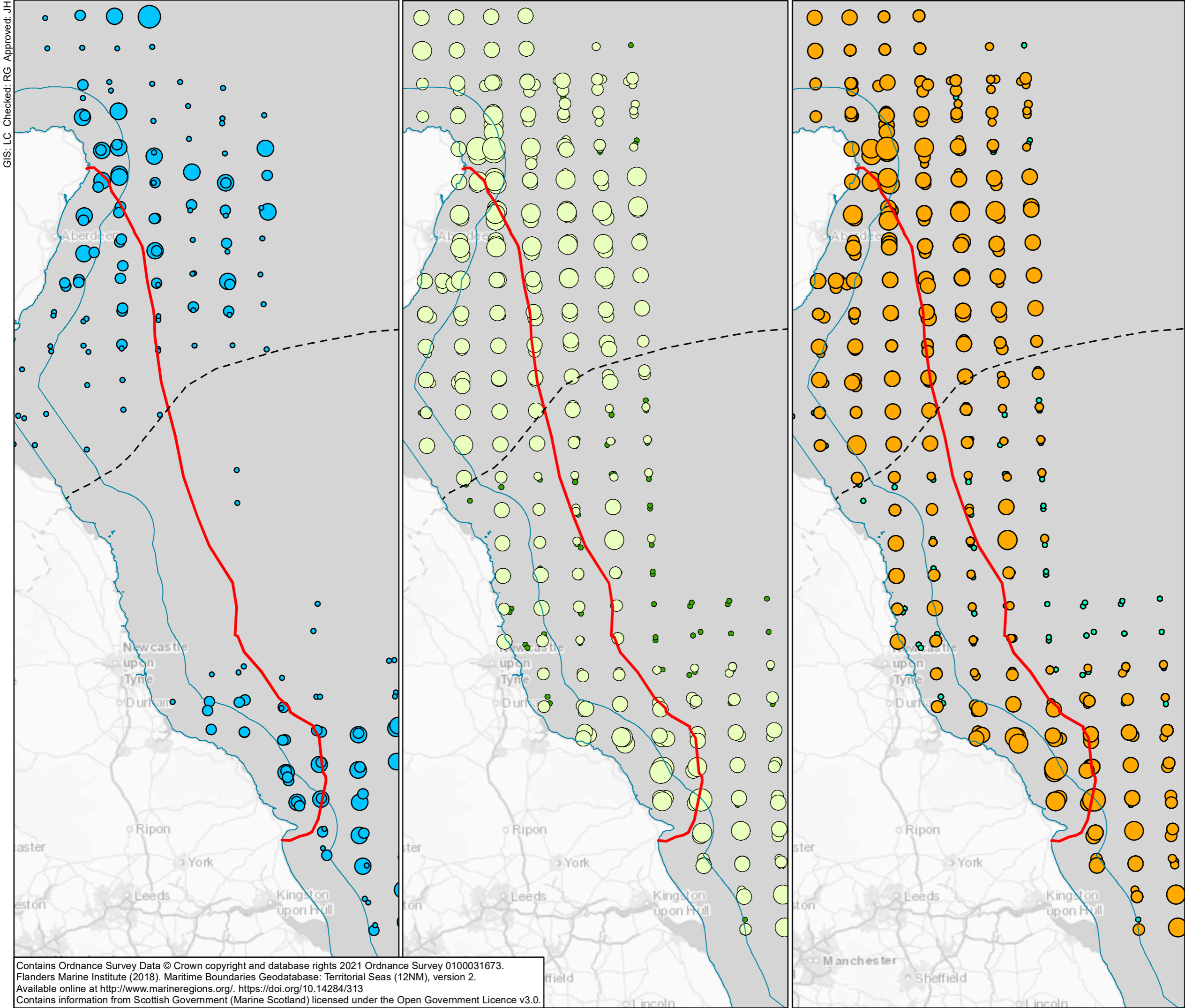
The 2018 to 2020 IHLS hauls within the study area show that a limited number of herring larvae were recorded in close proximity to the Marine Installation Corridor. Where herring were recorded, they were found in smaller numbers compared to sampling further north and south within the North Sea. During the 2010 to 2017 IHLS, egg and larvae were sampled close to the Marine Installation Corridor but were only 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 Installation Corridor 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 were generally dominated by four broad scale sediment types: muddy sand, coarse sediment, rippled sand, and mixed sediments (see Chapter 8: Benthic Ecology).

A total of 63 sampling locations were sampled within the subtidal Marine Installation Corridor during the benthic characterisation survey. The results of the potential herring spawning habitat study are presented in Table 9-5. Along the subtidal Marine Installation Corridor, only two benthic survey stations (Env_52 and EL_HG_B22_03) were found to have the sediment characteristics of preferred herring spawning habitat, with three stations classed as marginal habitat. These stations were located at approaches to Peterhead and Fraisthorpe nearshore areas, with two stations (Env_52 and Env_47) located further offshore. The remaining 58 survey stations had a large proportion of sand present, with very little gravel in most cases and were therefore classed as 'Unsuitable' (NEXTGeosolutions, 2022). This suggests a limited potential for prime herring spawning grounds being present within the Marine Installation Corridor.

Table 9-5: Potential herring spawning habitat in the Study Area

| Station | Kilometre Point | Modified Folk | Habitat Sediment Preference | Habitat Sediment Classification |
|--------------|-----------------|---------------|-----------------------------|---------------------------------|
| EL_HG_B2_01 | 1.4 | Gravelly sand | Suitable | Marginal |
| Env_52 | 12.0 | Gravelly sand | Sub-prime | Preferred |
| Env_47 | 54.3 | Gravelly sand | Suitable | Marginal |
| EL_HG_B22_02 | 433.7 | Gravelly sand | Suitable | Marginal |
| EL_HG_B22_03 | 432.0 | Gravelly sand | Sub-prime | Preferred |



PROJECT
Eastern Green Link 2

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

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 Larval and Egg
Abundance from IHLS surveys**

REFERENCE
SEGL2_M_EAR_9-7_v1_20220525

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Coordinate System: WGS1984 Zone 30N

Scale @ A3 1:2,000,000

9.5.3.2 Sandeel Spawning Grounds

Sandeel spawn on the seabed in specific habitat types and their eggs are demersal and remaining on the seabed. They are therefore sensitive to potential seabed impacts. 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, and 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).

Suitable sandeel habitat has been identified as consisting of substrate which contains a high percentage of medium to coarse sand (particle size of 0.25 mm to 2 mm), with a mud content of less than 10% (particles <63 µm). A gravel component is also considered to be suitable for sandeel habitat. The inclusion of gravel means that using Folk classifications (Folk, 1954) can often over represent the suitability of habitat for sandeel; however, this is used as a precautionary approach. Latto et al. (2013) states that the Folk classification divisions which best describes the preferred habitat for sandeel species in UK waters, are: sand – S; slightly gravelly sand - (g)S; and gravelly sand – gS. The following Folk classification sediment divisions are considered to be marginal habitat (accorded less confidence than the preferred habitat) for sandeel species in UK waters: sandy gravel – sG.

More specific definitions of sandeel preferred grounds using sediment particle size are provided by Greenstreet (2010). This method utilises the sediment fraction percentage by weight of the sample, separating into two distinct fractions: Silt and fine sand (particle sizes >0.25 mm) and medium to coarse sand (particles sizes 0.25 mm to 2.0 mm). Therefore, removing the coarse >2mm fraction that can often over represent the suitability of habitat. The results of the Greenstreet (2010) has been presented below.

The Marine Installation Corridor passes through areas designated as low and high intensity spawning grounds and low intensity nursery grounds for sandeel (Figure 9-6). The Scottish landfall (KP0) at is located within a large and important spawning ground for sandeel, with high concentrations of larvae present.

Of the 63 subtidal sampling locations within the Marine Installation Corridor, only eight were assessed to have prime / sub-prime sandeel spawning habitat (Table 9-6). Of these, six stations were considered to be prime habitat. Most areas of sandeel habitat are located in offshore waters but three were within shallow water depths on the approach to the Scottish landfall (<35 m). The limited number of prime / sub-prime sandeel habitat identified across the Marine Installation Corridor suggests a limited potential for prime sandeel spawning grounds being present.

Table 9-6: Sampling stations in Marine Installation Corridor with prime and sub-prime sandeel spawning habitat (Greenstreet, et al., 2010)

| Station | KP | Folk | Habitat preference (Greenstreet, 2010) |
|-------------|-------|------------------------|--|
| EL_HG_B1_01 | 0.5 | Sand | Prime |
| EL_HG_B2_01 | 1.4 | Gravelly Sand | Sub-prime |
| EL_HG_B3_01 | 2.5 | Sand | Prime |
| Env_52 | 12.0 | Gravelly Sand | Prime |
| Env_47 | 54.3 | Gravelly Sand | Sub-prime |
| Env_46 | 61.2 | Slightly Gravelly Sand | Prime |
| Env_45 | 69 | Slightly Gravelly Sand | Prime |
| Env_19 | 273.8 | Sand | Prime |

9.5.4 Commercial Fisheries

Species of commercial importance vary along the length of the Marine Installation Corridor depending on location. Details 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 consideration in the appraisal along with their associated value have been determined based upon potential activity / receptor interactions (Table 9-7). For the appraisal, those species considered to have the greatest sensitivity to a particular effect have been assessed at the species level, whereas those species with lower sensitivity have been assessed either at a high taxonomic level (e.g., elasmobranchs) or by functional group (e.g., demersal, pelagic and migratory) as appropriate.

Table 9-7: Fish and shellfish ecology receptors considered and their assigned value

| Receptor group | Species | Rationale | Value |
|-----------------------|---|--|----------------|
| Migratory species | European eel, Atlantic salmon, sea and river lamprey, and brown (sea) trout | <ul style="list-style-type: none"> 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 Electromagnetic Field (EMF); and Some species valuable economically (commercial species). | High |
| Pelagic fish species | Herring | <ul style="list-style-type: none"> National conservation importance; Presence of spawning and nursery grounds; Sensitive to habitat disturbance and underwater sound; and Commercially and ecologically (prey species) important. | Medium |
| | European sprat | <ul style="list-style-type: none"> Presence of spawning and nursery grounds; Sensitive to underwater sound ; and Commercially and ecologically (prey species) important. | Low |
| | Mackerel | <ul style="list-style-type: none"> Low intensity nursery grounds; and Commercially and ecologically (prey species) important. | Medium |
| Demersal fish species | Sandeel | <ul style="list-style-type: none"> National conservation importance (lesser sandeel a PMF); High/Low intensity spawning and nursery areas; Sensitive to increased suspended sediment concentration (SSC), smothering and habitat disturbance and/or loss; and Commercially and ecologically (prey species) important). | Medium |
| | Atlantic cod, haddock, whiting, European plaice, Dover sole | <ul style="list-style-type: none"> International and/or national conservation importance; Presence of spawning and nursery grounds; Sensitive to increased SSC and underwater sound; and Valuable economically (commercial species). | Low/ Medium |

| Receptor group | Species | Rationale | Value |
|--|---------------|--|--------|
| Elasmobranchs | All | <ul style="list-style-type: none"> Low intensity nursery ground for thornback ray and spurdog overlap with the Marine Installation Corridor; Some species are demersal and therefore considered sensitive to increased turbidity; Thornback ray is a demersal spawner and therefore considered sensitive to smothering and habitat disturbance and/or loss; Sensitive to EMF effects; Some species of national and international conservation importance, e.g., the basking shark is listed under several conventions including the Berne Convention, Wildlife and Countryside Act and Annex V of the OSPAR Convention; and Some species valuable economically (commercial species). | Medium |
| | Basking shark | Wildlife and Countryside Act 1981. | High |
| Shellfish of commercial and/or conservation importance | | <ul style="list-style-type: none"> There are important spawning and nursery grounds for Norway lobster <i>Nephrops norvegicus</i> which overlap with the Marine Installation Corridor; Some species and life stages are epibenthic or demersal and therefore sensitive to increased turbidity, smothering and EMF effects; and Norway lobster, European lobster, crabs and scallops valuable economically (commercial species). | Medium |
| General fish and shellfish communities | | <ul style="list-style-type: none"> Common, ubiquitous and of low commercial importance; Some species and life stages are demersal and therefore considered sensitive to increased turbidity and smothering; and Considered to have a high tolerance to change given their distribution and abundance. | Low |

9.6 Assessment of Potential Impacts

This section describes the potential impacts of the Marine Scheme on the fish and shellfish receptors during Installation, Operation and Maintenance, 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 and is based on a separate cable lay configuration. The following pathways detailed in Table 9-8 have been scoped into the appraisal.

Table 9-8: Summary of impacts pathways and Zols

| Potential impact | Zone of influence (Zol) |
|--|---|
| Landfall preparation and installation | |
| HDD operations and cable pull in. | Up to 0.01 km ² at each landfall |
| Vessel anchoring and use of spud legs | Up to 0.0003 km ² at each landfall |
| Route preparation and cable installation | |
| Temporary physical disturbance to fish and shellfish habitat– e.g., spawning grounds and animals on the seabed | 106.0 km of boulder clearance plough (25 m swathe) and 340 km of mechanical trenching (15 m swathe). Giving a total footprint of 7.6 km ² per cable, so 15.2 km ² for separate lay. |
| Permanent loss of fish and shellfish habitat due to placement of hard substrates on the seabed | Remedial and planned rock berm up to 146 km width a maximum of 7 m per cable totaling 1 km ² per cable or 2 km ² for separate lay. |

| Potential impact | Zone of influence (Zoi) |
|---|---|
| | <p>Crossings</p> <p>6 x pipeline crossings with an approximate footprint of 4,750 m² each</p> <p>18 x cable crossings with an approximate footprint of at 4,100 m² each</p> <p>Totaling 0.1 km² per cable or 0.2 km² if separate lay.</p> |
| | <p>Rock protection at landfalls</p> <p>0.01 km² per landfall, 0.02 km² total (same for separate lay/bundled cables).</p> |
| Temporary increase in SSC sediment deposition leading to contaminant mobilisation, turbidity and smothering effects on fish and shellfish | Footprint of the proposed works plus 1.5 km buffer; based on professional judgement and consideration of worst-case for fine particulates (Chapter 7: Physical Environment). |
| Underwater sound effects on fish and shellfish | Disturbance from 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 1.5 km buffer; based on professional judgement and consideration of worst-case for fine particulates (Chapter 7: Physical Environment). |
| Cable operation and maintenance | |
| Disturbance to fish and shellfish due to subsea cable thermal emissions | ~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 | See route preparation and cable installation, noting that durations and extents of activities will be significantly reduced. |
| Decommissioning | |
| Potential effects the same as route preparation and cable installation | Anticipated to be analogous to route preparation and cable installation. |

The unintentional or inadvertent loss of drilling fluids during drilling operations from the borehole to the ground surface from points other than its entry and exit points (known as frac-out) has not been considered in the appraisal as drilling fluid parameters such as circulation pressure, gel strength, mud weight, and viscosity will be continuously monitored and regular inspections along the drill path during pilot hole drilling conducted.

9.6.1 Embedded Mitigation

The following embedded mitigation have been incorporated into the Marine Scheme (as described fully in Chapter 2: Project Description), to avoid and/or minimise impacts to fish and shellfish ecology receptors (Table 9-9).

Table 9-9: Fish and shellfish embedded mitigation

| Activity / Issue | Embedded mitigation commitment |
|-----------------------------------|---|
| All phases | |
| Ecological mitigation | The Basking Shark Code of Conduct (available from: https://www.sharktrust.org/Handlers/Download.ashx?IDMF=6137b1a1-8518-4327-9922-7b280acb8336). |
| Marine Scheme vessel requirements | <ul style="list-style-type: none"> 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 vessels will be in compliance with the International Convention for the Prevention of Pollution from Ships (MARPOL) regulations and will therefore be equipped with waste |

| Activity / Issue | Embedded mitigation commitment |
|---|--|
| | <p>disposal facilities onboard. The discharging of contaminants is not permitted within 12 nm from the coast to preserve bathing waters;</p> <ul style="list-style-type: none"> Control measures and shipboard oil pollution emergency plans (SOPEP) will be in place and adhered to under MARPOL Annex I requirements for all vessels; Ballast water discharges from all vessels will be managed under International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 (BWM Convention); All vessels will adhere to the IMO guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species (Biofouling Guidelines) (resolution MEPC.207(62); and Where possible, vessels will operate with dynamic positioning which will minimise anchor disturbance on the seabed. |
| Installation Phase | |
| Route selection | <p>The Marine Installation Corridor has been selected to optimise the balance of environmental, technical, commercial and financial considerations, such as avoiding designated sites, known archaeological sites, recreational activities, key fishing grounds and third-party infrastructure as far as possible.</p> |
| Micro-routeing / detailed design post-consent | <p>Detailed route development and micro-routeing will be undertaken within the Marine Installation Corridor, informed by pre-installation evaluation of site-specific survey data to avoid or minimise localised engineering and environmental constraints. This will include minimising the footprint as much as possible;</p> <p>Navigational features such as charted or known anchorages, maintained channel depths and prohibited regions will be avoided;</p> <p>Changes to the sedimentary and metocean environments will be minimised by careful route selection and the use of appropriate burial techniques and cable protection methods such as fall pipes for the laying of rock placement;</p> <p>Cable configuration will be optimised to minimise EMF during detailed design;</p> <p>Reduction in charted water depth to LAT will be limited to less than 5% where possible; and</p> <p>A Cable Burial and Protection Plan will be submitted to include detailed micro-routeing, trenching methods and external protection measures for the final design of the Marine Scheme prior to commencement of Installation Phase activities.</p> |
| Construction Environmental Management Plan (CEMP) | <p>Prior to cable installation activities commencing, a CEMP, including an Emergency Spill Response Plan (ESRP), Waste Management Plan, Marine Mammal Management Plan, Marine Non-Native Species (MNNS) Plan, Fisheries Liaison and Co-existence Plan⁷ will be developed and agreed with relevant stakeholders in accordance with the coastal and marine environment site guide; and</p> <p>A commitment will be included with the CEMP and implemented via the SMWWC, to ensure that transiting vessels move at low speeds allowing any rafts of birds to disperse naturally well in advance of an approaching vessel. This will minimise the energy expended and avoid unnecessary flushing, which is especially important during the immediate post breeding dispersal periods of auks from early July to mid-September.</p> |
| Commercial fisheries mitigation | <p>A Fisheries Liaison Officer (FLO) will be appointed for the Installation Phase. Good practice guidance on the approach to fisheries liaison and mitigation (e.g., FLOWW, 2014; 2015 as relevant to cable projects) shall be implemented as far as possible; and</p> <p>A procedure for the claim of loss of/or damage to fishing gear will be developed.</p> |
| Landfall installation | <p>Horizontal Directional Drilling (HDD) will be used at both landfalls for the installation of the cables in the transition zone between the Onshore Schemes and the Marine Scheme which avoids any works in the intertidal environment; and</p> <p>This will keep sediment disturbance to a minimum, minimising the use of cable protection measures inshore of the 11 m depth contour at Sandford Bay and the 5 m depth contour at Fraisthorpe Sands. This avoids direct impacts on sensitive coastal and intertidal habitats and features.</p> |
| Drilling fluids | <p>Drilling fluids for HDD operations will be biologically inert and 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);</p> <p>During drilling, drilling fluids will be recycled, treated, and reused as far as possible, and any waste drilling fluid will be transported offsite for treatment and disposal; and</p> |

⁷ Note that this will be a single document that will perform the role of other fisheries liaison plans, for instance, a Fisheries Management and Mitigation Strategy.

| Activity / Issue | Embedded mitigation commitment |
|------------------|---|
| | Losses of drilling fluids are unavoidable; however they will be minimised insofar as practicable through the implementation of industry best practice for example, clearing runs or reducing the volume of drilling fluids in the borehole prior to breakout to the marine environment. |
| Cable protection | Cables will be trenched to a minimum depth of lowering of approximately 0.6 m, with a target depth of lowering of approximately 1.5 m; and The use of external protection will be limited to areas where cables cannot be trenched to the minimum depth of lowering, at crossings with third-party infrastructure and in some limited areas at both landfalls (as required). |
| Rock placement | Rock utilised in berms will be igneous, clean with low fines; and A vessel able to undertake a targeted placement method will be used, such as one fitted with a flexible fall pipe. |

9.6.2 Installation Phase

9.6.2.1 Temporary physical disturbance to fish and shellfish habitat

There are a number of route preparation and cable installation activities that will temporarily disturb seabed habitats, resulting in short term physical disturbance to, and temporary loss of, seabed habitats and in some instances physical damage of less mobile receptors (e.g., eggs, larvae or 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 less tolerant of such disturbance which may also result in physical damage in some instances.

Migratory fish (e.g., salmon, sea trout, sea and river lamprey and European eel) are not considered to have functional associations with seabed habitats due to their life history strategies and transient presence within the Marine Installation Corridor, therefore potential effects of habitat disturbance and/or loss are not considered for this receptor group.

Pelagic spawners known to be present within the study area include sprat, mackerel, cod, whiting and plaice. These pelagic spawners are considered to have low sensitivity to the temporary disturbance of the cable installation activities as recruitment of these species would be largely unaffected by direct disturbance of the seabed. As no distinguishable change from baseline conditions is expected for these pelagic receptors, they are not considered further in relation to this effect.

Installation Phase activities at the landfall location, which have the potential to cause temporary disturbance to and/or loss of benthic habitats and species are presented in Chapter 2: Project Description. The maximum footprint of temporary disturbance is 0.01 km² at each landfall, accounting for exit pit excavation, pre-trenching, and anchoring (Table 9-8).

Temporary disturbance as a result of Installation Phase activities will occur along the entire Marine Installation Corridor (436 km in length). The dominant habitat types along the Marine Installation Corridor were muddy sand, coarse sediment, rippled sand, and mixed sediments. Sand was the most frequently occurring habitat along the proposed route, occurring intermittently between KP56.3 to KP390.4 in variable water depths ranging between 57 m and 80 m.

Boulder clearance ploughs would result in the widest disturbance swathe, of up to 25 m per cable trench. It is anticipated that this method may be employed over a total of 106.0 km of the Marine Installation Corridor for each cable. In addition to this, 340 km of the Marine Installation Corridor may be subject to mechanical trenching (15 m swathe) giving a total footprint of 7.6 km² per cable, and 15.2 km² for separate lay (Table 9-8). This represents a worst-case estimate, assuming equipment with the largest footprint will be used throughout the Installation Phase.

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 species such as sandeel and life stages such as eggs and, to a lesser extent larva of some species which exhibit high site fidelity, is possible.

Herring and sandeel are likely to be particularly 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.

Herring

Along the subtidal Marine Installation Corridor, only two benthic survey stations at KP12 and KP432 identified the sediment characteristics of preferred sub-prime herring spawning habitat (NEXTGeosolutions, 2022).

The spatial extent of temporary disturbance to herring grounds is considered low in the context of alternative available habitat surrounding the Marine Scheme and the wider North Sea. 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 (Section 9.5.3.1). 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 Installation Corridor passes through areas designated by Ellis et al. (2012) as high intensity spawning grounds between KP0.7 and KP179.9 with almost the entirety of the route within an area considered in the low intensity nursery grounds for the species (Figure 9-6). Results of the sediment PSA along the Marine Installation Corridor assessed using the methodology outlined in Greenstreet (2010) indicated that out of the 63 sampling locations within the subtidal survey areas, only eight stations sampled were found to have prime / sub-prime sandeel spawning habitat. Of these, six stations were considered to be prime habitat and located at KP0.5, KP2.5, KP12, KP61.2, KP69 and KP 273.8. Most areas of sandeel habitat are located in offshore waters but also within shallow water depths of the Scottish landfall (<35 m) (NEXTGeosolutions, 2022).

The spatial extent of temporary disturbance to sandeel grounds is considered low 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 will 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 short to medium term (one to five 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

Whilst other fish may be present, and some temporary avoidance of the affected area around the installation works areas is expected, disturbance will be temporary, 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 negligible magnitude. Combined with the low to high value and medium sensitivity of all remaining fish receptors which may be affected by the landfall installation activities, the effect is predicted to be **negligible** and therefore **not significant**.

Shellfish

There is potential for shellfish, such as crabs and lobsters to be present at the shallow HDD breakout locations. However, these locations are not considered to be particularly important grounds for this species, with no scallop dredging known to occur in these areas (see Chapter 14: Commercial Fisheries).

Shellfish species including European lobster, crab, scallops and *Nephrops* 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 are able to disperse 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. Furthermore, observations of species such as *Nephrops* during the benthic characterisation survey confirmed a lack of suitable habitat for this species (NEXTGeosolutions, 2022). 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 Temporary increase in SSC and subsequent sediment deposition leading to contaminant mobilisation, turbidity and smothering effects on fish and shellfish

Seabed disturbance from pre-installation and installation activities have the potential to increase 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.

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.

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 from Installation Phase activities, is expected to be approximately 247 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 1.5 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 between KP210 and KP241, and that dispersion processes will also act to dilute the concentration of silt carried in suspension, elevated concentration levels at 1.5 km from the source will be negligible. It is considered that there will be no significant elevated concentration levels beyond the dispersal range calculated for fine sand which corresponds to a maximum 1.5 km from the point of mobilisation within the Marine Installation Corridor. Consequently, any impact from SSC is expected to be small and highly localised.

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 will also be rapidly diluted, so that the SSC will be low and the deposition thickness on the seabed, where the sediment will settle, will be negligible.

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). 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

Herring larvae and eggs have been identified as very tolerant to high levels of SSC and deposition (Kjørboe, Frantsen, Jensen, & Sørensen, 1981). In addition to this, as identified in Section 9.5.3.1, a lack of suitable herring habitat was also identified across the Marine Installation Corridor (NEXTGeosolutions, 2022).

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) where mobilised sediments are expected to settle rapidly, limiting dispersion. 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, the survey results indicate that suitable sand eel habitat within the Marine Installation Corridor is localised, sporadic and mostly located near the Scottish landfall. 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 Atlantic salmon, brown trout, sea and river lamprey (Section 9.5.2.1). Salmonids can be sensitive to increased SSC through reduced vision of prey (Abbotsford, 2021).

The increase in SSC, turbidity and deposition associated with cable installation has the potential to be a barrier to migration between marine and freshwater environments. Most of these species identified above have been shown to spend the majority of their time in the upper reaches of the water column, so unlikely to encounter mobilised sediment in bottom 5 m of the water column (Section 9.5.2.1). Such species are considered to be of low sensitivity, but of high value. Due to the short-term nature of any increase in SSC occurring during installation of the cable, the magnitude of impacts of increased SSC is predicted to be negligible. Therefore, the effect to 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, 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 and shellfish beds 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**.

9.6.2.3 Reduction in marine water quality

Release of HDD Drilling Fluids

The discharge of drilling fluids from HDD works in the shallow subtidal zone of the marine environment (Chapter 2: Project Description) has the potential to alter water quality and affect fish and shellfish at each of the landfall locations.

Drilling fluids will be selected from the OSPAR List of Substances/Preparations Used and Discharged Offshore (2021) which are Considered to Pose Little or No Risk to the Environment (PLONOR). For example, the most widely used fluid, bentonite, consists predominately of clay minerals and is biologically inert (OSPAR, 2019). A review by Aslan et al. (2019) found no evidence of a lethal response or reduced survival in bivalve molluscs or crustaceans, in realistic discharge conditions in an open marine environment.

Embedded mitigation measures will be implemented to minimise the release of drilling fluids 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 release of drilling fluids and drilled solids at HDD breakout (Chapter 2: Project Description) will reduce water quality locally for a period of time during and immediately after release. Any drilled solids released are predicted to settle rapidly in the vicinity of the breakout. Constituents of the drilling fluids, including silt-clay sized particles such as bentonite have a maximum theoretical range of 4.3 km, however, dilution processes over this distance will result in no detectable changes from the baseline beyond 1.5 km, therefore the Zol is considered to be 1.5 km.

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. 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 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**.

Mobilisation of contaminants

Sediment contaminants, such as heavy metals and PAHs, present in concentrations above the thresholds discussed above 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). Details of contaminants present across the Marine Installation Corridor are described in Chapter 7: Physical Environment.

Contaminants will be associated with finer material such as silts and clays, which are limited within the mostly sandier sediments within the Marine Installation Corridor. Sediment dispersal calculations for fine silts and clays has been calculated as up to 4.3 km from the source of disturbance, however, dilution processes over this distance will result in no detectable changes from the baseline beyond 1.5 km, therefore the ZOI is considered to be 1.5 km (see Chapter 7: Physical Environment). The 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 and shellfish to temporary and localised changes in water quality and as a result, fish and shellfish will have a tolerance to moderate changes in the surrounding water quality. The magnitude of impact will therefore 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**.

Discharges, leaks and spills from vessels, including loss of oils

The accidental release of pollutants (e.g., oil, fuels, lubricants, chemicals) and planned release of wastewater could occur from any of the vessels associated with the Installation Phase activities and any support vessels present and has the potential to alter water quality. Vessels involved in Installation Phase activities 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, with consequences for fish and shellfish receptors.

To ensure the risk of accidental spills is as low as reasonably practicable, the project will adhere to relevant guidance (e.g., Pollution Prevention Guidance). A Construction Environmental Management Plan (CEMP) including an Emergency Spill Response Plan and Waste Management Plan will be implemented during the installation phase of the project to minimise releases (Chapter 2: Project Description). Appropriate Health, Safety, and Environment (HSE) procedures (identified in the CEMP) will also be implemented, with strict weather and personnel limits to reduce any risk of accidental spillage. Furthermore, preparedness and swift response is essential for effective spill management and as such, response plans will be in place should an incident occur. Control measures and Shipboard Oil Pollution Emergency Plans (SOPEP) will be in place and adhered to under MARPOL Annex I requirements for all vessels. Planned effluent dischargers will be compliant with MARPOL Annex IV 'Prevention of Pollution from Ships' standards.

All effluent will be discharged in accordance with the applicable MARPOL Annex IV 'Prevention of Pollution from Ships' standards, 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 likelihood of impact to all fish and shellfish receptors from accidental leaks and spills from vessels and equipment is predicted to be unlikely and potential effect is negligible. Therefore, the overall risk of the potential impact occurring is considered to be **negligible**, which is **not significant**.

9.6.2.4 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 root-mean-square (rms) 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 9-10). Where a range of sound source levels was found in the literature a reasonable but realistic worst-case level has been assumed.

Table 9-10: Characteristics of underwater sound sources generated by the Marine Scheme construction phase

| Survey or cable installation activity | Operating Frequency (kHz) | Sound Pressure Level# (dB re 1µPa@1m) | Sound Source Data Reference | Screened into appraisal? |
|--|---------------------------|---------------------------------------|--|--------------------------|
| Swathe or multi-beam echo sounder (MBES) | 170 - 450 | 221 235 (peak) | Genesis Oil and Gas Consultants, 2011 | × |
| Side scan sonar (SSS) (e.g., EdgeTech 4200 Series) | 300 - 600 | 210 - 226 | Genesis (2011) and equipment specification sheet | × |
| Sub-bottom profiling (SBP) (e.g., Innomar SES-2000, Edgetech Chirp & Applied Acoustics 201 boomer) | 0.5 – 12 | 238 (peak) | Equipment specification sheets | ✓ |
| USBL (e.g., Kongsberg HiPAP 502) | 21 - 31 | 207 (peak) | Equipment specification sheet | × |
| Cable installation (e.g., jet trenching, mechanical trenching) | 1 - 15 | 178 | (Nedwell, Langworthy, & Howell, 2003); Nedwell et al., (2008); Hale (2018) | × |
| Rock placement. | n/a | ~172 | Vessel Rollingstone (Orsted, 2019) | × |
| HDD (e.g., break-out) | n/a | 129.5 | Nedwell et al. (2012) | × |
| Cable lay vessel (~140 m in length operating with DP) | 0.005 - 3.2 | 180 - 197 | Ross (1993) AT&T (2008) | × |
| Project support vessels including medium (50 m to 100 m) and small (<50) boats | Low to high frequency | 160 – 180 | Genesis (2011) Richardson <i>et al.</i> (1995) OSPAR commission (2009) | × |

Sound Pressure Level metrics in rms unless indicated.

A number of the above sound sources can be scoped out of the appraisal on the basis of their operating frequencies, source levels or context with regard to baseline noise levels:

- **MBES** – MBES operates at high frequencies that fall outside the hearing range of fish, thus it is not detectable and does not pose any risk of injury or disturbance.
- **SSS** – 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 assessment;
- **USBL** - Operates at high frequency (>1 kHz), producing sound that is outside the range of hearing of all fish and so this activity can be scoped out of the assessment;
- **Rock placement** – in four studies of rock placement, it was possible to faintly hear rocks falling through a fall tube to the seabed but the underwater sound from the operations was dominated by the sound of the vessel (Nedwell, Brooker, & Barham, 2012). A SPL_{rms} of 172 dB re. 1µPa was measured during the operation of the fall pipe vessel MV Rollingstone (Orsted, 2019). Thus, the

SPLs associated with this activity are not of a magnitude which poses a risk of disturbance or injury to fish or shellfish, and is screened out of the assessment;

- **HDD** – sound measurements made during a generic HDD operation, in shallow riverine water recorded a maximum unweighted Sound Pressure Level (SPL_{RMS}), of 129.5 dB re. 1 μ Pa (Nedwell, Brooker, & Barham, 2012). The Marine Scheme HDD breakout points will also be in shallow water where sound rapidly attenuates. Thus, the SPLs associated with this activity are not of a magnitude which poses a risk of disturbance or injury to fish or shellfish, and is screened out of the assessment;
- **Ploughing, jetting and trenching cable installation** - sound measurements made during a generic cable trenching recorded a maximum unweighted Sound Pressure Level (SPL_{RMS}), of 178 dB re. 1 μ Pa (Nedwell et al., 2003, and EGS Survey Group, 2018). Thus, underwater sound generated by trenching operations will be very low, and does not pose a risk of injury or significant disturbance to fish; and
- **Vessel movements** – there will be a limited number of vessels associated with the installation works. In comparison to background vessel activity in the North Sea (Chapter 13: Shipping and Navigation) the additional vessels operating to install the Marine Scheme is not considered to be a deviation from baseline conditions. As such, sound emissions from the installation vessels will not constitute a substantive change from the baseline soundscape including existing vessel sound, and hence there is not potential for adverse effects on fish. Thus, underwater sounds resulting from vessel movements are screened out of the assessment.

Thus, the appraisal addresses the remaining sound sources: impulsive sound from the operation of the SBP during the pre-installation geophysical survey and the installation works.

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, although one sub member of the clupeiform family, the Alosinae or shads are capable of detecting significantly higher frequencies, but these are not relevant receptors in the context of this project (Mann, Higgs, Tavolga, Souza, & Popper, 2001).

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 assessing 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. These species are susceptible to barotrauma and detect sound pressure as well as particle motion and include 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. 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; and
- **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 lamprey, flatfish and elasmobranchs.

There are fish species from all hearing groups found within the Marine Scheme Study Area. These include herring which have 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 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, Nedwell, & Workman, 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;
- **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.

Use of sub bottom profiler during survey and installation activities

Sub bottom profilers (SBP) operate at frequencies <1 kHz and so are within the hearing range of fish. The Popper et al (2014) threshold criteria for mid-frequency sonar (1 kHz to 10 kHz) can be used as a proxy for the SBP, although it should be noted that this is highly conservative. The criteria for injury, which includes mortality and potential mortal injury, recoverable injury and TTS for medium to high hearing sensitivity fish is a SPL_{rms} of 210 dB re. 1μPa, and for high hearing sensitivity fish only there is a behavioural SPL_{rms} threshold of 209 dB re. 1μPa. Also, it should be noted that these thresholds were the upper limit of the test, with actual thresholds likely to be significantly higher. In particular, no effect on the ear or non-auditory tissues was observed when the maximum received sound pressure levels were at 210 dB re 1 μPa SPL_{rms} and injury, if it occurs, is thought to begin at higher sound levels than tested to date (Halvorsen & Zeddies, 2011). The thresholds are therefore considered to be very conservative.

A standard geometric spreading calculation⁸, using a wave mode coefficient⁹ of 15 was used to determine the propagation of underwater sound from the SBP. The distance at which the injury and behavioural disturbance threshold is met is 46 m and 54 m respectively. From these calculations, injury and disturbance ranges are extremely limited where fish more likely to be disturbed by the presence of oncoming vessels and are expected to have moved away before entering the potential injury zone.

There may be some minor avoidance behaviour, but the vessels will be continuously moving and so the impact zone will also be transitory. As soon as the vessel has moved away normal 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**.

Shellfish

There has been 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

⁸ The standard formula used for estimating the transmission loss from underwater sound sources is $TL = A \log(r) + B r + C$ Where: TL = the transmission loss at a distance r from the source; A = the wave mode coefficient; B = an attenuation factor that is dependent on water depth and sea bottom conditions; C = a fixed attenuation due to acoustic screening. In open water C = 0.

⁹ Note that use of cylindrical spreading (A=10) is generally suited to shallow-to-mid water depths, and spherical spreading (A=20) is generally applicable to deep water depths. Cylindrical spreading (A=10) is more conservative (i.e. further sound propagation distances for a given source level) but is likely to be overly conservative for this assessment. Richardson (1995) suggests using A=15 for underwater transmission in shallow water conditions where the depth is greater than 5 times the wavelength. For low frequency, longer wavelength sound this is going to tend toward A=20. For high frequency, shorter wavelength sound this is going to tend toward A=10.

component (Popper, Salmon, & Horsch, 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.

A low density of *Nephrops* was observed across the Marine Installation during the benthic characterisation survey (NEXTGeosolutions, 2022). Sound from cable lay activities is therefore unlikely to cause significant disturbance to this species (see Chapter 14: Commercial Fisheries). 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).

Considering 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, and medium sensitivity the effect of the impact is predicted to be **negligible** and therefore **not significant**.

9.6.2.5 Vessel collision risk

Although records of collisions with fish are scarce, they are not unheard of. The main fish species that could be susceptible to collision is 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 (Section 9.5.2.4).

Embedded mitigation to reduce the significance of effect on basking sharks include The Scottish Marine Wildlife Watching Code (SMWWC) and The Basking Shark Code of Conduct. The presence of cable lay and support vessels is not considered to increase vessel traffic considerably above baseline levels, given the existing levels of vessel activity as detailed in Chapter 13: Shipping and Navigation. Given the confines of the Marine Installation Corridor, vessel presence would also be spatially limited. Installation 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 unlikely, the effect is predicted to be negligible and therefore the overall risk is considered to be **negligible** which is **not significant**.

9.6.3 Operation and Maintenance Phase

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

As part of the Installation Phase activities, there is a requirement to use rock protection and/or concrete mattresses within the subtidal (including nearshore and offshore zones) Marine Installation Corridor to protect the HDD exits, third-party asset crossings, cable joints, and in locations where the minimum depth of lowering cannot be achieved through trenching (Chapter 2: Project Description). The footprints of rock protection across the Marine Installation Corridor (Table 9-8) are as follows:

- **Planned/remedial rock berms** – 1 km² per cable or 2 km² if separate lay;
- **Crossings** - 0.1 km² per cable or 0.2 km² if separate lay; and
- **Landfall protection** - 0.01 km² per landfall, 0.2 km² in total.

Rock protection will also be required at locations to protect the cable where the target depth of lowering cannot be achieved through trenching (see Chapter 2: Project Description). The actual amount of rock

placement will vary depending on seabed conditions and not all of the identified areas will need full coverage by rock. Categories 1, 2, 3, 4 and 5 (3%, 25%, 50%, 75% and 100% length of each zone of the installation corridor requiring rock placement respectively) have been used to estimate the anticipated levels of rock protection required within each section of the Marine Installation Corridor, based on worst case assumptions of trenching success taking account of seabed conditions and available trenching tools (Chapter 2: Project Description). This results in a worst-case estimate of approximately 138 km of rock berm being required to protect each cable.

The total length of rock berm anticipated to be required for protection at crossings, cable joints, and the HDD exit pits is approximately 16.6 km per cable. As such the total length of rock berm per cable is approximately 154.3 km, equating to 308.6 km if the cables are laid separately.

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.

There are several demersal species for which the cables will cross within high and low intensity nursery and spawning grounds. However, most of the demersal species known, or likely, to be present in the 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 are 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

Herring nursery grounds identified by Coull et al. (1998) and Ellis et al. (2012) overlap with areas of proposed rock protection. Spawning grounds (undefined intensity) (Coull et al., 1998) are also located within areas of proposed rock replacement for areas along the Marine Installation Corridor requiring additional cable protection. However, sediment PSA for these locations shows that there were no stations within these areas of rock placement which represented 'prime' habitat for herring spawning (NEXTGeosolutions, 2022).

The area requiring rock protection (excluding contingency) that falls within spawning grounds (undefined intensity) is 0.87 km² with areas in high intensity herring nursery grounds 0.24 km². The area requiring rock protection at crossing locations that falls within spawning grounds (undefined intensity) is 0.2 km² with areas in high intensity herring nursery grounds 0.04 km².

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. 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 within close proximity of these areas. 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

High intensity spawning grounds and low intensity nursery grounds (Ellis et al., 2012) for sandeel are known to occur along the Marine Installation Corridor. The spawning and nursery grounds overlap with 18 crossing locations and 23 crossing locations, respectively. However, prime/sub-prime sand eel habitat, identified using sediment PSA, has only been identified at eight KPs along the cable route (NEXTGeosolutions, 2022). Similarly, spawning and nursery grounds for sandeel (Ellis et al., 2012) overlap with areas of multiple rock replacement locations.

The area requiring rock protection (excluding contingency) that falls within high intensity sandeel spawning grounds is 0.23 km² with areas in low intensity nursery grounds 0.82 km². The area requiring

rock protection at crossing locations that falls within high intensity sandeel spawning grounds is 0.04 km² with areas in low intensity nursery grounds 0.14 km².

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

Studies have shown that some fish and shellfish species 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 sandy mosaic habitats. These fish species are therefore considered to have low sensitivity to habitat loss associated with the placement of rock or concrete mattresses as subsequent habitat and food resource may be available on the structures themselves.

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. 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. 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 negligible magnitude. Combined with the medium value of these receptors, the effect is predicted to be **negligible** and therefore **not significant**.

Shellfish

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 (e.g., 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.

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 negligible 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 of commercial and/or of conservation importance, the overall effect is predicted to be **negligible** 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 an impact considered significant 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**.

9.6.3.2 Potential effects on fish and shellfish due to subsea cable electromagnetic field (EMF) emissions

The design for the Marine Scheme is presented in Chapter 2: Project Description. It is presumed that protecting a cable by burial, may mitigate EMF emissions and potential impacts on species. An animal moving along a cable route may be exposed to variable EMFs due to varied trenching depth and that combined with a fish's position in the water column determines the distance from source and EMF exposure (Hutchison, Gill, Sigray, He, & King, 2021). Modelling 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 cables, and the properties of electromagnetic fields in water, both with and without the influence of background geomagnetic fields. For the separated cables, the magnetic field resulted in a combined field strength of 404 μT at the seabed, reducing to slightly above the background level at 20 m from the cables. The bundled cable had significantly lower magnetic fields due to cancellation of the magnetic fields between poles. EMF from a bundles cable reduced to the background geomagnetic field strength around 5m to 10 m from the cable, having only a very localised effect.

As detailed in Chapter 2, while the cable shielding will prevent emission of electric fields, the tidal movement of seawater over the cables will result in the generation of localised induced electric (iE) fields. For the separated cables and considering typical tidal current speeds in the Marine Installation Corridor, the iE field strength is anticipated to be 303 $\mu\text{V/m}$ at the seabed, reducing to the background level within 20 m from the cables. The bundled cable had significantly lower iE field strength, reducing to a background level within 8 m from the cable, having only a very localised effect.

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 1.3 km of the route towards the Scottish landfall and 10 km towards the English, where depths are below 20 m. Consequently, species occupying the upper layers of the water column will not be exposed to EMFs above background levels for the majority of the cable route, with marginally elevated field strengths being present in shallow waters.

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 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 (Table 9-7).

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 submarine cables. 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).

Salmonids have been the focus of many studies that have shown distinct directional reactions and magnetoreception-based orientation (Formicki, Korzelecka-Orkisz, & Tański, 2019); 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 small area around the cable (modelled value at 20 m just above background). 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 cables.

Thus, during operation of the HVDC cables migratory species may respond by changes in swimming speed or adjustments in swimming direction. However, the migratory species identified above have been shown to spend most of their time in the upper reaches (top 10 m) of the water column (Section 9.5.2.1), therefore are unlikely to experience EMFs above background levels in water depths less than 30 m. Migration routes from rivers in the vicinity of the Marine Installation Corridor are generally in a direction to or from the north of the Marine Scheme, as such, the Peterhead landfall and approaches are the areas where migration routes may be crossed in shallow water. The seabed shelves rapidly on the approaches to Peterhead, and the 30 m depth contour is within approximately 2 km of the shore, as such the area where EMF emissions from the cables have the potential to affect diadromous fish is extremely limited, with no potential for barrier effects to occur.

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 high sensitivity, EMF emissions from the proposed cables are 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 cables 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 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 **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 (404 μT) is not thought to be high enough to elicit any physiological or behavioural responses. This is based on evidence from studies exposing juvenile flounder to magnetic fields with a strength of 3,700 μT , 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 (Metcalf, 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.

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 (Hutchison, et al., 2018).

Elasmobranchs have an electroreceptor system and use magnetic fields for choosing their direction of movement and orientation in their surroundings (Formicki, Korzelecka-Orkisz, & Tański, 2019). Laboratory experiments to determine the effect of 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 mm², the ability to carry 600 V to 1000 V and rated from 25 A to 730 A 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). Behavioural conditioning studies have shown that the lesser spotted dogfish cannot discriminate between artificial and natural DC electric fields. If this behavioural response is common among elasmobranchs, then it might explain why some sharks and rays are known to bite submarine cables (Newton, Gill, & Kajiura, 2019).

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 0 MW, 100 MW and 330 MW capacity with the corresponding EMF generated above background levels of 0.4 μT , 4.0 μT and 14 μT (Hutchison, et al., 2018). Little skate exposed to EMF generated by the cable travelled between 20% and 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. 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). More recent studies have also concluded similar behaviour responses of little skate to anthropogenic emissions of EMF. Such responses include longer traveling distances at slower

speeds when exposed to EMF levels 65.3 μ T. This can be indicative of increased exploratory and/or area restricted foraging behaviour (Hutchison, Gill, Sigray, He, & King, 2020).

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 Marine Installation Corridor passes through known spawning 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 3,700 μ T 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 3,000 μ T for a period of 27 days. Rainbow trout eggs and larvae exposed to EMF with a strength of 10,000 μ T for a period of 36 days did not show any significant effects on mortality, growth or development (Fey, et al., 2019).

The magnetic field strengths tested in these laboratory experiments are considerably higher (by two to three 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.

More recent studies into the effect of magnetic fields generated by the DC cables of offshore wind farms on lesser sandeel larvae identified that larvae exposed to 150 μ T to 50 μ T did not affect the spatial distribution, swimming speed, acceleration or distance moved of lesser sandeel larvae (Cresci, et al., 2022).

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 μ T were found to have limited physiological and behavioural impacts. At exposure of 500 μ T and 1000 μ T 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. It should also be noted that the Marine Scheme does not have the potential to emit EMF with strengths of 500 μ T, as such this effect is considered unlikely to occur.

In addition to this, recent research into the effects of EMF on European lobster and edible crab have identified that chronic exposure to static EMF of 2,800 μT throughout embryonic development resulted in significant differences in stage-specific egg volume and resulted in stage I lobster and zoea I crab larvae exhibiting decreased carapace height, total length, and maximum eye diameter. An increased occurrence of larval deformities was observed in addition to reduced swimming test success rate amongst lobster larvae (Harsanyi, et al., 2022). It should however be noted that the field strength used in this study was orders of magnitude higher than those anticipated during the Marine Scheme.

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 Zol 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.

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 between 100 μT and 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 Zol.

The magnitude of the impact of EMF exposure is expected 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 considered to be **not significant**.

9.6.3.3 Potential effects on fish and shellfish due to subsea cable thermal emissions

HVDC 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 bi-pole 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°C which has been calculated based upon a maximum seabed ambient surface sediment temperature of 15°C (Chapter 2: Project Description). Where only the minimum DOL of approximately 0.6 m is achieved, the temperature increase below the seabed surface will be approximately 5°C, noting that this will not result in a corresponding 5°C increase on the seabed surface, due to the cooling effect of the sea water. 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. Thus, only the species with a close association with the benthos, particularly sandeel and demersal spawning herring and shellfish species have the potential to be affected by an increase in sediment temperature.

Herring and Sandeel Spawning Grounds

Herring is the only marine clupeoid which lays demersal eggs. Eggs are laid on gravel areas on the seabed. 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).

Herring and sandeel lay their eggs on top of the seabed and are therefore not likely to come into contact with any significant sediment heating as the temperature increase is minimal in the top layers of the seabed from the buried cable. Thus, such a small increase in temperature is unlikely to significantly impact any eggs in the vicinity of the operational cable. 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. However, the benthic survey found very limited evidence of *Nephrops* habitat within the Marine Installation Corridor (NEXTGeosolutions, 2022). The magnitude of the impact in *Nephrops* is therefore considered to be negligible. Thus, for all demersal and burrowing fish and shellfish species, the effect of thermal effects is considered to be **negligible** and therefore **not significant**.

9.6.3.4 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 of a significantly shorter duration.

The only exception is where rock protection would be required (where previously not rock placed) as part of maintenance and cable repair works to achieve cable retrenching. In the event additional placement of rock or concrete mattresses on the seabed be required to achieve reburial of the submarine cable, further permanent physical disturbance to and/or loss of fish and shellfish would likely arise.

The Marine Installation Corridor will be routed to achieve the precautionary target depth of lowering as much as possible and a detailed review of rock placement requirements has already been undertaken.

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;
- 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, depending upon the decommissioning option chosen. and therefore, as a worst case, the significance of the effects to fish and shellfish are predicted to be **negligible** to **minor adverse**, which is considered **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

As no additional mitigation was required because there were no likely significant effects fish and shellfish identified, the residual effects of the Marine Scheme remain as reported in Section 9.6.

9.9 Summary of Appraisal

Table 9-11: Summary of environmental appraisal

| Phase | Potential Impact | Receptor | Sensitivity | Magnitude | Significance | Additional Mitigation | Magnitude after Mitigation | Significance of Residual Effect |
|---------------------------|--|--------------------|-------------|------------|---------------|-----------------------|----------------------------|---------------------------------|
| Installation Phase | Temporary physical disturbance to fish and shellfish habitats and species during cable lay | Herring | Medium | Low | Minor adverse | Not applicable | Low | Not significant |
| | | Sandeel | Medium | Low | Minor adverse | | Low | |
| | | Elasmobranchs | Medium | Negligible | Negligible | | Negligible | |
| | | Shellfish | Medium | Low | Minor adverse | | Low | |
| | Temporary increased suspended sediment concentrations, and subsequent settlement of sediment causing smothering of fish habitat | Herring | Low | Negligible | Negligible | Not applicable | Negligible | Not significant |
| | | Sandeel | Medium | Low | Minor adverse | | Low | |
| | | Diadromous species | Low | Negligible | Negligible | | Negligible | |
| | | Shellfish | Medium | Low | Minor adverse | | Low | |
| | Underwater sound effects on fish and shellfish | Fish | Low to high | Negligible | Negligible | Not applicable | Negligible | Not significant |
| | | Shellfish | Medium | Negligible | Negligible | | Negligible | |
| | 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 | Not applicable | Negligible | 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 | Unlikely | Negligible | Not applicable | Unlikely | Not significant |
| | Vessel collision risk | Fish and shellfish | Low to high | Negligible | Negligible | Not applicable | Negligible | Not significant |
| Operation and Maintenance | 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 | Not applicable | Low | Not significant |
| | | Sandeel | Medium | Low | Minor adverse | | Low | |
| | | Flatfish | Medium | Negligible | Negligible | | Negligible | |

| Phase | Potential Impact | Receptor | Sensitivity | Magnitude | Significance | Additional Mitigation | Magnitude after Mitigation | Significance of Residual Effect |
|-----------------|---|---|----------------|------------|---------------|-----------------------|----------------------------|---------------------------------|
| | | Shellfish | Medium | Negligible | Negligible | | Negligible | |
| | Effects of Electromagnetic field (EMF) emissions from buried cable | Diadromous species | Low | Negligible | Negligible | Not applicable | Negligible | Not significant |
| | | Pelagic species | Low | Negligible | Negligible | | Negligible | |
| | | Demersal species | Low | Negligible | Negligible | | Negligible | |
| | | Elasmobranchs | Medium | Low | Minor adverse | | Low | |
| | | Spawning fish, eggs, larvae and juvenile fish | Low to medium | Negligible | Negligible | | Negligible | |
| | | Shellfish | Medium to high | Negligible | Negligible | | Negligible | |
| | Effects of thermal emissions from buried cable | Spawning grounds | Medium | Negligible | Negligible | Not applicable | Negligible | Not significant |
| | | Shellfish | Medium to high | Negligible | Negligible | | Negligible | |
| | Maintenance potential effects the same as Installation Phase | | | | | | | |
| Decommissioning | Potential effects of decommissioning the same as Installation Phase | | | | | | | |

9.10 References

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