Offshore Wind Power Limited

West of Orkney Offshore EIA Report

Volume 2, Supporting Study 7: Fish and Shellfish Ecology Baseline Report

WO1-WOW-CON-EV-RP-0046: Approved by S.Kerr
Document Control 15/09/2023

ASSIGNMENT	L100632-S05
DOCUMENT	L-100632-S05-A-REPT-002

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REVISIONS & APPROVALS

REV	DATE	DESCRIPTION	ISSUED	CHECKED	APPROVED	CLIENT
A01	04/09/2023	Issued for Use	JG	DB	DB	OWPL
R02	16/01/2023	Re-issued for Review	JG	DB	DB	OWPL
R01	09/12/2022	Issued for Review	JG	FdB/DB	DB	OWPL

CONTENTS

1 INTRODUCTION

The Applicant, Offshore Wind Power Limited (OWPL), is proposing the development of the West of Orkney Windfarm ('the Project'), an Offshore Wind Farm (OWF) located approximately 23 kilometres (km) from the north coast of Scotland and 28 km from the west coast of Hoy, Orkney. Crown Estate Scotland (CES) awarded OWPL the Option Agreement Area (OAA) in January 2022 for the development of the proposed Project following the ScotWind leasing round which launched in June 2020. The OAA lies wholly within the "N1" Plan Option (PO), which is one of 15 PO areas around Scotland that the Scottish Government considered suitable for the development of commercial scale OWFs.

The purpose of this Fish and Shellfish Ecology Baseline Report ('this Report') is to provide a detailed characterisation, where possible, of the fish and shellfish ecology receptors within the defined study area ('the fish and shellfish ecology offshore study area'), which incorporates the offshore Project[1] and the zone of potential impact.

This Report is structured as follows:

- Section 1: Introduction
- Section 2: Methodology – an overview of the desk-based review and site-specific surveys that have informed this Report;
- Section 3: Results and discussion
  - Section 3.1: Spawning and nursery grounds – a description of the fish spawning and nursery grounds that overlap with the study area;
  - Section 3.2: Marine finfish – a description of the ecology of the key marine finfish species of commercial or conservation importance expected to be present in the study area;
  - Section 3.3: Shellfish – the ecology of the key shellfish species of commercial or conservation importance expected to be present in the study area;
  - Section 3.4: Elasmobranchs – the ecology of the elasmobranch species of commercial or conservation importance expected to be present in the study area;
  - Section 3.5: Diadromous fish and associated features – the ecology of the elasmobranch species of commercial or conservation importance; and
  - Section 3.6: Future baseline – a description of the predicted changes to the fish and shellfish environmental baseline;
- Section 4: Summary and conclusion
  - Section 4.1: Fish and shellfish ecology baseline – a summary of the fish and shellfish ecology baseline;
  - Section 4.2: Species taken forward for assessment – a summary of the key species taken forward for assessment within the Offshore Environmental Impact Assessment (EIA) Report; and
  - Section 4.3: Key data gaps and limitations – a summary of the data gaps in the fish and shellfish environmental baseline and the limitations of the data sources used to inform this Report.

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[1] *The offshore Project, which defines the Red Line Boundary for the Section 36 consent and the Marine Licence applications, includes all offshore components seaward of MHWS (wind turbine generators (WTGs), cables, foundations, offshore substation platforms (OSPs) and all other associated infrastructure) and all Project stages from pre-construction to decommissioning.*

This Report will be summarised within the environmental baseline description in chapter 11: Fish and shellfish ecology of the Offshore EIA Report.

2 METHODOLOGY

A desk-based review of publicly available baseline information was conducted to characterise the fish and shellfish populations within the fish and shellfish ecology offshore study area. Information was collated at various spatial scales to understand the abundance, distribution and ecology of the fish and shellfish species potentially present, with a focus on species of commercial and/or conservation importance.

The desk-based review has been augmented by site-specific environmental DNA (eDNA) surveys to understand the potential presence of fish and shellfish species. In addition, site-specific benthic survey data has also been reviewed to understand the suitability of the sediment type at the offshore Project area for spawning sandeel (*Ammodytes spp*.), herring (*Clupea harengus*) and flapper skate (*Dipturus intermedius*). Visual observations from footage captured during the site-specific surveys have also been reviewed.

2.1 Study area

The fish and shellfish ecology offshore study area is spatially delineated by the International Council for Exploration of the Sea (ICES) Rectangles within which the OAA and offshore Export Cable Corridor (ECC) ('the offshore Project area') is found, including ICES Rectangles 46E5, 46E6 and 47E5, as shown on Figure 2-1. ICES rectangle 47E6 has also been considered within the study area due to its close proximity to the OAA.

A wider regional context is also considered where this is ecologically relevant, for instance in relation to diadromous fish species and the availability of fish spawning and nursery grounds. In general, this wider regional context extends as far as Scottish waters (the Scottish Zone extending out to 200 nautical miles (nm)).

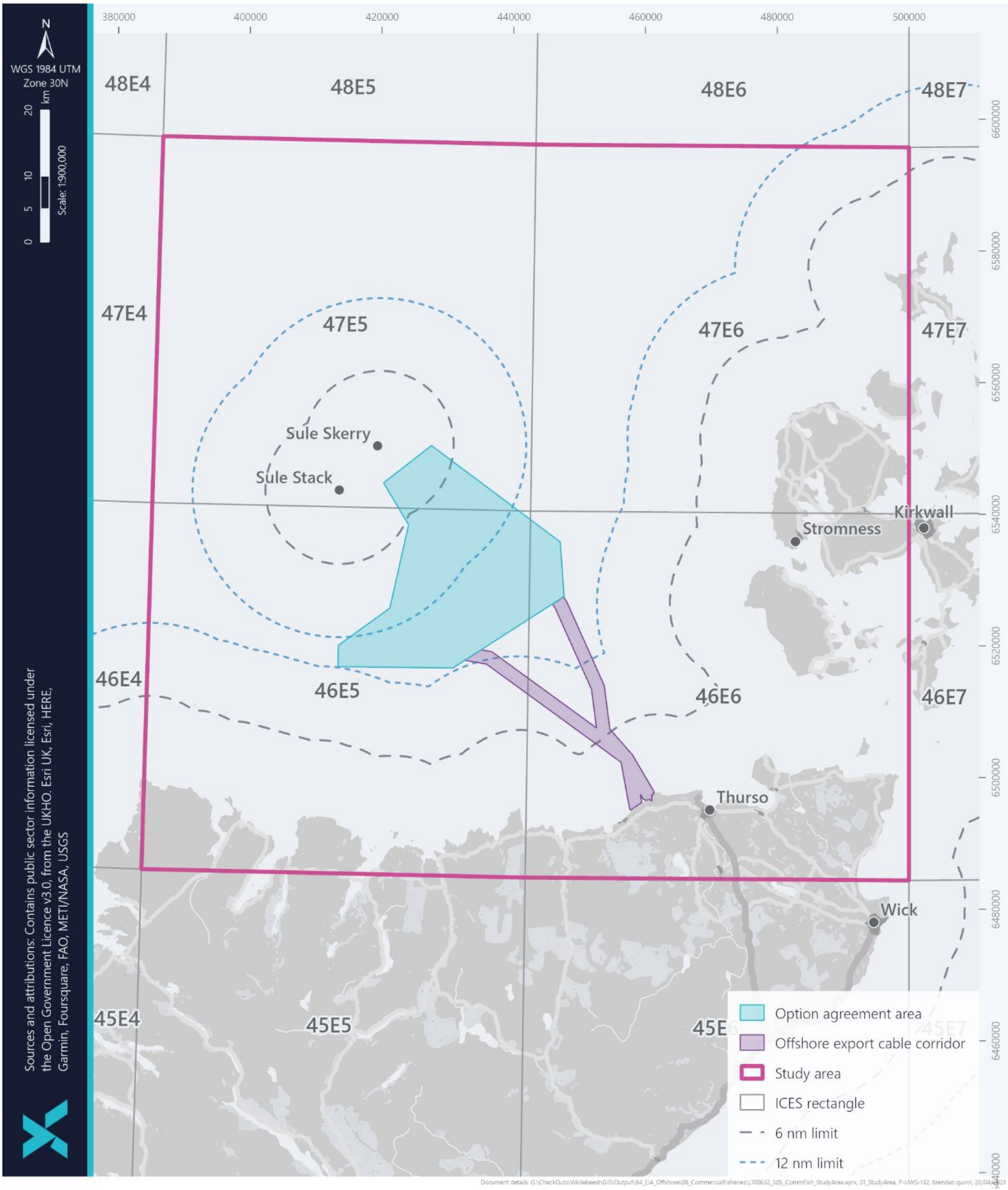


Figure 2-1 Fish and shellfish ecology offshore study area[2]

[2] *Although ICES rectangles extend onshore, for the avoidance of doubt, the fish and shellfish ecology baseline focusses on marine species.*

2.2 Desk-based review

The key desk-based data sources used to inform the fish and shellfish baseline characterisation presented within this Report are summarised in Table 2-1.

Table 2-1 Data sources

DATA SOURCE	DESCRIPTION	RELEVANT SPECIES / FUNCTIONAL GROUP
Fisheries Sensitivity Maps in British Waters (Coull *et al.*, 1998)	Indicative spawning and nursery ground locations and timings around UK waters.	• Spawning and nursery grounds.
Spawning and nursery grounds of selected fish species in UK waters (Ellis *et al.*, 2012)		• Spawning and nursery grounds.
Spawning grounds of Atlantic cod (*Gadus Morhua*) in the North Sea (Gonzalez-Irusta and Wright, 2016a)	Distribution model for cod spawning grounds, using International Bottom Trawl Survey (2009 – 2014) data assessed against environmental variables.	• Cod spawning grounds.
Spawning grounds of haddock (*Melanogrammus aeglefinus)* in the North Sea and West of Scotland (Gonzalez-Irusta and Wright, 2016b)	Distribution model for haddock spawning grounds, using International Bottom Trawl Survey (2009 – 2015) data assessed against environmental variables.	• Haddock spawning grounds.
Spawning grounds of whiting (*Merlangius merlangus*) (Gonzalez-Irusta and Wright, 2017)	Distribution model for whiting spawning grounds, using International Bottom Trawl Survey (2009 – 2015) data assessed against environmental variables.	• Whiting spawning grounds.
Updating Fisheries Sensitivity Maps in British Waters (Aires *et al.*, 2014)	Likelihood of 0-group aggregations (0-group fish represent juvenile fish less than 1 year old), taking into account the findings of Ellis *et al.* (2012) and Coull *et al.* (1998) together with findings from the National and International Bottom Trawl Surveys, the Beam Trawl Survey, International Herring Lavae Survey (IHLS) and other standalone surveys.	• Spawning and nursery grounds.
International Herring Larvae Survey (IHLS) reports	IHLS reports include estimated herring larval abundance for the Orkney / Shetland spawning area from annual surveys.	• Spawning and nursery grounds.
A verified distribution model for the lesser sandeel *Ammodytes marinus* (Langton *et al.*, 2021)	Distribution model for the probability and predicted density of sandeel burrows in the North Sea and Celtic Sea regions. The North Sea dataset overlaps with the eastern portion of the offshore Project area.	• Sandeel.
Landings data (value and weight) by species (MMO, 2022)	Landings by live weight for UK vessels between 2017 and 2021.	• Commercial fish and shellfish.
Shark Trust Sightings Database (Shark Trust, 2022a, b)	Public sightings database of elasmobranchs and empty egg cases that is regularly updated. Sightings data collection began in 1994 for elasmobranchs and 2003 for empty egg cases.	• Elasmobranchs.

DATA SOURCE	DESCRIPTION	RELEVANT SPECIES / FUNCTIONAL GROUP
Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables (Malcom *et al.*, 2010)	Literature review on migratory patterns, timing and behaviour of diadromous fish in Scotland.	• Diadromous fish.
Fishermen's Knowledge: Salmon in the Pentland Firth (Youngson, 2017)	Review of the current knowledge around Atlantic salmon migratory patterns and behaviour in the Pentland Firth.	• Atlantic salmon.
Fish tagging and genetic studies on diadromous fish published by Marine Scotland (e.g. Cauwelier *et al.*, 2015, Downie *et al.*, 2018 and Armstrong *et al.*, 2018)	Various empirical studies published by Marine Scotland on diadromous fish in Scotland.	• Diadromous fish.

Additional data sources used to inform this Report include:

- ICES publications;
- Marine Life Information Network (MarLIN);
- Environmental baseline (and associated Appendices) of the UK Offshore Energy Strategic Environmental Assessment (OESEA);
- Publications available through the Caithness District Salmon Fishery Board (DSFB);
- Sectoral marine plan – regional locational guidance (Scottish Government, 2020);
- Publications available through the Orkney Sustainable Fisheries Trust; and
- Other relevant peer-reviewed publications and assessments.

2.3 Site-specific surveys

Site-specific eDNA and offshore benthic ecology surveys were conducted across the offshore Project area between 13th August and 13th September 2022. Nearshore benthic surveys were also conducted between 17th October and 25th October 2022.

2.3.1 eDNA surveys

An eDNA survey is a non-invasive sampling method used to determine the presence of species, based on the DNA found within water samples. It involves sampling the DNA that accumulates in the environment (e.g. through excretions or secretions), rather than through direct sampling of an organism.

Water samples of 5 L were collected at the 20 locations across the offshore Project area shown on Figure 2-2, one near the sea surface and one near the seabed, giving a total of 40 water samples. The sample locations were driven by the survey requirements for gathering data on water quality (e.g. temperature, conductivity, dissolved oxygen levels, and total suspended solids), and provided a good coverage of samples for eDNA analysis.

Upon recovering the water samples to the vessel, the eDNA was extracted using a commercial DNA extraction kit and Polymerase Chain Reaction (PCR) amplification was carried out. Four to twelve successful PCR replicates were obtained for 38 of the water samples and two of the water samples failed to replicate. The amplified DNA replicates were then sequenced and processed using a bioinformatics pipeline, and taxonomy was assigned (Nature Metrics, 2022). More detail on the survey methodology is provided in Offshore EIA Report, Supporting Study (SS) 5: Benthic environmental baseline report.

The samples were analysed to detect the DNA of:

- Fish and vertebrate communities (all samples) (12S gene);
- Marine mammals (near surface samples) (16S gene); and
- Invertebrates (near seabed samples) (18S gene).

Two separate PCR amplifications were conducted for fish and vertebrates, using the fish and vertebrate 12S rRNA assays, respectively. The assays used for the amplifications are associated with a specific target group, whereby the assay for fish has the highest sensitivity to detect fish species, with the broader vertebrate assay also detecting some fish species. Therefore, the fish assay targets *Actinopterygii* species only, whereas the vertebrate assay is dominated by *Actinopterygii*, but also includes marine mammal and bird eDNA (NatureMetrics, 2022). It is important to note that although there will be some overlap in the fish species detected using these two assays, some detections may not be the same, as the assays use a different gene region. In this way, PCR amplification for both fish and vertebrates provides the fullest detection of the fish community.

The eDNA surveys have been used to indicate the presence of fish and shellfish species. However, it should be acknowledged that this survey provides a 'snapshot' of the fish and shellfish assemblage at the time of the survey (between 13th August and 13th September 2022), and that fish and shellfish communities are subject to both seasonal and annual variation.

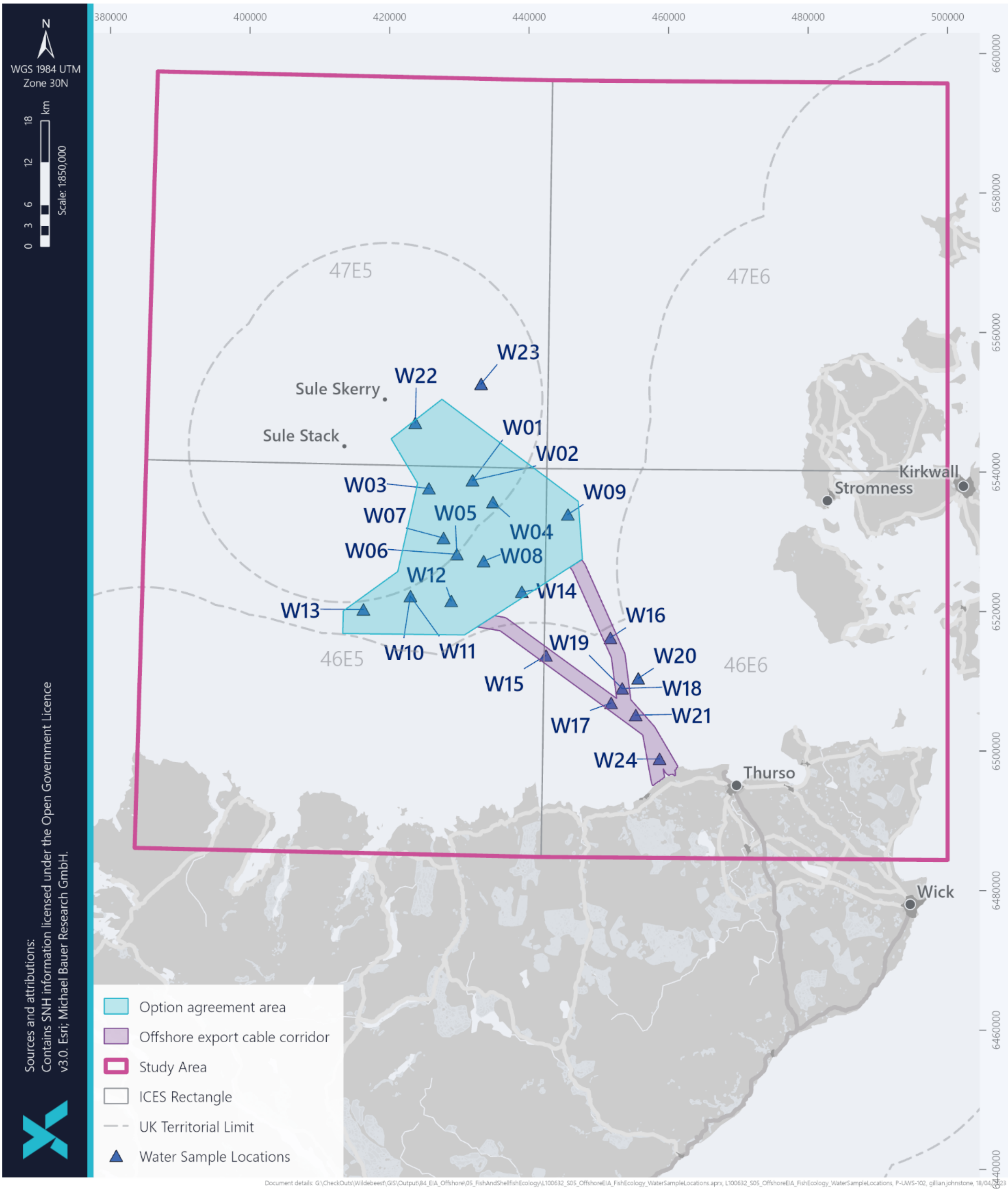


Figure 2-2 Water sample locations

2.3.2 Benthic surveys

The benthic surveys were conducted across the offshore Project area, and involved the following survey techniques:

- Grab sampling (mixture of 0.1 m^2 Dual Van Veen grab and Hamon grab and 0.5 m^2 Shipek grab);
- Drop Down Video (DDV); and
- Video transects.

DDV and Particle Size Analysis (PSA) data have been reviewed to understand the potential suitability for spawning habitat for sandeel, herring, and flapper skate, as described in the following sections. Of the 73 stations where grab sample attempts were made in the offshore area, adequate samples were achieved at 67 stations. Three of the four samples for the nearshore area were successfully achieved. In several locations, no grab sampling was attempted due to the potential presence of Annex I reef (further details provided in SS5: Benthic environmental baseline report).

Sandeel

The potential presence of sandeel spawning habitat can be inferred from the PSA data using the methods and habitat suitability categories devised by Latto *et al.* (2013), presented within MarineSpace Ltd (2013a, as cited in MarineSpace Ltd, 2018). This has been used to categorise locations as "preferred", "marginal" and "unsuitable" habitat for sandeel spawning, as described in Table 2-2.

Table 2-2 Sandeel potential spawning habitat (MarineSpace Ltd, 2013a, as cited in MarineSpace Ltd, 2018)

% PARTICLE CONTRIBUTION (MUDS = CLAYS AND SILTS < 63 µM)	HABITAT SEDIMENT PREFERENCE	FOLK SEDIMENT UNIT	HABITAT SEDIMENT CLASSIFICATION
< 1% muds, > 85% sand	Prime	Part Sand, part slightly gravelly Sand and part gravelly Sand	Preferred
< 4% muds, >70% sand	Sub-prime	Part Sand, part slightly gravelly Sand and part gravelly Sand	Preferred
< 10% muds, > 50% sand	Suitable	Part gravelly Sand and part sandy Gravel	Marginal
> 10% muds, < 50% sand	Unsuitable	Everything excluding Gravel, part sandy Gravel and part gravelly sand	Unsuitable

The habitat sediment classifications for sandeel spawning do not account for other biotic or abiotic factors which could influence sandeel spawning potential (e.g. water depth), and therefore, indicates ranked potential spawning habitat rather than actual locations. Therefore, these data have been reviewed alongside other datasets to understand the importance of the area for potential sandeel spawning.

It should also be noted that following the settlement of larvae on the seabed, sandeel are understood to typically remain in the same habitat types for the majority of their adult life (Tien *et al.*, 2017). Thus, the habitat preferences described above are also relevant to the juvenile and adult phase for sandeels.

Further details are provided in section 2.3.2

Herring

Similar to sandeels, potential herring spawning habitat can also be identified from the PSA results using the methods devised by Reach *et al.* (2013), presented in MarineSpace Ltd (2013b). Using this method, locations are classified as "preferred", "marginal" and "unsuitable" habitat for herring spawning, as described in Table 2-3.

Table 2-3 Herring potential spawning habitat (MarineSpace Ltd, 2013b)

% PARTICLE CONTRIBUTION (MUDS = CLAYS AND SILTS < 63 µM)	HABITAT SEDIMENT PREFERENCE	FOLK SEDIMENT UNIT	HABITAT SEDIMENT CLASSIFICATION
<5% muds, >50% gravel	Prime	Gravel and part sandy Gravel	Preferred
<5% muds, >25% gravel	Sub-prime	Part sandy Gravel and part gravelly Sand	Preferred
<5% muds, >10% gravel	Suitable	Part gravelly Sand	Marginal
>5% muds, <10% gravel	Unsuitable	Everything excluding Gravel, part sandy Gravel and part gravelly Sand	Unsuitable

The limitations described for using PSA to identify sandeel spawning habitat are also relevant to herring. Further details are provided in section 3.1.

Flapper skate

Unlike herring and sandeel, a quantitative approach for identifying potential flapper skate spawning habitat has not yet been devised.

The Orkney Skate Trust is a voluntary group that is undertaking extensive monitoring and research of flapper skate around the Orkney Islands and now maintains a large flapper skate record database. The Trust's research includes Baited Remote Underwater Video (BRUV), Remotely Operated Vehicle (ROV) inspections, tag and release angling, diver observations and egg case records (including in situ and those washed ashore) (Orkney Skate Trust, 2022). The Orkney Skate Trust research is focussed on the inshore waters around the Orkney Islands and no research by this organisation has been carried out within the offshore Project area that could be used to identify flapper skate egg-laying habitats. However, there are available data on the preferred egg-laying habitats for this species which can be compared with the survey data for the offshore Project area.

Phillips *et al*. (2021) characterised the habitat preferences for flapper skate egg-laying grounds in the waters around Orkney by analysing records of detached egg cases, diver observations and camera surveys. The preferred egg-laying habitats identified by Phillips *et al*. (2021) were:

- Boulder or rocky substrates;
- Sites with a water depth > 20 m; and
- Significant current flow (0.3 to 2.8 knots) with low sedimentation.

The Philips *et al.* (2021) characterisation is consistent with the NatureScot guidance provided on flapper skate egg-laying grounds in the Sound of Jura Nature Conservation Marine Protected Area (NCMPA), which suggests that flapper skate lay their eggs in habitats with cobbles and mixed sediments at depths between 25 – 50 m (NatureScot, 2021).

The benthic site-specific survey data have been compared with the habitat characteristics above to provide a qualitative assessment of the potential suitability of the offshore Project area for egg-laying by flapper skate.

3 RESULTS AND DISCUSSION

Fish and shellfish ecology receptors relevant to the fish and shellfish ecology offshore study area include marine finfish (pelagic and demersal), shellfish (crustaceans and molluscs), elasmobranchs (sharks and rays), and diadromous fish. The following sections provide an overview of the key fish and shellfish species potentially present within the fish and shellfish ecology offshore study area according to these functional groups.

3.1 Spawning and nursery grounds

Several fish and shellfish species potentially spawn or have nursery grounds within the fish and shellfish ecology offshore study area. The following sections delineate the potential spawning and nursery grounds that overlap with the fish and shellfish ecology offshore study area using a combination of existing data sets and the benthic site-specific survey data. An assessment of the potential suitability of the offshore Project area based on site-specific seabed survey data for sandeel, herring and flapper skate spawning is also provided.

3.1.1 Spawning grounds

The potential areas for fish spawning within the fish and shellfish ecology offshore study area are shown in Figure 3-1. The following species have spawning grounds which directly overlap with the offshore Project area (Coull *et al.*, 1998; Ellis *et al.*, 2012):

- Herring;
- Lemon sole;
- Norway pout;
- Sandeel;
- Sprat; and
- Whiting.

The spawning grounds established by Coull *et al.* (1998) and Ellis *et al.* (2012) for whiting, haddock and cod were updated by Gonzalez-Irusta and Wright (2016a,b; 2017) using International Bottom Trawl Survey (IBTS) data and predictive environmental variables. The spawning potential for whiting, haddock and cod is shown in Figure 3-2, and the following conclusions can be made from this data (Gonzalez-Irusta and Wright. 2016a,b; 2017):

- Cod – the fish and shellfish ecology offshore study area contains a mixture of areas characterised as "unfavourable", "rare", "occasional" and "recurrent" grounds for spawning cod. The offshore Project area mostly overlaps with rare or occasional grounds for spawning cod;
- Haddock – spawning grounds for haddock are of greater importance towards the northwest and southeast of the fish and shellfish ecology offshore study area. Areas within the offshore Project area are considered to be of low to moderate importance for haddock spawning (mean rescaled value range[3]: 0.04 – 0.65); and

[3] *Mean rescaled values range from 0 to 1, where 0 indicates a 'low' preference as spawning ground and 1 indicates 'high' preference as a spawning ground (Marine Scotland, 2022)*

- Whiting – the data only covers the west of the offshore Project area. The data indicates that the offshore Project area are of low to moderate importance for spawning whiting (mean rescaled value range: 0.14 – 0.43).

A description of the spawning behaviours of the species with spawning grounds that overlap the offshore Project area is provided in section 3.2. Whilst most species spawn into the water column of moving water masses over extensive areas, benthic spawners (e.g. sandeel, herring and flapper skate) have habitat suitability requirements, and as a consequence their spawning grounds are typically more spatially limited than pelagic spawners. Considering this, the potential presence of spawning habitat for sandeel, herring and flapper skate has been assessed in further detail in sections 3.2 and 3.4.

3.1.2 Nursery grounds

Fish typically migrate to inshore sheltered waters during the nursery period (BEIS, 2022a). The fish nursery grounds within the fish and shellfish ecology offshore study area are shown in Figure 3-3 and Figure 3-4. Several nursery grounds directly overlap the offshore Project area.

Figure 3-5 displays the potential for 0-group aggregation fish within the fish and shellfish ecology offshore study area. There is considered to be a moderate to high probability of haddock, Norway pout and whiting 0-group aggregations and a low to moderate probability of 0-group aggregations for anglerfish / monkfish (*Lophius spp*.), blue whiting (*Micromesistius poutassou*), cod, European hake (*Merluccius merluccius*), herring, horse mackerel (*Scomber scombrus*), mackerel, plaice, sole (*Solea solea*) and sprat within the offshore Project area (Aires *et al*., 2014).

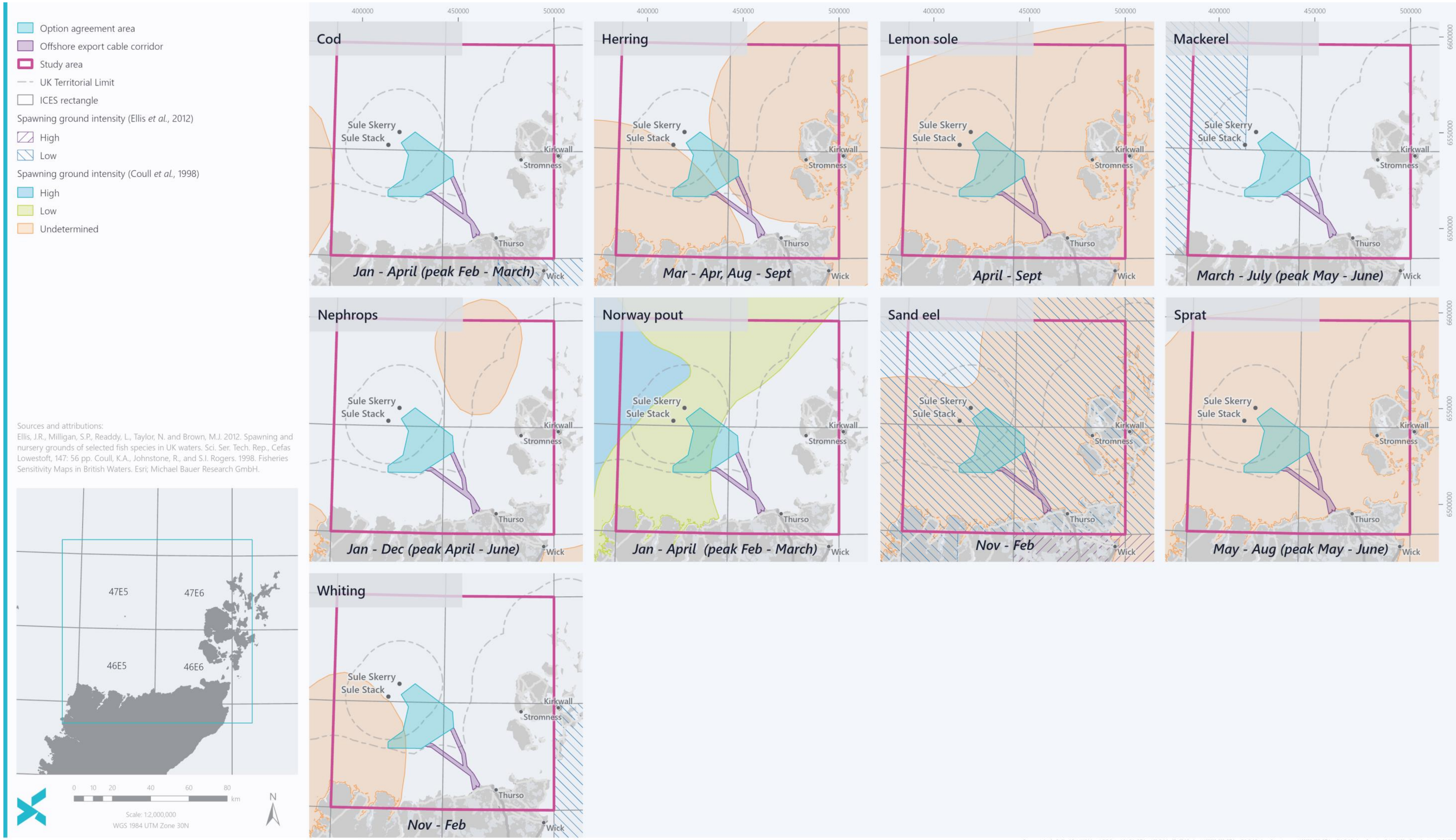


Figure 3-1 Spawning grounds within the fish and shellfish ecology offshore study area (Ellis et al., 2012 and Coull et al., 1998) (Note: Spawning period for each species is inclusive of the months listed)

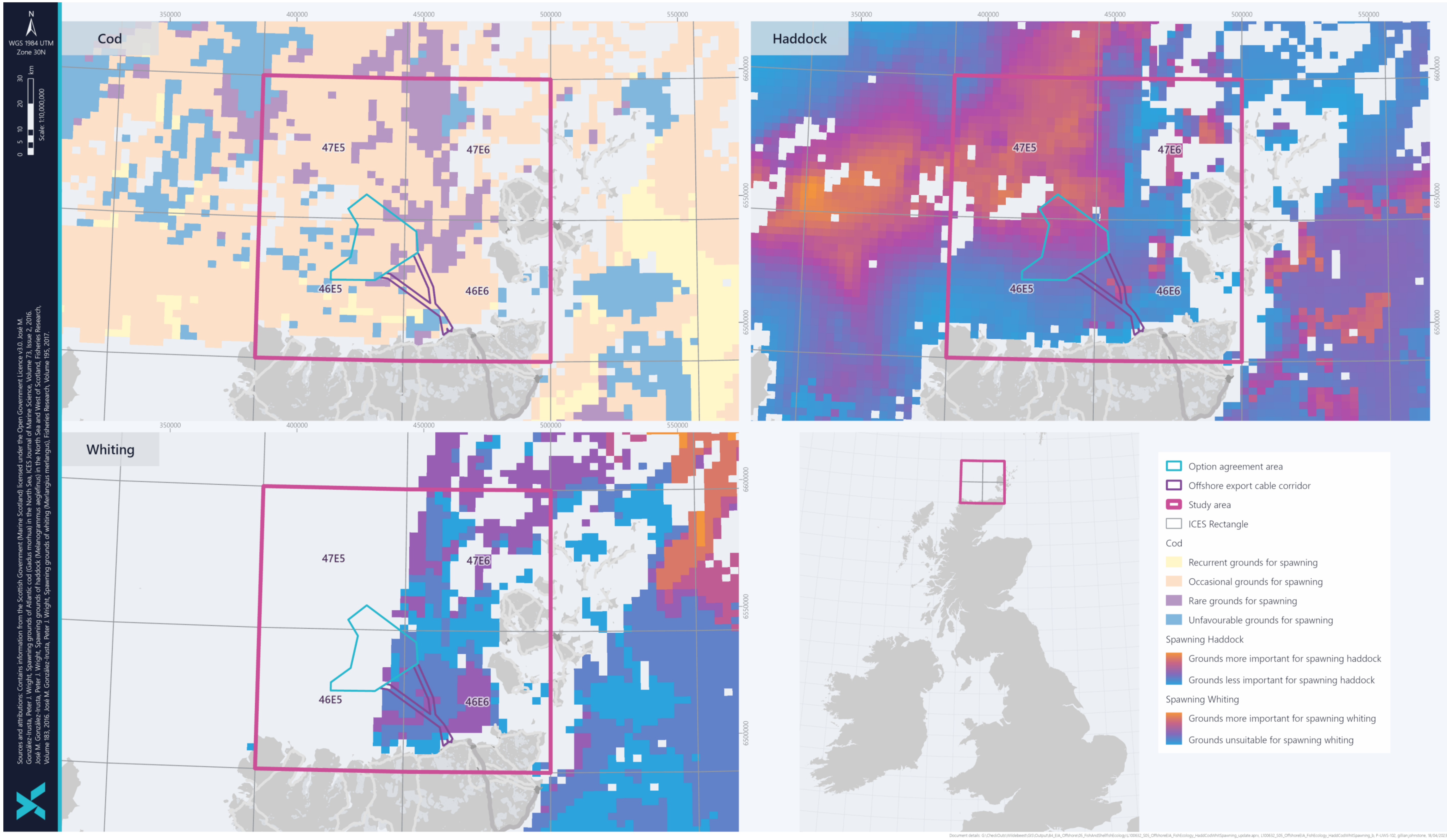


Figure 3-2 Whiting, cod and haddock spawning grounds (Gonzalez-Irusta and Wright, 2016a,b; Gonzalez-Irusta and Wright, 2017)

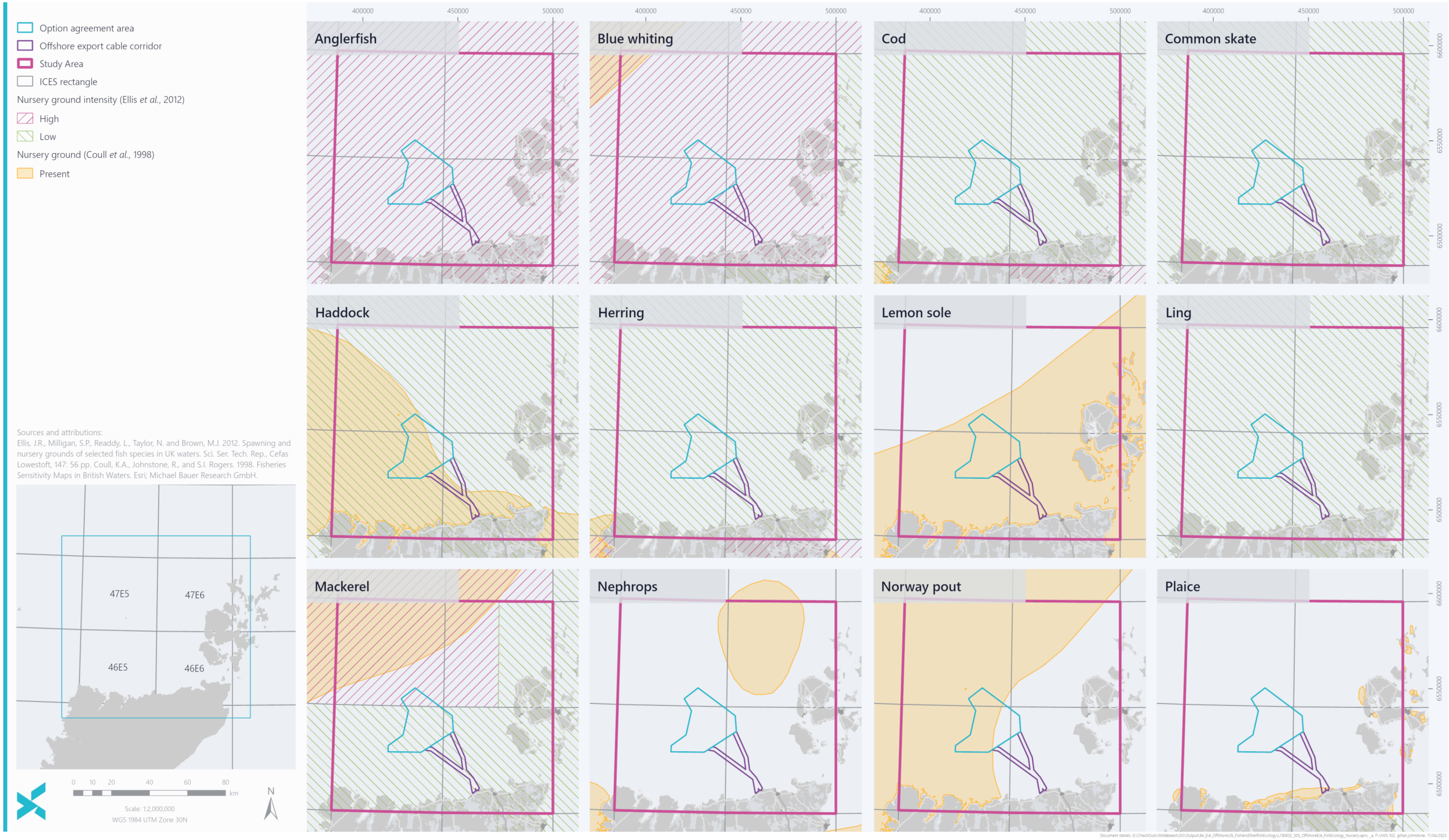


Figure 3-3 Nursery grounds within the fish and shellfish ecology offshore study area (Ellis et al., 2012 and Coull et al., 1998) (1 of 2)

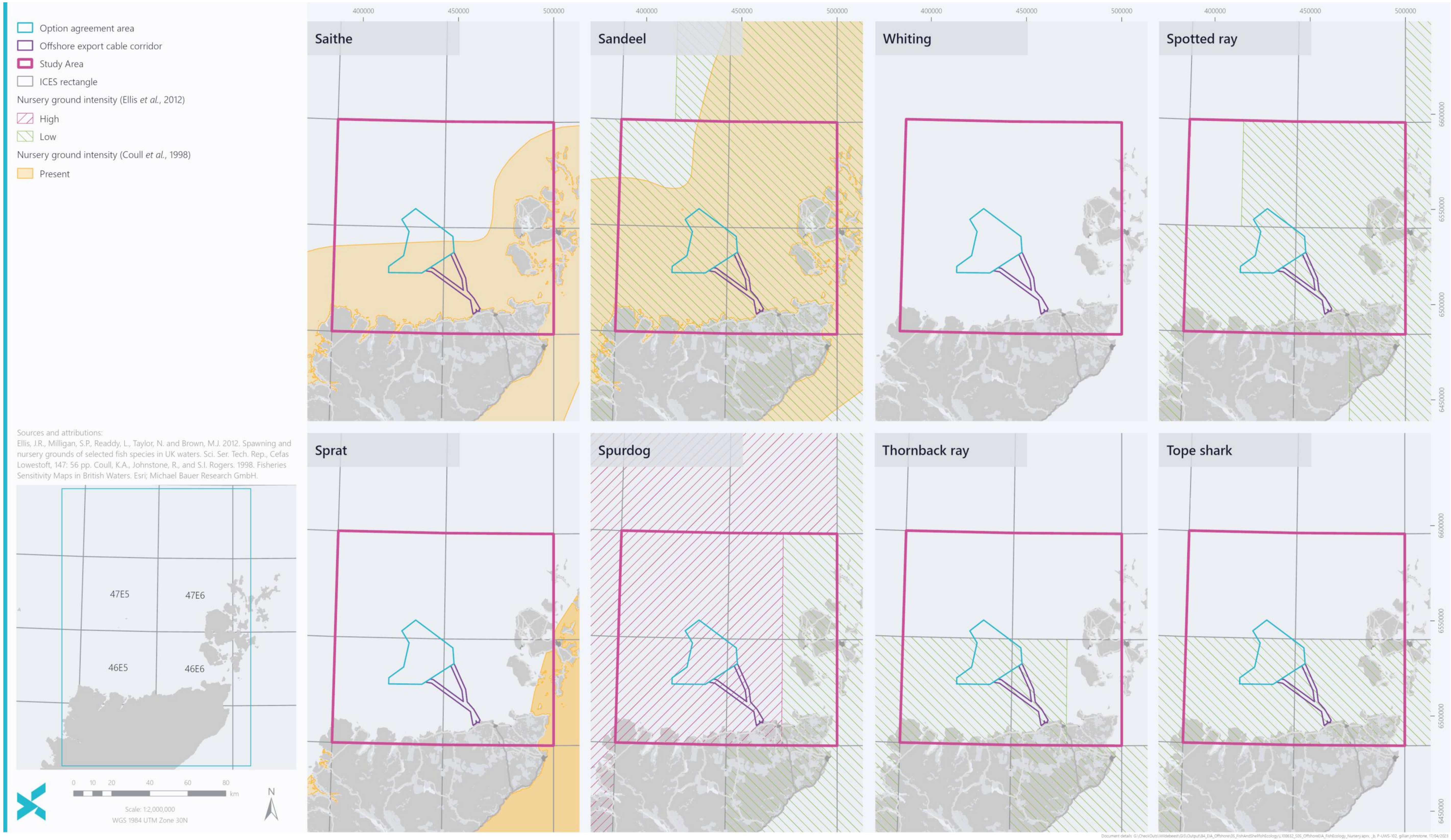


Figure 3-4 Nursery grounds within the fish and shellfish ecology offshore study area (Ellis et al., 2012 and Coull et al., 1998) (2 of 2)

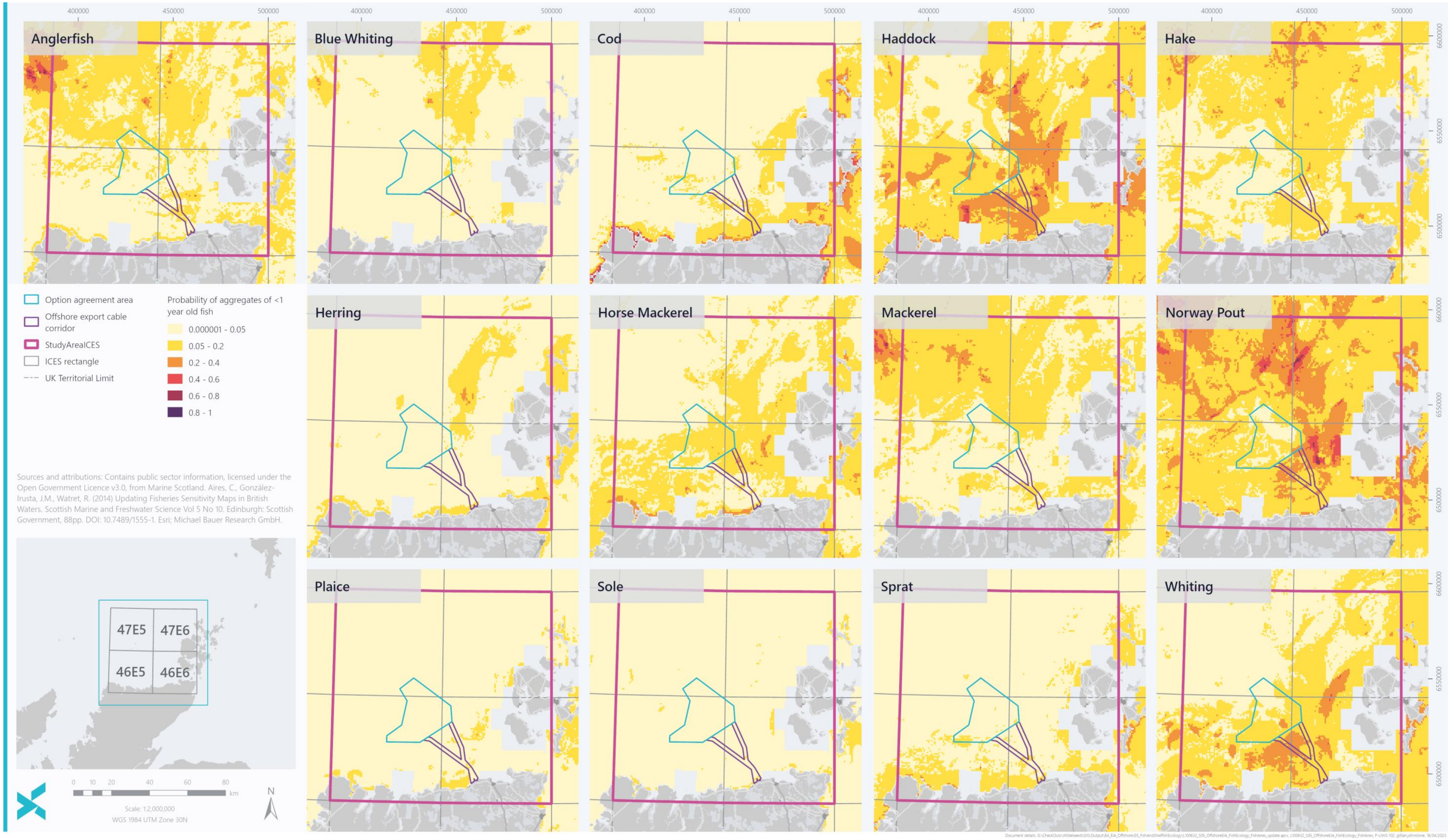


Figure 3-5 Probability of 0-Group fish aggregation (Aires et al., 2014)

3.2 Marine finfish

3.2.1 Overview

In the context of this Report, marine finfish are defined as non-diadromous marine teleosts, including pelagic finfish (fish that inhabit the water column) and demersal finfish (bottom dwelling). Demersal finfish are then further categorised into flatfish, gadoids, and 'other' demersal finfish.

3.2.2 Site-specific survey results

eDNA survey results

34 taxa were detected in the 40 samples analysed for eDNA under the fish assay. 28 taxa were identified to species level, and the remaining taxa were identified to genus or family level. The total number of fish taxa in a sample (i.e. taxon richness) ranged from 2 to 14 (see SS5: Benthic environmental baseline report).

As shown on Figure 3-6, the most frequently recorded taxa for the eDNA analysed under the fish assay were mackerel, poor cod (*Trisopterus minutus*) and haddock, with mackerel accounting for 26.5% of the total sequence reads[4]. The most frequently recorded families include Gadidae spp. (e.g. poor cod, haddock, cod and whiting) (detected in 35 samples), Scombridae (e.g. Atlantic mackerel) (detected in 30 samples), Ammodytidae (e.g. sandeels) (detected in 17 samples) and Clupeidae (e.g. sprat and herring) (detected in 14 samples) (see SS5: Benthic environmental baseline report).

32 fish taxa were identified in the analysis for eDNA under the vertebrate assay. In this analysis, Gadidae spp. accounted for 20.2% of total sequence reads, and other frequently recorded species included poor cod and Atlantic mackerel, which is generally consistent with the eDNA analysed under the fish assay described above. The most frequently recorded fish families also include Gadidae (detected in 28 samples), Scombridae (e.g. Atlantic mackerel) (detected in 17 samples), Ammodytidae (detected in 14 samples) and Pleuronectidae (e.g. plaice and lemon sole) (see SS5: Benthic environmental baseline report).

Further details on the eDNA analyses are provided in SS5: Benthic environmental baseline report.

[4] *The sequence reads refers to the number of copies of the same DNA sequence obtained for each species within a sample. This is often related to relative abundance but can also be influenced by biomass, activity, survey area, condition, distance from the physical sample, primer bias and specific-specific variation in the genome (Nature Metrics, 2022; SS5: Benthic environmental baseline report).*

Figure 3-6 The proportion of the sequencing output from the fish assay allocated to the different species (rows) within each sample (columns). Each bubble per sample represents the proportion of DNA for each species for that sample. The size of the bubble is relative to the number of sequences from all species detected in that sample (Nature Metrics, 2022; SS5: Benthic environmental baseline report) (y-axis = taxa, x-axis = sample location).

Site-specific survey observations

During the site-specific surveys in August and September 2022, there were several visual observations of marine finfish species, including those of conservation importance:

- Sandeel – ten sample locations (S01, S05, S07, S12, S14, S18, S29, S33, S49, and S67);
- Norway pout (*Trisopterus esmarkii*) – four sample locations (S05, S18, S43 and S76);
- Cod – three sample locations (S46, S64 and S65);
- Ling (*Molva molva*) – three sample locations (S05, S65 and T96);
- Whiting – two sample locations (S65 and S84); and
- Monkfish (*Lophius piscatorius*) – one sample location (T96).

The locations where these species were identified are shown on Figure 3-7. In addition, the sediment samples collected at the offshore Project area contained four adult sandeels and four juvenile sandeels. Further details are available in SS5: Benthic environmental baseline report.

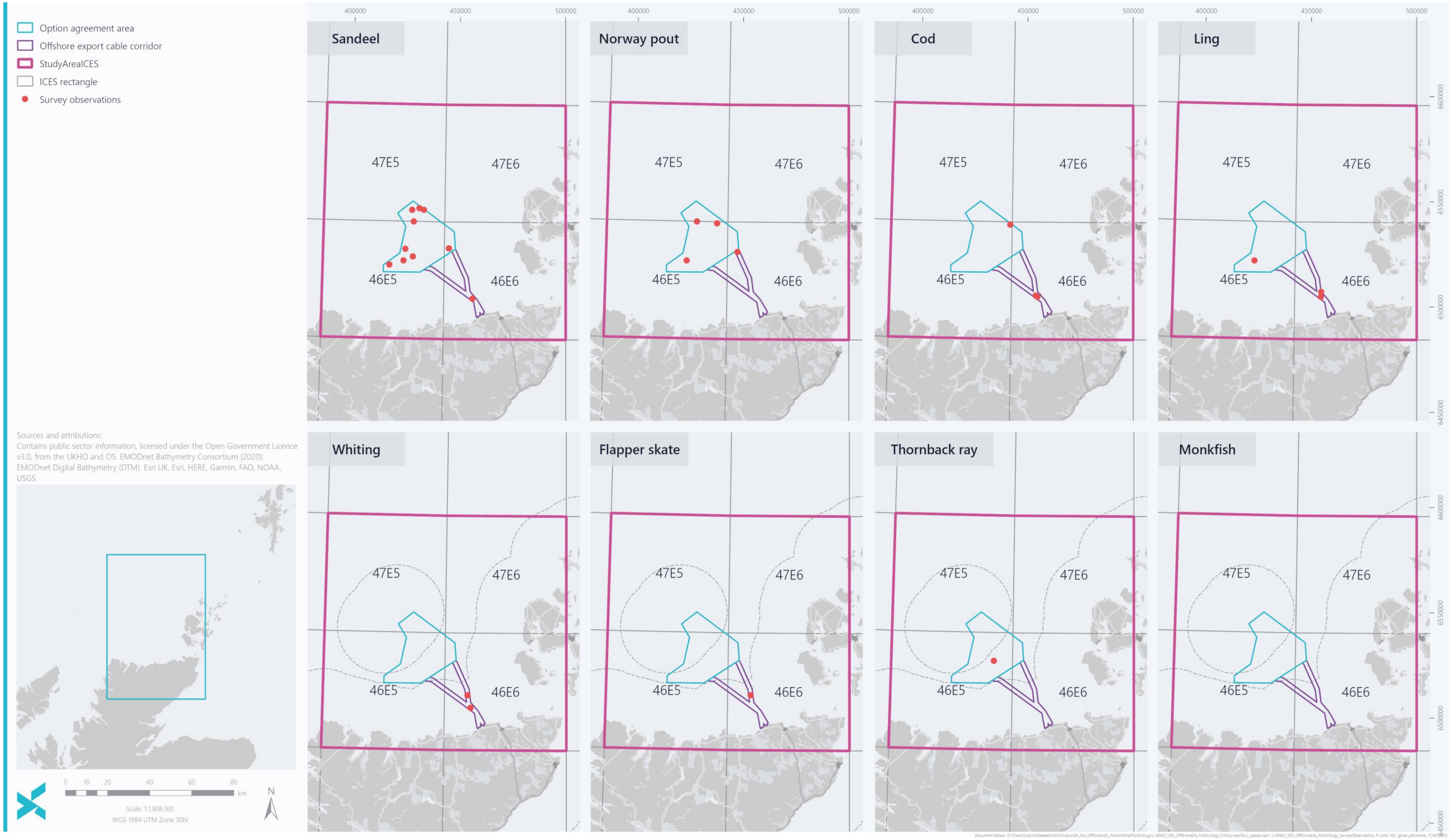


Figure 3-7 Visual observations of marine finfish during the site-specific surveys

3.2.3 Commercially important species

The landings data provides an indication of the characteristic commercial marine finfish within the fish and shellfish ecology offshore study area. However, it is acknowledged that commercial landings do not provide an accurate representation of species composition, as landings will be influenced by the fishing methods used, seasonality, quotas, bycatch, discards, and Total Allowable Catch (TAC) limits.

A total of 50 different marine finfish species were landed within the fish and shellfish ecology study area between 2017 and 2021. Table 3-1 displays the average live weights (2017 – 2021) for marine finfish for the ICES rectangles within the fish and shellfish ecology offshore study area. Species are presented in descending order in terms of total live weights across the fish and shellfish ecology offshore study area, and only the top 10 commercially exploited marine finfish species are listed. Appendix A presents the full list of average live weights (tonnes, 2017 – 2021) for the marine finfish functional group.

Mackerel alone accounts for 27% of the average live weights across the fish and shellfish ecology study, mainly associated with ICES rectangle 47E5. Mackerel are followed by haddock, herring, cod and monkfish / anglerfish in terms of average live weights. Cod and monkfish live weights are particularly high in ICES rectangle 47E6 when compared with the other ICES rectangles in the fish and shellfish ecology offshore study area. Likewise, herring live weights are highest in ICES rectangle 46E5.

Table 3-1 Average live weights (tonnes, 2017 – 2021) of commercially exploited marine finfish from the ICES rectangles in the fish and shellfish ecology offshore study area (MMO, 2022)

SPECIES	AVERAGE LIVE WEIGHTS (TONNES)				
	46E5	46E6	47E5	47E6	TOTAL
Mackerel (*Scomber scombrus*)	4.9	7.0	2,180.0	254.0	2,445.9
Haddock (*Melanogrammus aeglefinus*)	242.2	451.0	367.6	316.7	1,377.6
Herring (*Clupea harengus*)	557.6	0.1	138.4	21.8	717.9
Cod (*Gadus morhua*)	16.5	212.8	67.1	365.0	661.4
Monks or anglers (*Lophius spp.*)	5.1	77.9	63.3	334.3	480.6
Whiting (*Merlangius merlangus*)	7.9	64.3	43.3	141.8	257.3
Saithe (*Pollachius virens*)	19.8	9.0	188.9	33.4	251.1
Megrim (*Lepidorhombus whiffiagonis*)	1.8	9.4	25.6	66.1	103.0
Plaice (*Pleuronectes platessa*)	5.4	25.7	27.3	28.3	86.6
Ling (*Molva molva*)	8.2	3.5	51.5	17.3	80.5
Key					
	First ranking species in terms of average live weights for that ICES rectangle.				

SPECIES	AVERAGE LIVE WEIGHTS (TONNES)				
	46E5	46E6	47E5	47E6	TOTAL
	Second ranking species in terms of average live weights for that ICES rectangle.				
	Third ranking species in terms of average live weights for that ICES rectangle.				

3.2.4 Species of conservation importance

There are several marine finfish of conservation importance potentially present within the fish and shellfish ecology offshore study area. This includes those species which are:

- Listed as qualifying interests or features of designated sites; and/or
- Listed under conservation legislation or biodiversity action lists.

Designated sites

The North-West Orkney NCMPA is approximately 11 km northeast of the OAA, as shown on Figure 3-8. The North-West Orkney NCMPA is designated for lesser sandeels (*Ammodytes marinus*) and was fully designated in July 2014. High densities of sandeel have been recorded within the NCMPA and the area contains suitable habitat for sandeel. Newly hatched larvae within the NCMPA drift in currents to sandeel grounds (e.g. within the Moray Firth), and therefore, the site supports wider sandeel populations in Scotland (JNCC, 2014).

Species of conservation importance

A number of marine finfish receptors potentially present within the fish and shellfish ecology offshore study area, as indicated by the site-specific surveys, landings data and available datasets on spawning and nursery grounds, are listed under conservation legislation or biodiversity action lists. These are summarised in Table 3-2.

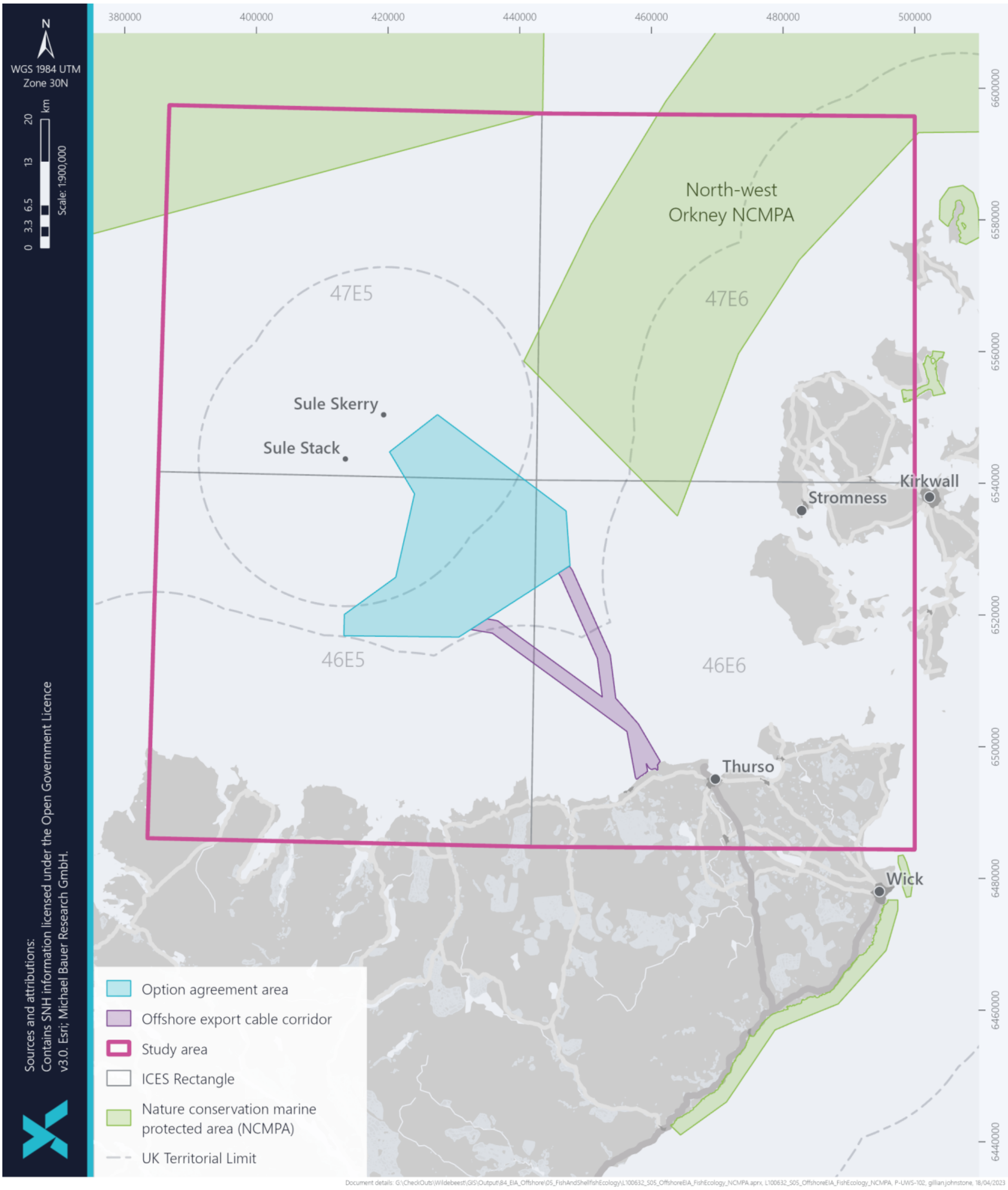


Figure 3-8 North West Orkney NCMPA

Table 3-2 Marine finfish species of conservation importance

SPECIES	OSPAR*	IUCN**	PMF***
Pelagic marine finfish			
Mackerel (*Scomber scombrus*)	-	Least concern	✓
Herring (*Clupea harengus*)	-	Least concern	✓
Blue whiting (*Micromesistius poutassou*)	-	-	✓
Horse mackerel (*Trachurus trachurus*)	-	Vulnerable	✓
Demersal marine finfish (flatfish)			
Plaice (*Pleuronectes platessa*)	-	Least concern	-
Sole (*Solea solea*)	-	Data deficient	-
Demersal marine finfish (gadoids)			
Cod (*Gadus morhua*)	✓	Vulnerable	✓
Whiting (*Merlangius merlangus*)	-	Least concern	✓
Haddock (*Melanogrammus aeglefinus*)	-	Least concern	-
Saithe (*Pollachius virens*)	-	-	✓
European hake (*Merluccius merluccius*)	-	-	✓
Ling (*Molva molva*)	-	-	✓
Blue ling (*Molva dypterygia*)	-	-	✓
Norway pout (*Trisopterus esmarkii*)	-	Least concern	✓
Demersal marine finfish (other)			
Sandeel (*Ammodytes spp.*)	-	-	✓
Monkfish (*Lophius piscatorius*)	-	-	✓
Atlantic halibut (*Hippoglossus hippoglossus*)	-	Endangered	✓
Greenland halibut (*Reinhardtius hippoglossoides*)	-	-	✓
Black scabbard fish (*Aphanopus carbo*)	-	-	✓

* OSPAR = The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR, 2023)
** IUCN = International Union for Conservation of Nature (IUCN, 2023)
*** PMF = Priority Marine Feature (Tyler-walters *et al.*, 2016)

3.2.5 Key species accounts

This section describes the ecology of the key marine finfish species potentially present within the fish and shellfish ecology offshore study area, focussing on those species identified as being of commercial or conservation importance.

The ecology of the species has been used to inform chapter 11: fish and shellfish ecology of the Offshore EIA Report. However, it should be noted that for some impacts, species may not be considered on an individual basis but as a 'marine finfish' functional group.

Pelagic marine finfish

Mackerel

Mackerel are widespread across the northeast Atlantic and are one of the most abundant pelagic fish species in UK waters (BEIS, 2022a). They are a schooling fish that prey on zooplankton and small fish, and perform climate-driven migrations between spawning, feeding and overwintering grounds (Langøy *et al*., 2006; Jansen *et al.*, 2012). There are two main stocks in UK waters, a Western and North Sea stock, and the north of Scotland is an area of mixing between the two (Ellis and Heessen, 2015, as cited in BEIS, 2022a).

Mackerel perform a northerly migration to their overwintering grounds in the northern North Sea and Norwegian Sea. The Western stock follow the currents along the continental shelf edge, and the North Sea stock migrate northwards from the central and southern North Sea (Uriarte *et al*., 2001; Jansen and Gislason, 2013). Following the overwintering period, mackerel migrate southwards towards spawning grounds (Uriarte *et al*., 2001). Spawning by Western stock mackerel occurs between March and July and spawning for the North Sea stock mackerel occurs between May and August (Ellis *et al*., 2012).

The offshore Project does not overlap with the spawning grounds of this species but overlaps with high and low intensity nursery grounds (Ellis *et al*., 2012). In addition, mackerel was one of the most frequently recorded species in the eDNA analysis, as described in section 3.2.2. Mackerel are a key commercial species for the fish and shellfish ecology study area and accounted for the high proportion of the commercial landings live weights, especially in ICES rectangle 47E5 which overlaps northern portion of the OAA.

Mackerel is a PMF and is listed as being of 'Least Concern' on the IUCN red list of threatened species.

Herring

Herring are also widely distributed across the northeast Atlantic. Several spawning stocks exist within UK waters, and the fish and shellfish ecology offshore study area overlaps with the Buchan / Shetland population (as shown on Figure 3-10) which spawn between August and September (Barreto and Baily, 2015).

As adults and juveniles, herring form large shoals. Adults are mainly distributed in deeper waters at depths over 200 m, whereas juveniles are typically found in shallower coastal waters. Herring feed mainly on copepods and small fish and form a key prey species for large gadoids, marine mammals and seabirds (ICES, 2006a).

Herring are demersal spawners, congregating together in shoals to lay dense sticky 'egg carpets' on gravel and other coarse sediments (Ellis *et al*., 2012). Each female releases her eggs in a single batch and the resulting 'egg carpet' may be several layers thick and cover a considerable area, with eggs hatching after approximately 1 – 3 weeks (BEIS, 2022a). The pelagic larvae then drift passively with the currents towards nursery grounds (Dickey-Collas *et al.*, 2015, as cited in BEIS, 2022a).

Herring spawning grounds identified by Coull *et al.* (1998) and Ellis *et al.* (2012) overlap with the offshore Project area, as shown in section 3.1.1. The potential for herring spawning has been further examined using site-specific survey data, as described in section 2.3.2. The suitability of the sediments in the offshore Project area for herring spawning habitat, based on Marine Space (2013b) is shown in Figure 3-9 and detailed in Appendix B. The majority of sediment samples across the offshore Project area are classified as being unsuitable for herring spawning, mainly as a result of a low gravel content. However, there are areas within the OAA and in the northwest of the offshore ECC that are classified as being preferred (sub-prime or prime).

Larval herring abundance can also provide an indication as to whether spawning grounds are in use. The ICES programme of IHLS in the North Sea and adjacent areas has been in operation since 1967. The main purpose of this programme is to provide quantitative estimates of herring larval abundance, which are used as a relative index of changes of the herring spawning-stock biomass. This dataset also provides information regarding the number of larvae present within the areas surveyed during the IHLS survey campaigns. The number of larvae < 10 mm in length represent the number of 'newly hatched' larvae, and this can be used to inform the location or intensity of spawning grounds (ICES, 2022).

The density of newly hatched larvae within the Orkney / Shetland area during the 2018, 2019 and 2020 IHLS surveys are provided in Figure 3-10. The survey stations within the fish and shellfish offshore study area are located within ICES rectangles 46E6 and 47E6. It should be noted that the 2018 / 2019 survey was stopped early due to technical difficulties, and therefore, the coverage for the Orkney / Shetlands area is low for this year (ICES, 2020).

Overall, the larval abundance for the Orkney / Shetland area was low for the surveys conducted between 2018 and 2020, particularly on the west coast of Orkney near the offshore Project area (ICES, 2022; ICES 2021, ICES 2021). It is acknowledged that the abundance of herring larvae can vary considerably between years. However, the trend of low larval abundance, especially on the west coast of Orkney, can also be seen for previous years (2007 – 2016/2017) in the heat maps of newly hatched herring presented within Boyle and New (2018).

Taking the PSA data and IHLS data into account it is likely that herring spawning may occur within areas of the OAA, with the likelihood of herring spawning decreasing for the offshore ECC. Herring nursery grounds also overlap with the offshore Project area, and as described above, herring DNA was detected at three sample locations during the eDNA survey analysis. Herring also account for a relatively high proportion of commercial landings live weights in ICES rectangle 46E5 and 47E5, within which the OAA and the most easterly portion of the offshore ECC are located.

Due to the dependency of herring on specific spawning habitats, spawning grounds for herring are spatially limited, making herring potentially sensitive to seabed disturbance. Herring are also potentially sensitive to noise disturbance, as their swim bladder is connected to the inner ear, vibrations from the swim bladder are propagated to the ear (ICES, 2006a). This means that herring can detect sound pressure as well as particle motion, making them susceptible to barotrauma (Popper *et al.*, 2014).

Herring is a PMF and is listed as being of 'Least Concern' on the IUCN red list of threatened species.

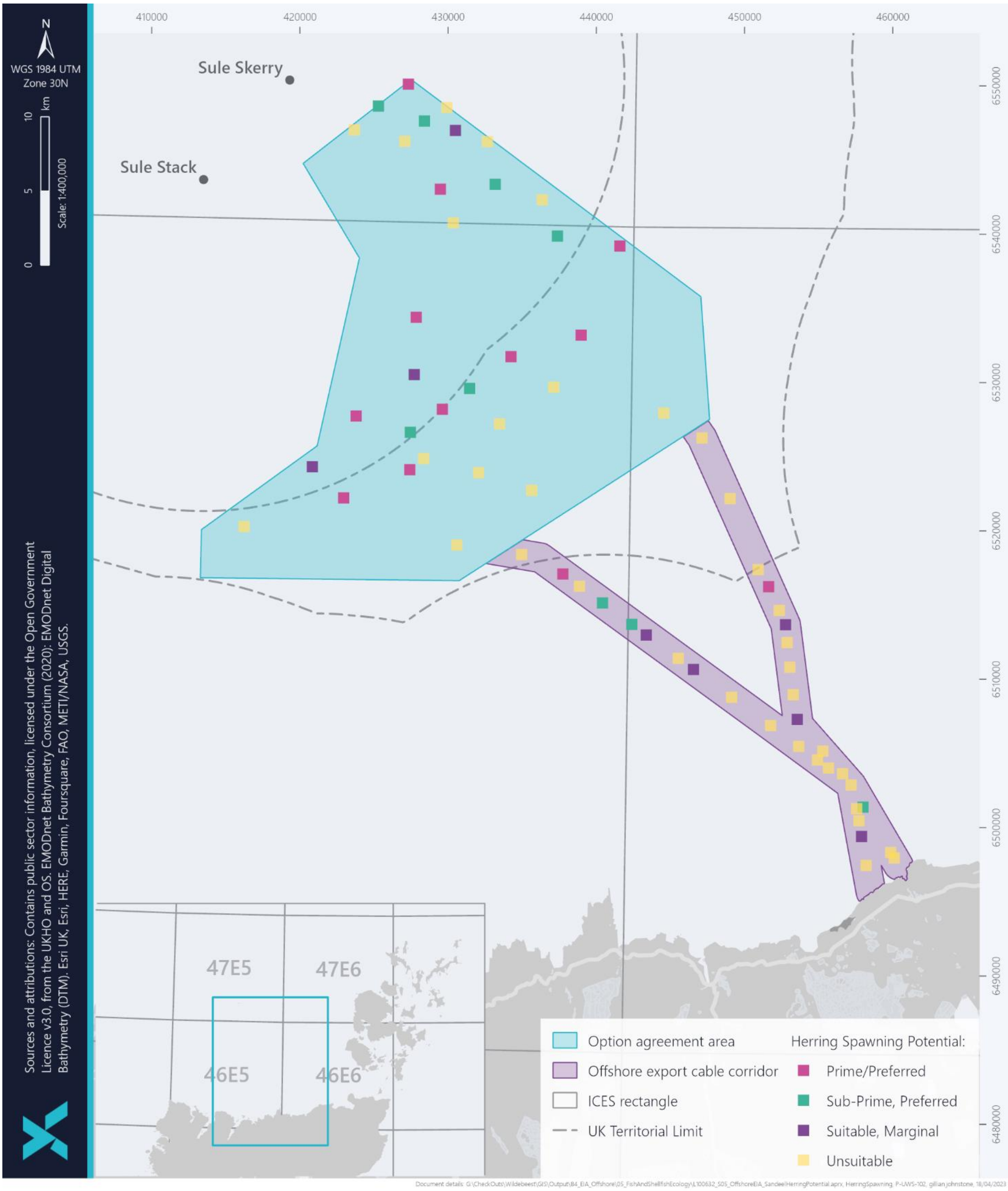
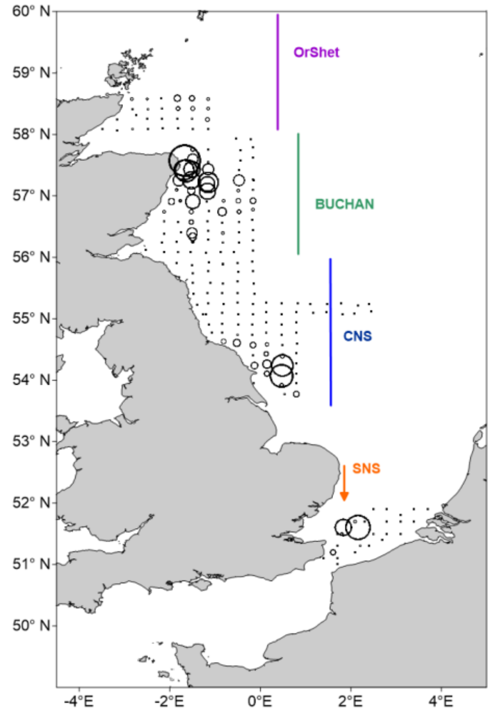
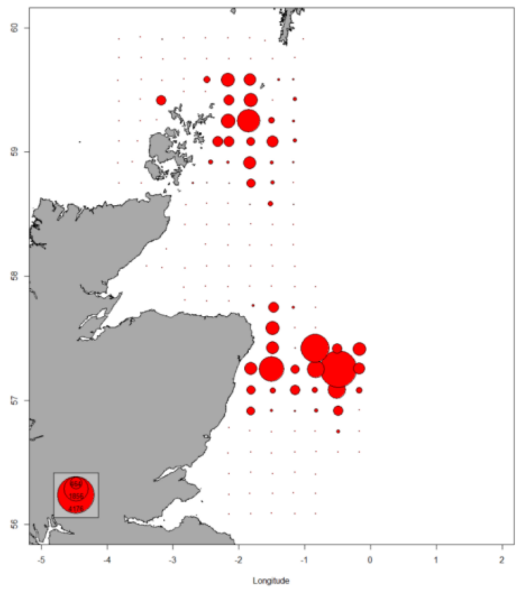


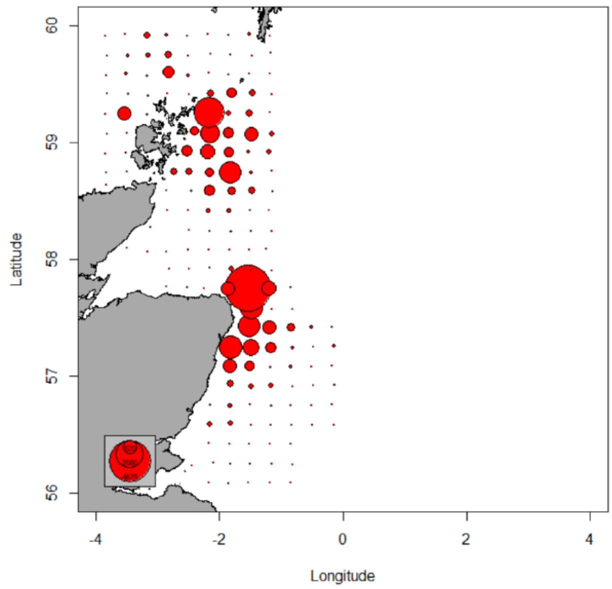
Figure 3-9 Herring spawning potential



a) September 2018



b) September 2019



c) September 2020

Figure 3-10 Abundance of herring larvae (<10 mm per m²) in the Orkney / Shetlands and Buchan area in a) September 2018 (maximum circle size = 3,500 larvae per m²), b) September 2019 (maximum circle size = 4,176 larvae per m², and c) September 2020 (maximum circle size-= 4,700 larvae per m²(ICES, 2022; ICES, 2021; ICES, 2020)

Sprat

Sprat are a small pelagic schooling species that are typically found in dense shoals within coastal waters of < 50 m water depth (BEIS, 202a2; ICES 2006b). Sprat abundance is highest within the southern North Sea, with lower densities expected in the waters off the north of Scotland (ICES, 2006b). However, sprat are a key prey resource for higher trophic levels, including large gadoids, salmonids, seabirds and marine mammals (BEIS, 2022a).

The offshore Project area overlaps with sprat spawning grounds. Sprat are broadcast spawners that release multiple pelagic egg batches within one spawning period which occurs between May and August (ICES, 2006b).

Similar to herring, as a clupeid, sprat also have a swim bladder that is connected to the inner ear and are potentially susceptible to barotrauma.

Sprat DNA was detected in several of the water samples subject to eDNA analyses. Sprat are not considered to be a key commercial species for the fish and shellfish ecology offshore study area and are not listed on any conservation legislation or biodiversity lists.

Demersal marine finfish

Sandeel

Sandeel are seabed dependent for the vast majority of their adult and juvenile lives and inhabit burrows except when feeding and spawning (Van Deurs *et al.*, 2011; Tien *et al.*, 2017). The greatest association with the seabed occurs during winter hibernation, when sandeels remain inactive within their burrows for extended periods of time, as a response to reduced prey availability, day length and temperature (Van Deurs *et al.*, 2010).

Sandeel spawning occurs between November and February (Coull *et al.*, 1998). Females lay demersal eggs on sandy substrates with a low silt content. Once the eggs hatch after several weeks, the larvae are pelagic for approximately two to five months (BEIS, 2022a).

Sandeel spawning usually occurs in sandy sediments with a high proportion of medium and coarse sand and a low silt content (BEIS, 2022a; Holland *et al.*, 2005). These specific spawning habitat requirements mean that spawning habitat availability is limited for sandeel. This, in conjunction with their demersal egg phase, makes this species vulnerable to any seabed disturbance that may alter its habitat availability.

Sandeel spawning grounds identified by Coull *et al.* (1998) and Ellis *et al.* (2012) overlap with the offshore Project area, as described above. Considering the vulnerability of sandeel to any impacts that may affect their spawning habitat availability, the potential for sandeel spawning has been further examined using site-specific survey data, as described in section 2.3.2.

The sediment samples across the offshore Project area were classified as sandy gravel, slightly gravelly sand, gravelly sand or sand. The sediment samples contained a high proportion of medium to coarse sand (250 µm – 2 mm) (average of 60.2%) and a relatively low silt content (average of 1.2%) (see SS5: Benthic environmental baseline report), indicating that there is the potential for preferred sandeel habitat (Holland *et al.*, 2005; Greenstreet *et al.*, 2010).

The suitability of the sediments in the offshore Project area for sandeel habitat, based on Marine Space (2013a, as cited in Marine Space Ltd, 2018) is shown in Figure 3-11 and detailed in Appendix B. As shown, a high proportion of the samples in the offshore ECC are classified as preferred sandeel habitat (either prime or sub-prime), especially within the eastern corridor option. Areas of the OAA are also classified as preferred (prime) sandeel habitat. However, it is important to note that this does not necessarily indicate a high abundance of sandeel.

It should also be noted that sandeel remain within close proximity to their spawning grounds for the majority of their life and also selectively inhabit areas of sandy sediments with low silt and gravel content as juveniles and adults (Holland *et al*., 2005; Wright *et al*., 2019). Therefore, the assessment of the suitability of the offshore Project area for sandeel spawning also reflects the suitability for sandeel burrows as juveniles and adults.

According to the recent distribution model developed by Langton *et al*. (2021) (which partially overlaps with the east of the offshore Project area), areas within the offshore Project area have a moderate to high probability of sandeel burrow presence, with a predicted density of buried sandeels which ranges from 0 to 42.5 per m^2, as shown on Figure 3-12. It should be noted that depth bias in the distribution model mean that the predictions for sandeel burrow density in waters over 70 m deep is less accurate.

Taking both the PSA data and the distribution model developed by Langton *et al*. (2021), it is likely that sandeel spawning grounds are present in both the offshore ECC and the OAA, although this distribution may be patchy and confined to areas of sandy substrate. Nursery grounds for sandeel also overlap the offshore Project area, and in addition, sandeel were also observed at 10 of the survey sample locations during the site-specific surveys and were detected through the eDNA survey analysis at several sample locations.

Due to the specific habitat requirements for their spawning habitat and burrows, sandeel are potentially sensitive to seabed disturbance. Sandeel also form an important component of the food-web, being a prey species for marine mammals and seabirds and acting at intermediate trophic levels to transfer energy from zooplankton to top predators (Frederiksen *et al*., 2006; BEIS, 2022a). For instance, breeding success in black-legged kittiwake and other seabirds has been linked to changes in sandeel populations. As sandeel have a high degree of site fidelity, they are vulnerable to local disturbance or habitat loss which can have onward impacts on the wider ecosystem (Furness and Tasker, 2000; Olin *et al*., 2020).

Sandeel are not of commercial importance but are a PMF species and a protected feature of the North West Orkney NCMPA approximately 11 km northeast of the OAA as described in section 3.2.4.

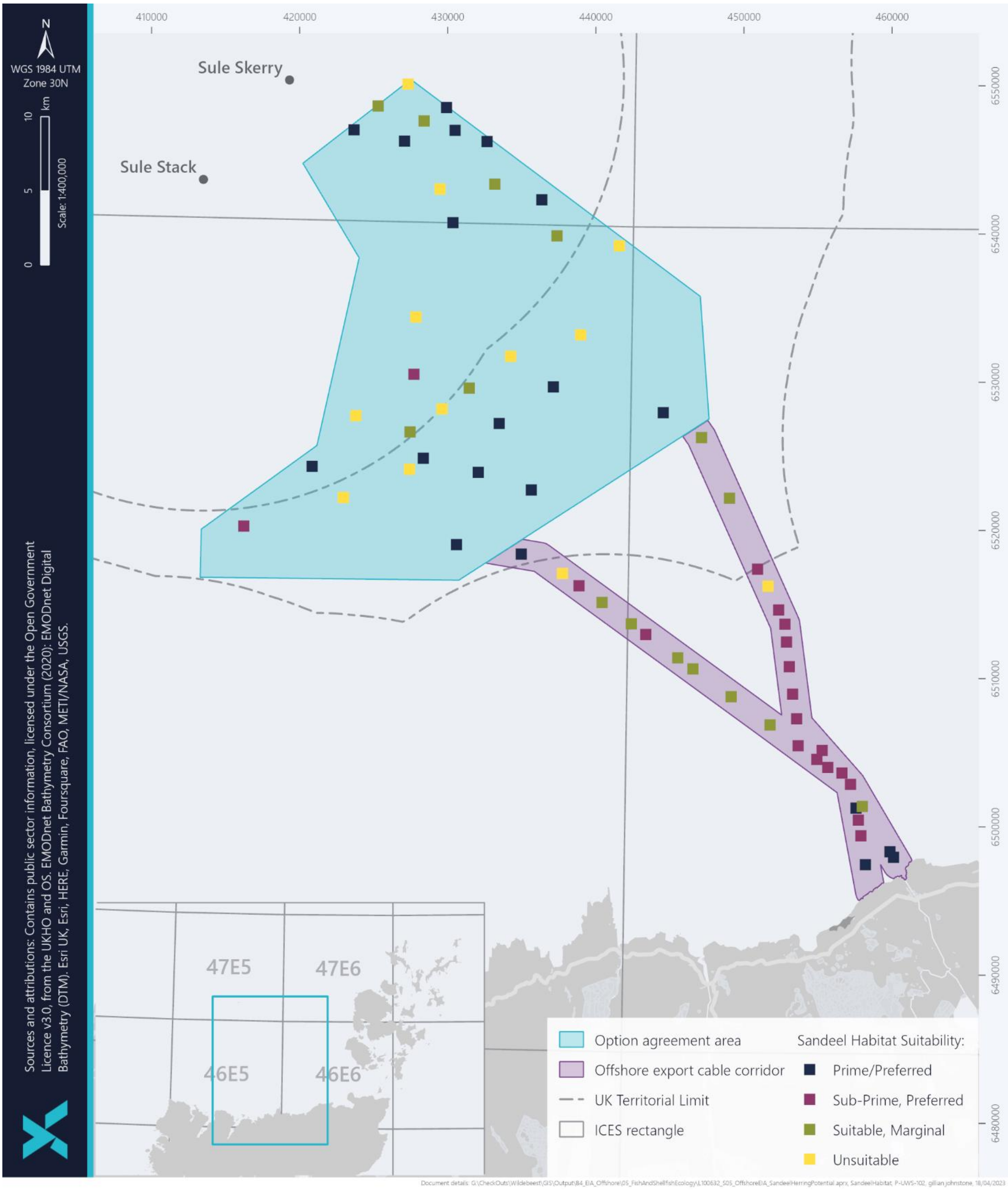


Figure 3-11 Sandeel habitat suitability

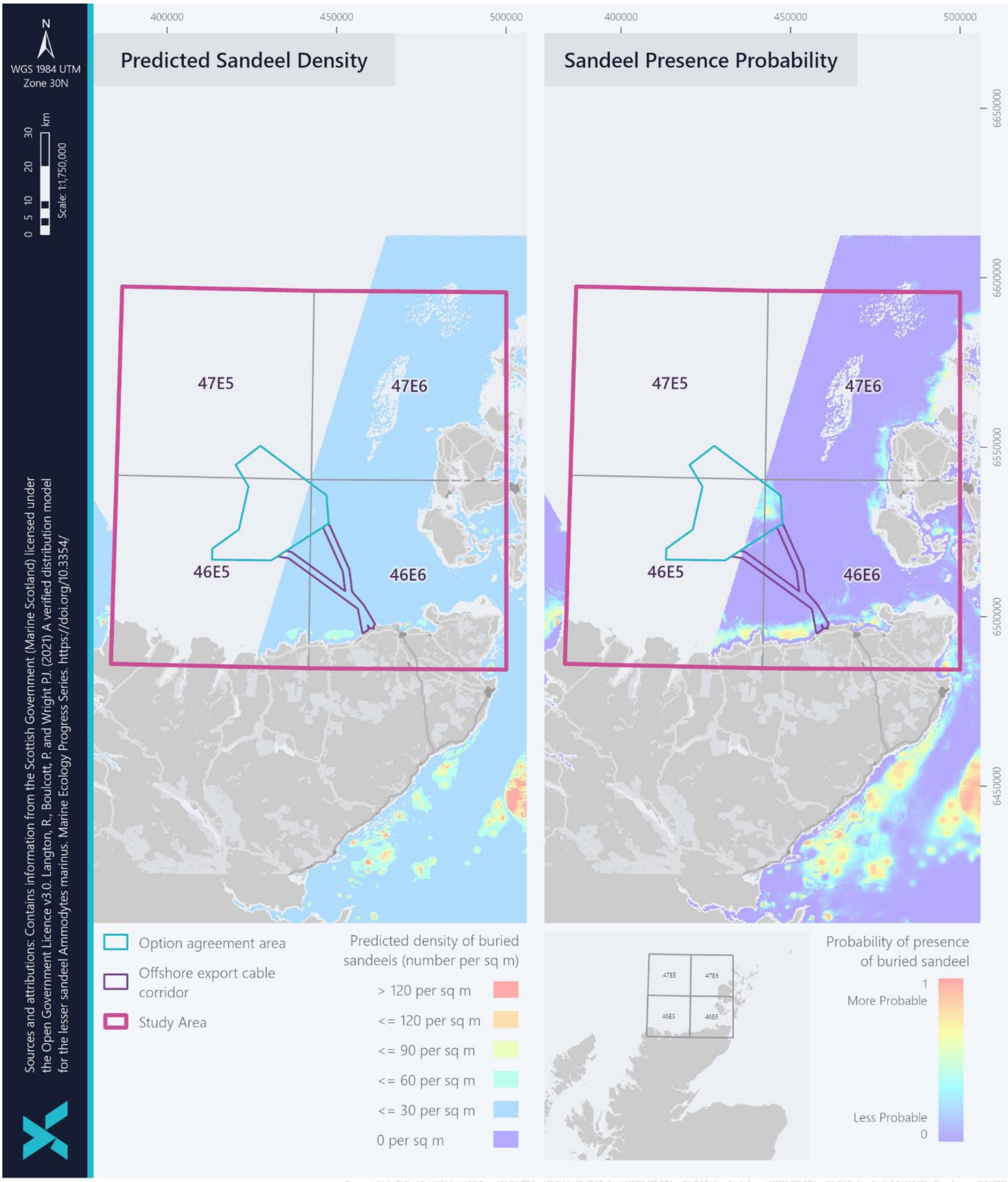


Figure 3-12 Sandeel a) predicted density of sandeel burrows (individuals per m²) and b) probability of presence (Langton et al., 2021)

Haddock

Haddock are a demersal gadoid species, mainly distributed in shoals at depths between 10 to 450 m. Haddock are mainly found in northerly latitudes, with a lower density in the southern North Sea. Larval haddock feed on small copepods, whereas adults predate larger copepods and small fish, such as sandeel and Norway pout. Juveniles may be predated on by other gadoid and demersal fishes, and larger adults may be taken by marine mammals (ICES, 2006c).

Spawning occurs between February and May, mainly at depths between 100 and 150 m, preferring highly saline waters in the northern North Sea and along the continental shelf edge off western Scotland (Gonzalez-Irusta and Wright; 2016a; BEIS, 2022a). The offshore Project area does not overlap with any of the spawning grounds for haddock identified by Coull *et al*., (1998) but areas within the offshore Project area were categorised as being of low to moderate importance for haddock spawning by Gonzalez-Irusta and Wright (2016b). Females lay pelagic eggs, spawning several batches over a single season (BEIS, 2022a). Pelagic eggs hatch within approximately three weeks (ICES, 2006c).

The offshore Project area also overlaps with low intensity nursery grounds for haddock and characterised by Aires *et al*., (2014) as having a moderate to high probability of 0-group fish, mainly within the offshore ECC. As 0-group juveniles, haddock remain pelagic for a short period of time before becoming demersal (ICES, 2006c).

Haddock were one of the most frequently detected species in the eDNA analysed from the water samples at the offshore Project area and contribute to a high proportion of landings across the fish and shellfish ecology offshore study area. Haddock is a commercially important species within the fish and shellfish ecology offshore study area, across all ICES rectangles. This species is listed as being of 'Least Concern' on the IUCN red list of threatened species.

Gadoids are less sensitive to underwater noise compared with herring and sprat. However, their swim bladder is in close proximity to the ear (although not connected) and therefore they are still potentially sensitive to underwater noise disturbance (Nedwell *et al*., 2004). Haddock also vocalise calls known as 'grunts' to conspecifics as a means of communication and these vocalisations may be masked by anthropogenic noise (Hawkins and Picciulin, 2019).

Cod

Cod are also a demersal gadoid species and have a wide distribution across UK waters over various habitat types, with a greater abundance in the northern North Sea than in the southern North Sea (ICES, 2006d; BEIS, 2022a). Cod mainly feed on copepods as larvae and juveniles, and their diet progresses to be dominated by fish as adults. Cod are a relatively large fish and are therefore not predated by a large number of other species. The main predators of cod include larger conspecifics, grey gurnards, and marine mammals (ICES, 2006d).

Cod are batch spawners, spawning several batches of pelagic eggs in a single spawning period, typically between January and February (ICES, 2006d). The offshore Project area does not overlap with any of the spawning grounds for cod identified by Coull *et al*., (1998) and Ellis *et al*., (2012) but areas within the offshore Project area were categorised as being of rare or occasional cod spawning grounds by Gonzalez-Irusta and Wright (2016a). The offshore Project area however does overlap with nursery grounds for cod. The data by Aires *et al.* (2014) indicates that offshore Project area is of relatively low probability for 0-group cod. However, larval cod have been recorded in high densities off the north coast of Scotland (BEIS, 2022a).

Cod were detected in the eDNA analysis of the water samples at the offshore Project area and also contribute to a relatively high proportion of the commercial landings live weights in ICES rectangles 46E6 and 47E6, in the east of the fish and shellfish ecology offshore study area. Cod are also listed on the OSPAR list of threatened and/or declining species and habitats, listed as 'Vulnerable' on the IUCN red list of threatened species, and are a PMF.

Cod are potentially sensitive to underwater noise as their swim bladder is located in close proximity to their inner ear (Nedwell *et al.*, 2004). Similar to haddock, as a gadoid, cod hearing sensitivity is expected to be less than that of herring and sprat. Cod also vocalise grunts as a means of communication, which may be masked by anthropogenic noise (Hawkins and Picciulin, 2019).

Whiting

Whiting are a demersal gadoid, typically found at depths between 10 and 200 m in a wide range of habitats across the North Sea (BEIS, 2022a). There are thought to be two separate populations to the north and south of Dogger Bank, and there may also be two separate inshore and offshore populations in the northern North Sea (Rogers and Stock, 2001). Whiting diet varies by season but mostly consists of small fish and crustaceans as adults, and zooplankton as larvae. Whiting are an important prey species for other gadoid and demersal fishes (including larger conspecifics) (ICES, 2006e).

The west of the offshore Project area overlaps with whiting spawning grounds (Ellis *et al*., 2012) and Gonzalez-Irusta and Wright (2017) categorised the east of the offshore Project area as being of low to moderate importance for spawning whiting. Whiting are batch spawners, shedding multiple batches of pelagic eggs over a single spawning period, typically between November and February (ICES, 2006e). The offshore Project area also overlaps with whiting nursery grounds, with a moderate probability of 0-group fish presence (Ellis *et al*., 2012; Aires *et al*., 2014). Whiting DNA was detected in several water samples retained for eDNA analyses and this species contributes to a moderate proportion of the commercial landings live weights in the fish and shellfish ecology offshore study area.

Whiting is listed as being of 'Least Concern' on the IUCN red list of threatened species and is a PMF species.

As for haddock and cod, whiting are gadoids and therefore potentially sensitive to underwater noise impacts.

Norway pout

Norway pout are a small gadoid species, typically found in large shoals at depths between 80 and 200 m (BEIS, 2022a; ICES, 2006f). Juveniles are more abundant in coastal waters, with adults moving to deeper waters over 100 m with increasing age. Adults and juveniles feed mainly on crustaceans. They are predated by a number of large fish, such as larger gadoids, but mackerel are their main predator (ICES, 2006f).

The offshore Project area overlaps with Norway pout spawning grounds and spawning typically occurs between January and April (peak spawning is February to March) (Coull *et al.*, 1998). Prior to maturing, individuals migrate towards the northern North Sea. Females in the north and north-western areas of the North Sea spawn pelagic eggs which drift in the water column towards the Skagerrak and Kattegat region. (Nash *et al.*, 2012; Institute of Marine Research, 2019). The western portion of the offshore Project area also overlaps with nursery grounds for Norway pout with a moderate to high probability of 0-group fish. In addition, Norway pout DNA was detected in the water samples subject to eDNA analyses.

This species is not of commercial importance for the fish and shellfish ecology offshore study area. Norway pout is PMF species and listed as being of 'Least Concern' on the IUCN red list of threatened species.

Monkfish / anglerfish

Monkfish, also known as anglerfish, is a species group including all fish species under the genus *Lophius*. The two key species within the UK include white-bellied (*Lophius piscatorius*) and black-bellied (*L. budegassa*) monkfish. Monkfish are a demersal species, typically found in the northern North Sea at depths up to 1,100 m (Rogers and Stocks, 2001). Monkfish feed on a variety of fish species, but have few predators (Institute of Marine Research, 2020).

Monkfish have not been identified as potentially spawning in the offshore Project area. However, monkfish nursery grounds overlap with the offshore Project area with low to moderate probability of 0-group fish, and this species was detected in one water sample analysed for eDNA. Monkfish also contribute to a high proportion of commercial landings live weights, particularly in ICES rectangle 47E6.

White-bellied monkfish is listed as a PMF species.

Saithe

Saithe are a demersal gadoid that occupy deep offshore waters over the continental shelf edge, concentrated as adults in the Skagerrak and Kattegat region, and as juveniles, within the shallower coastal habitats around Shetland and Orkney. Saithe mainly feed on copepods and other small pelagic organisms as juveniles, progressing towards a diet of larval and juvenile fish as adults, including herring, Norway pout and sandeel. Juvenile saithe form part of the diet of other gadoids, demersal fish, and marine mammals (ICES, 2006g).

The offshore Project area overlaps with low intensity nursery grounds for saithe (Ellis *et al.*, 2012). Saithe were not detected in the water samples analysed for eDNA. However, the higher taxonomic grouping Gadidae spp. made up a high proportion of the sequence reads in the vertebrate assay eDNA analysis. Saithe also contribute to a high proportion of the commercial landings live weights in ICES rectangle 47E5 and are the third most commercially important marine finfish species in this ICES rectangle. Saithe is also a PMF species.

As saithe are a gadoid, they are assumed to have a similar sensitivity to underwater noise as cod and haddock, as described previously.

Lemon sole

Lemon sole are a demersal flatfish that are mainly located on coarser sediments out to depths of 200 m (BEIS, 2022a). Lemon sole are concentrated off the coasts of northern Scotland and around Orkney, feeding on benthic invertebrates such as crustaceans and polychaete worms (Rogers and Stocks, 2001).

The offshore Project area overlaps with the spawning grounds of lemon sole and the spawning period is between May and October, peaking between May and August. Recent studies suggest that spawning may continue on until November (Geffen *et al.*, 2021). Lemon sole are not selective in their widespread spawning habitats, and they have pelagic eggs and larvae (Rogers and Stocks, 2001; Geffen *et al.*, 2021).

The offshore Project overlaps with nursery grounds for lemon sole and this species was detected in several water samples analysed for eDNA. Lemon sole are not of commercial importance in the offshore fish and shellfish ecology study area. This species is not listed on any conservation legislation and is not a PMF.

3.3 Shellfish

3.3.1 Overview

The shellfish species considered within this Report include larger crustaceans and molluscs, such as those of commercial importance. Smaller crustaceans, including sedentary habitat forming species (e.g. flame shells), are considered within SS4: Benthic intertidal and subtidal baseline report and within chapter 10: Benthic subtidal and intertidal ecology of the Offshore EIA Report.

3.3.2 Site-specific survey results

The identification of invertebrate species through eDNA analysis, such as shellfish, to species-level is limited by an incomplete genetic reference library. As a result, most invertebrate taxa are identified to higher taxonomic levels. One water sample contained eDNA identified as the decapod galatheidae family (e.g. porcelain crabs and some squat lobsters). However, it was noted that there is lower support for this classification as it was based on fewer than three matches to sequences in the reference database. Several bivalve mollusc taxa were identified in samples across the survey area including:

- *Hiatella spp.;*
- Cardiida spp.;
- *Limaria pellucida* (Antilliean file shell);
- Mytillidae spp. (e.g. mussels species);
- Nuculidae spp. (e.g. clams);
- Pectinida spp. (e.g. scallops); and
- Venerida spp. (venus clams).

Pectinida were observed most frequently out of the aforementioned shellfish taxa and were detected in 16 of the 20 samples. All other shellfish taxa were detected at less than five of the sample stations. In addition, the sediment samples collected at the offshore Project area contained 61 juvenile scallops (59 *Pectinidae* spp. and two *Aequipecten opercularis*) (see SS5: Benthic environmental baseline report).

The lack of brown crab in the eDNA results was unexpected, given the commercial importance of this species, as outlined below. However, this lack of eDNA does not necessarily equate to lack of presence. For instance, the lack of crab may be due to a sampling bias whereby eDNA from hard-shelled invertebrates is less numerous in the marine environment, as these organisms typically shed less DNA than softer-bodied organisms.

3.3.3 Commercially important species

20 shellfish species were landed from the ICES rectangles within the fish and shellfish ecology offshore study area. Table 3-3 displays the average live weights (2017 – 2021) for shellfish for the ICES rectangles within the fish and shellfish ecology offshore study area. Species are presented in descending order in terms of total live weights across the fish and shellfish ecology offshore study area, and only the top 10 commercially exploited shellfish species are listed. Appendix A presents the full list of average live weights (tonnes, 2017 – 2021) for the shellfish functional group.

Brown crab (*Cancer pagurus*) make up the majority of the shellfish average live weights (69% of all shellfish average live weights). Brown crab are followed by scallops (*Pecten maximus*) (mainly within ICES rectangle 46E6 and to a lesser extent 46E5) and velvet crabs (*Necora puber*). Overall, shellfish account for a greater proportion of the average live weights within the coastal ICES rectangles of 46E5, 46E6 and 47E6, with lower live weights associated with ICES rectangle 47E5.

Table 3-3 Average live weights (tonnes, 2017 – 2021) of commercially exploited shellfish from the ICES rectangles in the fish and shellfish ecology offshore study area (MMO, 2022)

SPECIES	AVERAGE LIVE WEIGHTS (TONNES)				
	46E5	46E6	47E5	47E6	TOTAL
Crabs (C.P.Mixed Sexes) (*Cancer pagurus*)	357.6	557.2	155.7	429.9	1,500.4
Scallops (*Pecten maximus*)	93.6	144.0	9.4	7.4	254.3
Crabs – velvet (swim) (*Necora puber*)	6.1	75.4	0.0	46.5	128.0
Whelks (*Buccinum undatum*)	0.9	90.4	0.0	5.4	96.8
Squid (Cephalopoda spp.)	43.9	10.1	9.4	11.4	74.7
Lobsters (Nephropidae spp.)	7.9	43.0	0.2	6.0	57.2
Nephrops (Norway lobster) (*Nephrops norvegicus*)	8.6	4.0	0.5	11.8	24.9
Green crab (*Carcinus maenas*)	1.4	19.7	0.0	2.4	23.4
Queen scallops (*Aequipecten opercularis*)	0.0	10.7	0.0	0.6	11.2
Mixed squid and octopi	1.5	0.2	0.7	1.0	3.3
Key					
(dark teal)	First ranking species in terms of average live weights for that ICES rectangle.				
(light blue)	Second ranking species in terms of average live weights for that ICES rectangle.				
(pale blue)	Third ranking species in terms of average live weights for that ICES rectangle.				

3.3.4 Species of conservation importance

There are no commercial shellfish species listed under conservation legislation or biodiversity lists. There are also no designated sites protected for shellfish within the fish and shellfish ecology offshore study area.

3.3.5 Key species accounts

This section describes the ecology of the key shellfish species potentially present within the fish and shellfish ecology offshore study area. The ecology of the species has been used to inform chapter 11: Fish and shellfish ecology within the Offshore EIA Report. However, it should be noted that for some impacts, species may not be considered on an individual basis but as a 'shellfish' functional group.

Brown crab

Brown crab (also known as edible crab) are typically found on bedrock habitats to depths up to 100 m, but can also inhabit offshore mixed coarse, sand and soft sediments. They feed as an active predator or scavenger on a variety of crustaceans and molluscs (Neal and Wilson, 2008). Dredge and trawl survey data indicate that female and male crabs have similar distributions across the North Sea, but female catch rates are slightly higher further offshore. Juveniles are predominantly distributed in shallower inshore habitats (Mesquita *et al.*, 2021).

Brown crab undertake wide-ranging migrations out to offshore overwintering grounds (Coleman and Rodrigues, 2017). Coleman and Rodrigues (2017) tagged male and female adult crabs within the 12 nm limit around Orkney between 2010 and 2016, recording the location of the recapture. Female brown crabs were observed to undertake both short inshore migrations and longer offshore migrations, out to 258 km from the original release site. Migrations were predominantly in a westward direction, and as shown on Figure 3-13, these routes overlap with the fish and shellfish ecology offshore study area. Male crab migrations were considerably shorter than females, with most remaining within 6 km of the original release site (Coleman and Rodrigues, 2017). The drivers behind the extensive female brown crab migration are still not known, but it is possible that female crabs are migrating towards brooding sites on the northwest of Scotland (Coleman and Rodrigues, 2017).

Brown crab spawning occurs between November and February (Edwards, 1979, as cited in BEIS, 2022a). During which 'berried' female crabs carry their eggs under their abdomen and are often found buried under sediment with limited mobility during this time. Larvae are released in early spring / summer and drift with the water current before settling in intertidal habitats (Neal and Wilson, 2008).

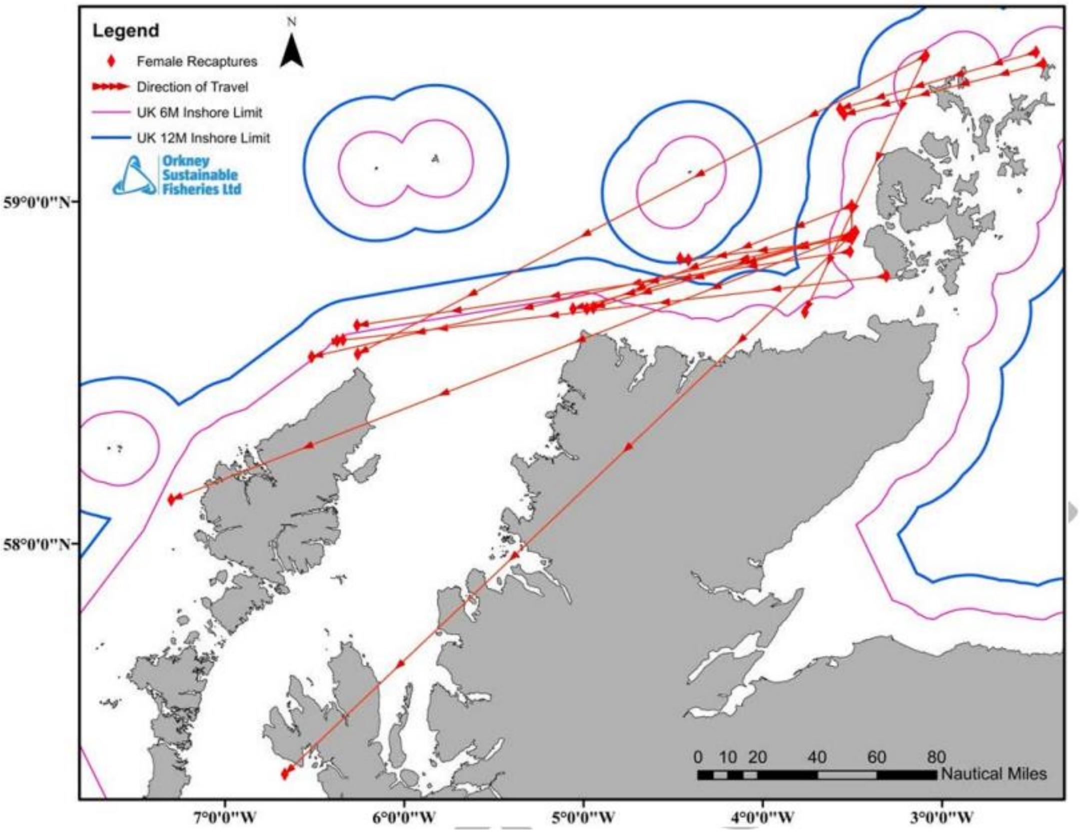


Figure 3-13 Female crab migratory routes (2010 – 2016) (Coleman and Rodrigues, 2017)

Shellfish stock assessments across 11 assessment areas in Scotland are used to inform fisheries management decisions. In the most recent stock assessments for crab, for 2016 to 2019, the male brown crab stocks in the Orkney and Sule assessment areas were categorised as having mortality above $F_{\text{Maximum Sustainable Yield (MSY)}}$[5], and female brown crab stocks were categorised as being at F_{MSY} in the Orkney assessment area and above F_{MSY} in the Sule assessment area. The Orkney assessment area covers ICES rectangles 47E6, 47E7, 46E6 and 46E7, extending to just beyond the 12 nm limit around the Orkney Islands. The Sule assessment areas covers ICES rectangles 46E5, 47E5, 48E5, 46E4, 47E4, 48E4, 37E2 and 48E2. Overall, nine of the 11 assessment areas were assessed at being above or at F_{MSY} for brown crab, indicating that the stocks are fully exploited or over exploited (Mesquita *et al.*, 2023). Similar results were also recorded for the 2013 to 2015 stock assessment for the Orkney assessment area (Marine Scotland, 2020). This Orkney brown crab fishery also failed to meet the Marine Stewardship Council (MSC) fishing standard in 2018 and now continues to be on a Fishery Improvement Project (FIP), aiming to reach the MSC fishing standard by 2027 (Fishery Progress, 2022).

Brown crab were not detected in the water samples analysed for eDNA. However, they account for a high proportion of the live weights throughout the fish and shellfish ecology offshore study area and are commercially important in the region.

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[5] *F_{MSY} is the fishing mortality that results in the largest yield that can be taken from a stock in the long term*

Brown crab are less mobile than fish and are potentially sensitive to seabed disturbance, especially berried females who remain mostly stationary (Neal and Wilson, 2008). Recent publications have also indicated that brown crab may be sensitive to Electromagnetic Fields (EMF), with high field strengths resulting in physiological effects such as larval deformities or behavioural effects (Harsanyi *et al.*, 2022; Scott *et al.*, 2021).

Scallops

Scallops are a mollusc predominantly found in the south and west of the UK down to depths of over 100 m, as well as along the Scottish coastline. Scallop distribution in UK waters is patchy, and they are typically found in aggregations on areas of seabed with clean sand, fine or sandy gravel away from areas of strong currents. Scallops are relatively immobile filter feeders and therefore rely on factors affecting the hydrographic regime for survival (Marshall and Wilson, 2008). Their patchy and aggregated distribution reflects the environmental factors required for survival.

Scallop spawning occurs in the summer. Pelagic larvae drift in the water column for approximately one month to then settle in aggregations on the seabed (Marshall and Wilson, 2008).

Feeding on phytoplankton and suspended detritus, scallops and inhabit shallow depressions (recesses) in the seabed (BEIS, 2022a; Marshall and Wilson, 2008). They have a limited mobility but can use jet propulsion as an escape reaction. Adults are largely sessile and therefore potentially sensitive to disturbance (Marshall and Wilson, 2008).

The offshore Project area overlaps with the Orkney scallop assessment area, which maintains a relatively small fishery when compared with other assessment areas around Scotland (Dobby *et al.*, 2017). As described in SS13: Commercial fisheries baseline report, Vessel Monitoring System (VMS) data indicates that scallop dredging is patchy within both the offshore ECC and OAA. However, higher areas of effort are located to the southwest of the OAA, potentially indicating a higher abundance or density of scallops in this area when compared with the offshore Project area itself.

Juvenile scallops were identified in the sediment samples obtained during the site-specific surveys and were detected in 16 of the 20 water samples analysed for eDNA. Scallops are of commercial importance within the fish and shellfish ecology offshore study area, especially in ICES rectangle 46E6.

Velvet crab

Velvet crabs are a fast-moving crab that can be found across the UK coastline, typically on stony or rocky substrates in shallow waters (Wilson, 2008). The larvae are pelagic and develop in deeper offshore waters (Rey *et al.*, 2015). The most recent Scottish stock assessment for Orkney indicates that both male and female crabs are fished at levels above F_{MSY} (Mesquita *et al.*, 2023).

Velvet crab were not detected in the water samples analysed for eDNA. However, velvet crab are of commercial importance within ICES rectangles 46E6 and 47E6.

Whelk

Whelks are carnivorous gastropod molluscs located in coastal environments. Whelks are mobile and are commonly found across the UK coastline. This species spawn eggs that attach to the seabed in November (BEIS, 2022a).

Whelks were not detected in the water samples analysed for eDNA. However, whelks are of commercial importance in ICES rectangle 46E6.

Squid

There are several squid species distributed throughout the UK, including long-finned squid, short-finned squid, bobtails, cuttlefish, and octopuses. The most frequently recorded squid within the fish and shellfish ecology study area are expected to include the long-finned squids, *Alloteuthis subulata* and *Loligo forbesii*; the short-finned squid, *Todarodes sagittatus*; *Gonatus fabricii* and *Onychoteuthis anguill*; the bobtail squids, *Rossia macrosoma*, *Sepiola atlantica* and *Sepietta oweniana*; the octopus, *Eledone cirrhosa* (BEIS, 2022b). Squid typically spawn inshore and then migrate further offshore (Shelmerdine and Mouat, 2021).

Squid were not detected in the water samples analysed for eDNA. As described in SS13: Commercial fisheries baseline report, it is understood through consultation that a coastal squid fishery is present approximately 25 km to the west of the offshore ECC. However, they are not expected to be commercially important within the offshore Project area itself.

3.4 Elasmobranchs

3.4.1 Overview

Elasmobranchs are cartilaginous fish, including sharks and skates. There are over 30 species of elasmobranchs present in Scottish waters, the most abundant being the small spotted catshark (*Scyliorhinus anguilla*) and nursehound (*Scyliorhinus stellaris*), spurdog (*Squalus acanthias*), tope shark (*Galeorhinus galeus*), thornback ray and cuckoo ray (*Leucoraja naevus*) (BEIS, 2022a; Baxter *et al.,* 2011). It should be noted that basking sharks (*Cetorhinus maximus*) are not included within this Report and are instead considered within chapter 12: Marine mammals and megafauna of the Offshore EIA Report.

A total of 13 elasmobranch species were landed within the fish and shellfish ecology study area between 2017 and 2021. The landings statistics, detailed in Appendix A, show that the average live weights for elasmobranchs are relatively low across the fish and shellfish study area. Small spotted catshark, spotted ray (*Raja montagui*) and thornback ray contribute to the highest average live weights.

The potential elasmobranch species present in the fish and shellfish ecology offshore study area can also be informed though the data recorded within the Shark Trust sightings database. The Shark Trust sightings database records locations of shark sightings across the world from 1994 to 2022, including sightings from individuals and organisations. These data are subject to survey effort, and therefore, cannot be used to inform density estimates, but is an important data source to understand the key species likely to be present in the region. Species sighted within the vicinity of the fish and shellfish ecology offshore study area, either though visual sightings in the water or strandings on beaches, include blue shark (*Prionace glauca)*, thresher sharks (*Alopias spp*.), blue skate (*Dipturus batis*), porbeagle (*Lamna nasus*) and small spotted catshark (Shark Trust, 2022a).

The Shark Trust has also been running the Great Eggcase Hunt since 2003 and the Orkney Skate Trust gathers data on *in situ* or washed up egg cases around Orkney, as described in section 2. The project involves individuals and organisations recording empty egg cases located on beaches or underwater. All skates and some sharks lay eggs within an egg case. The egg cases of the following species have been recorded in the vicinity of the fish and shellfish ecology offshore study area (ordered from most to least common) (Shark Trust, 2022b):

- Small spotted catshark;
- Flapper skate;
- Spotted ray;
- Thornback ray;
- Blonde ray (*Raja brachyura*);
- Cuckoo ray;
- Starry ray (*Amblyraja radiata*);
- Blue skate;
- Nursehound;
- Undulate ray (*Raja undulata*); and
- Small-eyed ray (*Raja microocellata*).

Elasmobranchs are slow to mature and have a low fecundity, leading to a relatively slow recovery to population level impacts (e.g. flapper skate take over 10 years to reach sexual maturity) (Baxter *et al.*, 2011; NatureScot, 2022a). Several elasmobranch species are oviparous and deposit egg cases that subsequently hatch, as detailed in sections 3.4.4 and 3.4.5. As a result of these egg cases being deposited on the seabed, they are sensitive to disturbance (NatureScot, 2022a). Furthermore, elasmobranchs are able to detect electric fields through electro-sensory receptors known as ampullae of Lorenzini for the detection of prey, conspecifics and predators (Gill *et al.*, 2005).

3.4.2 Site-specific survey results

During the site-specific surveys in August and September 2022, there were several visual observations of elasmobranch species, including:

- Flapper skate – one sample location (S84); and
- Thornback ray (*Raja clavata*) – one sample location (S35).

No elasmobranch DNA was identified in the water samples analysed for eDNA.

3.4.3 Species of conservation importance

Several elasmobranch species potentially present within the fish and shellfish ecology offshore study area are listed under conservation legislation or biodiversity lists. These are summarised in Table 3-4.

Table 3-4 Elasmobranch species of conservation importance

SPECIES	OSPAR	IUCN	PMF
Sharks			
Blue shark (*Prionace glauca*)	-	Near threatened	-
Tope shark (*Galeorhinus galeus*)	-	Critically endangered	-
Spurdog (*Squalus acanthias*)	✓	Vulnerable	✓
Porbeagle (*Lamna nasus*)	✓	Vulnerable	✓
Leafscale gulper shark (*Centrophorus squamosus*)	✓	Endangered	✓
Portuguese dogfish (*Centroscymnus coelolepis*)	✓	Near threatened	✓
Gulper shark (*Centrophorus granulosus*)	✓	Endangered	-
Skates			
Common skate (which includes flapper skate (*Dipturus intermedius*) and blue skate (*Dipturus batis*)	✓	Critically endangered	✓
Spotted ray (*Raja montagui*)	✓	Least concern	✓
Sandy ray (*Leucoraja circularis*)	-	Endangered	✓
Thornback ray (*Raja clavata*)	✓	Least concern	-
White skate (*Rostroraja alba*)	✓	Critically endangered	-

3.4.4 Sharks

The most abundant sharks in the UK include the lesser spotted dog fish, spurdog and the tope shark (BEIS, 2022a). small spotted catshark, nursehound, gulper shark (*Centrophorus granulosus*), blue shark, thresher sharks, and porbeagle were either recorded within the landings for the ICES rectangles within the fish and shellfish ecology offshore study area or within the Shark Trust sightings. Spurdog and tope shark also have nursery grounds that overlap the offshore Project area (Ellis *et al.*, 2012).

Sharks can employ a variety of reproductive strategies including (Baxter *et al.*, 2011):

- Oviparous: Egg laying;
- Ovoviviparous: Live young nourished by a yolk sac; and
- Viviparous: Live young nourished by a placental connection.

The characteristics of the key shark species potentially present within the fish and shellfish ecology offshore study area are included in Table 3-5.

Table 3-5 Characteristics of the key shark species expected to be present within the fish and shellfish ecology offshore study area (Baxter et al., 2011; MarLIN, 2022)

SPECIES	REPRODUCTIVE STRATEGY	HABITAT PREFERENCES	DISTRIBUTION IN SCOTTISH WATERS
Small spotted catshark (*Scyliorhinus canicula*)	Oviparous	Demersal species, present out to depths of 400 m	Widespread
Nursehound (*Scyliorhinus stellaris*)	Oviparous	Demersal species, present on rocky substrates out to 125 m	Widespread
Spurdog (*Squalus acanthias*)	Ovoviviparous	Demersal species, present at depths out to 900, mostly 10 to 200 m	Widespread
Tope shark (*Galeorhinus galeus*)	Ovoviviparous	Demersal species, out to depths of 550, typically off the continental shelf	Widespread
Blue shark (*Prionace glauca*)	Viviparous	Mid-water species, typically to depths to 600 m	Annual migration through Scottish waters
Porbeagle (*Lamna nasus*)	Ovoviviparous	Mid-water species, typically found in depths between 200 and 700 m	Widespread
Leafscale gulper Shark (*Centrophorus squamosus*)	Ovoviviparous	Demersal species, present at depths out to 1,000 m	Off the north and west coast of Scotland
Portuguese dogfish (*Centroscymnus coelolepis*)	Ovoviviparous	Demersal species, typically found in deep waters offshore at depths between 400 and 2,700 m	Off the north and west coast of Scotland
Gulper shark (*Centrophorus granulosus*)	Ovoviviparous	Demersal species at depths out to 1,200 m	Rare
Thresher sharks (*Alopias spp.*)	Ovoviviparous	Offshore waters over 330 m deep	Rare

3.4.5 Skates

General

The most widespread skates within the UK include the thornback ray and cuckoo ray. Spotted ray, thornback ray, cuckoo ray, flapper skate, undulate ray, white skate (*Rostroraja alba*), starry ray, blonde ray, small-eyed ray, and blue skate were either recorded in the ICES landings statistics within the fish and shellfish ecology offshore study area or within the Shark Trust sightings. Spotted ray and thornback ray nursery grounds overlap with the offshore Project area (Ellis *et al.*, 2012).

The characteristics of the key skate species potentially present within the fish and shellfish ecology offshore study area are included in Table 3-6. All skates are oviparous.

Table 3-6 Characteristics of the key skate species expected to be present within the fish and shellfish ecology offshore study area (Baxter et al., 2011; MarLIN, 2022; Froese and Pauly, 2022)

SPECIES	HABITAT PREFERENCES	DISTRIBUTION IN SCOTTISH WATERS
Thornback ray (*Raja clavata*)	Various habitat types at depths between 10 and 300 m	Widespread
Spotted ray (*Aetobatus narinari*)	Soft substrates at depths out to 530 m	Widespread
Cuckoo ray (*Leucoraja naevus*)	Various habitat types at depths between 20 and 50 m	Widespread
Flapper skate (*Dipturus intermedius*)	Typically found between depths of 20 and 225 m	Concentrated on the west of Scotland and in the waters around Orkney and Shetland
Blue skate	Typically found on sandy seabed at depths between 100 and 600 m.	Distributed from Celtic sea to Northwest Scotland with highest densities in the south of the UK.
White skate (*Rostroraja alba*)	Typically found over sandy sediments at depths between 30 and 600 m	Rare
Starry ray (*Amblyraja radiata*)	Soft sediments at depths between 18 and 1,400 m	Widespread
Blonde ray (*Raja brachyura*)	Soft sediments at depths between 10 and 900 m	Widespread
Small-eyed ray (*Raja microocellata*)	Coastal species, occupying sandy substrates to depths of up to 100 m	Rare
Undulate ray (*Raja undulata*)	Sandy substrates at depths between 50 and 200 m	Rare
Sandy ray (*Leucoraja circularis*)	Offshore sandy or muddy areas at depths from 70 to 275 m	Widespread, but mainly to the northwest of Scotland

Flapper skate

The potential importance of the offshore Project area for flapper skate was highlighted in the Marine Scotland Licensing Operations Team (MS-LOT)[6] Scoping Opinion and during consultations with NatureScot (MS-LOT, 2022a). Flapper skate, which are categorised as critically endangered by the IUCN, are relatively rare across the UK, but have a high abundance on the west coast of Scotland and around Orkney and Shetland. Following years of overexploitation, flapper skate are now extinct across large extents of their natural range (NatureScot, 2022a).

[6] *MS-LOT have since been renamed Marine Directorate Licensing Operations Team (MD-LOT)*

Overall, the understanding of the ecology and behaviour of juvenile and adult flapper skate in Scotland is limited (NatureScot, 2021). It is understood that flapper skate typically occupy waters at depths between 20 and 225 m and recent research on the west coast of Scotland indicates a migration to shallower waters (25 – 75 m) in winter months and a higher occupancy of deep waters (100 – 150 m) over summer. An inverse relationship between size and depth has also been observed, with larger females occupying shallower waters in winter. These movements may relate to females migrating to shallow and sheltered locations for egg laying (Thorburn *et al.*, 2021).

A recent publication by McGeady *et al*. (2022) describes the spatial and temporal distribution of common skate (including flapper skate and blue skate), using publicly available ICES groundfish trawl survey data across the North east Atlantic (where flapper skate are primarily recorded in the trawl surveys in the west coast of Scotland and in the North Sea and blue skate are primarily recorded in the Irish and Celtic Seas). The trawl survey data were combined with environmental predictor variables, such as depth, temperature, salinity and current velocity to develop Generalised Additive Models (GAMs) to predict the distribution of common skate across the North East Atlantic. These data indicate that the maximum probability of common skate presence occurred in areas of 75 – 300 m depth 32.5 Practical Salinity Unit (PSU) salinity, 9 – 11 °C temperature and at low (<0.02 m/s) and high (>0.15 m/s) current velocities (McGeady *et al*., 2022). Figure 3-14 shows the modelled distribution of flapper skate between 2018 and 2020, indicating a low probability of presence within the OAA and a higher probability of presence in the offshore ECC. For temporal variation, McGeady *et al.* (2022) demonstrate that the probability of presence for common skate increased from 2003 to 2020 across areas in the north and north west Scotland, indicating a potential recovery for these species in these areas.

Flapper skate reach maturity at around 10 years and have a relatively low fecundity, laying large eggs (10 – 14 cm in width) within a tough egg case (NatureScot, 2022a). There is considered to be the potential for flapper skate spawning based on the available site-specific data. Females can lay approximately 0.24 – 1 eggs a day, and with an estimated fecundity of approximately 40 eggs per year, females may be present on egg laying grounds for up to approximately 160 days per year (Thorburn *et al*., 2021). The eggs are typically laid in sheltered locations between boulders and eggs hatch approximately 18 months after egg-laying (NatureScot, 2021).

As described in section 2.3.2, flapper skate prefer boulder or rocky substrates at a depth of > 20 m with a moderate current flow (0.3 to 2.8 knots) for their egg laying (Phillips *et al.,* 2021). They appear to lay their eggs in crevices between boulders and rocks (NatureScot, 2021).

SS3: Marine physical and coastal processes supporting study details the physical environment for the majority of the OAA and the offshore ECC, mean peak flows at spring tide are expected to range between 0.5 m/s and 1.0 m/s, reducing to less than 0.5 m/s during neap tide. Therefore, the current flows are considered to be consistent with the preferred egg laying habitat characterised by Phillips *et al*. (2021) (0.15 m/s to 1.44 m/s).

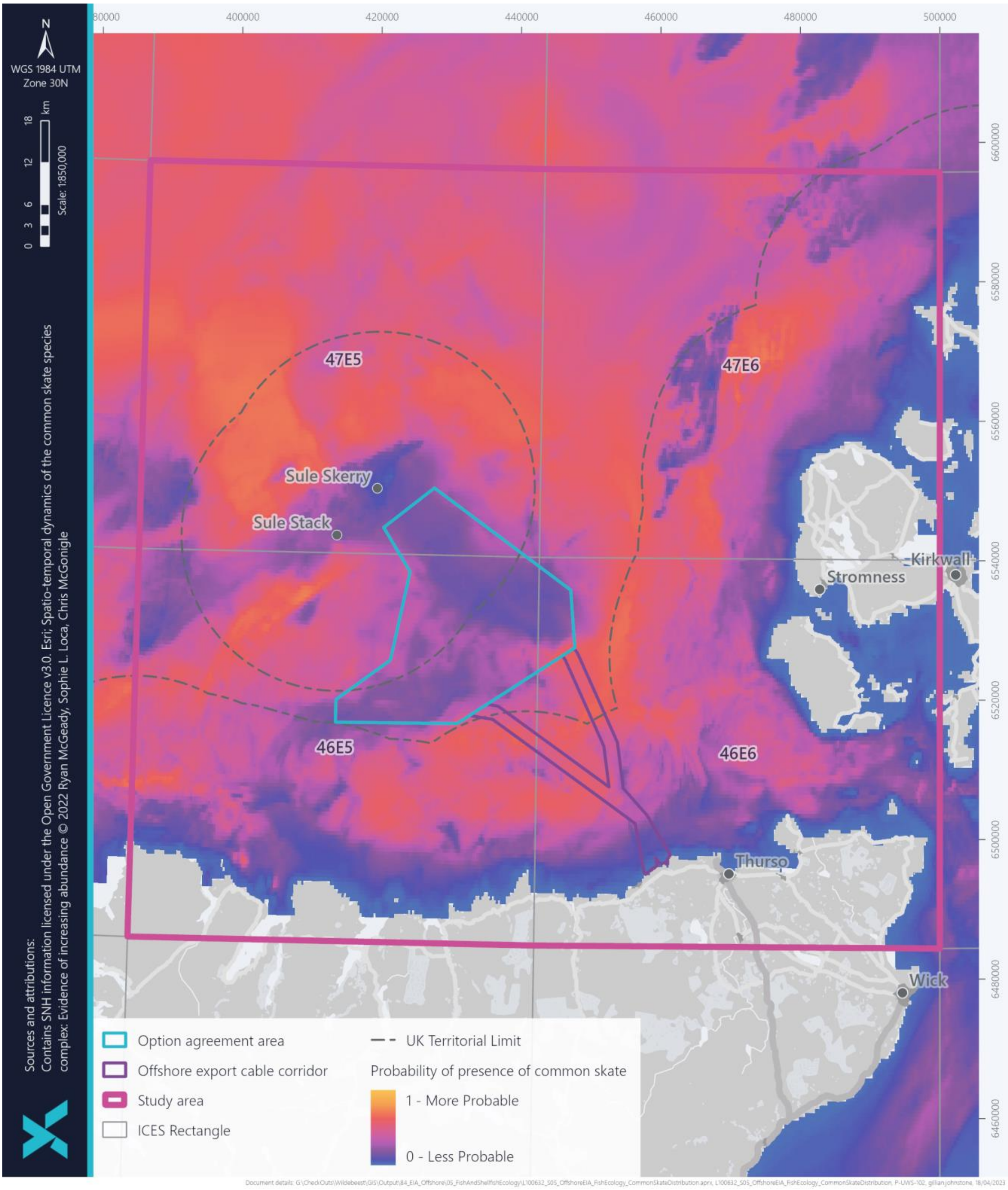

Figure 3-14 Probability of common skate presence (2018 – 2020) (McGeady, 2022)

Table 3-7, Figure 3-15 and Figure 3-16 detail the benthic habitats identified within the OAA and offshore ECC during the site-specific surveys. Those which contain rocky substrates include:

- Atlantic infralittoral rock – which makes up 1% of the offshore ECC; and
- Atlantic circalittoral rock – which makes up 18% of the OAA and 7% of the offshore ECC.

In addition, areas of boulders and cobbles were identified across the offshore Project area associated with MC42 – Atlantic circalittoral mixed sediment. MC42 is the most dominant habitat type in the OAA (37%) and also covers approximately 22% of the offshore ECC.

Table 3-7 Benthic habitats present within the OAA and offshore ECC (SS5: Benthic environmental baseline report)

BENTHIC HABITAT	COVERAGE WITHIN OAA (km^2)	COVERAGE WITHIN OFFSHORE ECC (km^2)	% OF TOTAL AREA
MB12 – Atlantic infralittoral rock	0.00 (0%)	1.3 (1%)	0.2%
MC12 – Atlantic circalittoral rock	118.18 (18%)	8.47 (7%)	16%
MC32 – Atlantic circalittoral coarse sediment	167.71 (26%)	11.25 (9%)	23%
MC32 – Atlantic circalittoral coarse sediment/ MC52 – Atlantic circalittoral sand	41.21 (6%)	17.06 (14%)	8%
MC42 – Atlantic circalittoral mixed sediment	241.57 (37%)	27.6 (22%)	35%
MC52 – Atlantic circalittoral sand	86.99 (13%)	56.94 (47%)	19%
MC52 – Atlantic circalittoral sand / MC12 – Atlantic circalittoral rock	0.00 (0%)	0.14 (0.1%)	<0.1%

Within the OAA, the seabed is characterised mainly by dense cobbles, boulders and rocky substrates (Atlantic circalittoral rock) which are consistent with potential flapper skate egg laying habitat. Depths within this region range from 45 to 99 m, which are over the 20 m threshold for flapper skate egg laying habitat defined by Phillips *et al.* (2021). It has been indicated that flapper skate have a preference to lay eggs in water depths between 25 and 50 m, particularly in the deeper waters of this range, as this is adjacent to the deeper water waters that are preferred by adult flapper skate (100 – 200 m) (NatureScot, 2021; Thorburn *et al.*, 2018). Areas with finer sediments (Atlantic circalittoral coarse sand and Atlantic circalittoral sand) in the south and northeast of the OAA are likely to be less preferred for flapper skate egg laying.

Within the offshore ECC, depths range from 44 m to 110 m. There are patches of rocky substrate such as Atlantic infralittoral rock and Atlantic circalittoral rock interspersed with Atlantic circalittoral mixed sediment with dense cobbles and boulders which may potentially act as flapper skate egg laying habitat concentrated within the mid-sections of the offshore ECC. Areas of finer sandy sediment (Atlantic circalittoral coarse sand and Atlantic circalittoral sand) are also present in the northeast, west and southern sections of the offshore ECC which may be less preferred by flapper skate.

Flapper skate are potentially sensitive to seabed disturbance or alterations to their preferred egg-laying habitats (NatureScot, 2021). As described above, both the OAA and offshore ECC have areas which contain rocky substrate or boulders at depths over 20 m and current flows which are considered suitable for flapper skate egg laying. Therefore, it is likely that flapper skate egg laying habitat may be present. However, it is important to re-iterate that the predicted habitat preferences of flapper skate, described by Phillips *et al*. (2021) and Nature Scot (2021), are relatively broad and indicate the potential presence of flapper skate egg laying grounds, rather than actual locations. Furthermore, the data from McGeady *et al*. (2022) also indicate that the probability of flapper skate presence is relatively low within the OAA and in the nearshore areas .

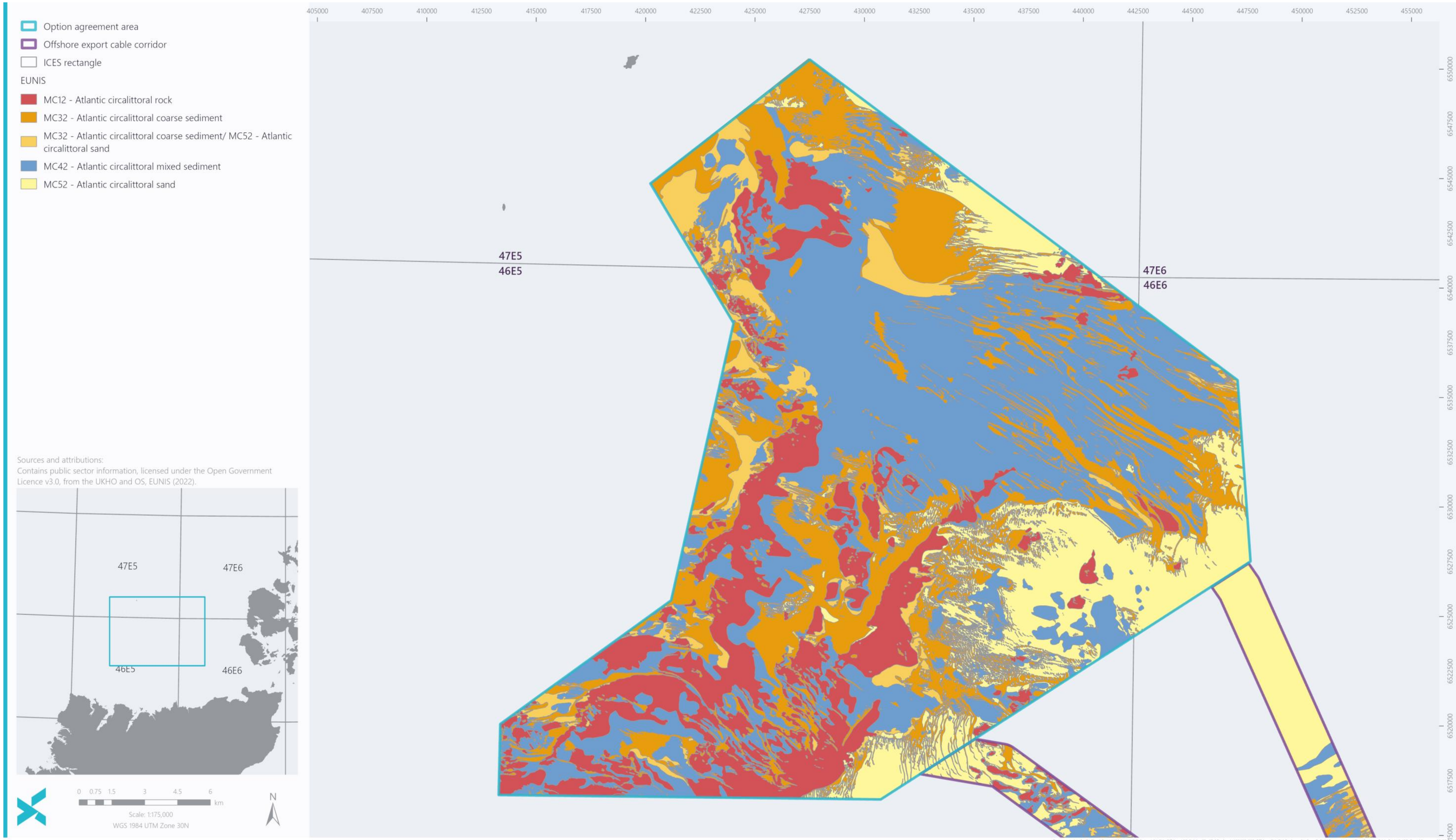

Figure 3-15 Distribution of habitats within the OAA (SS5: Benthic environmental baseline report)

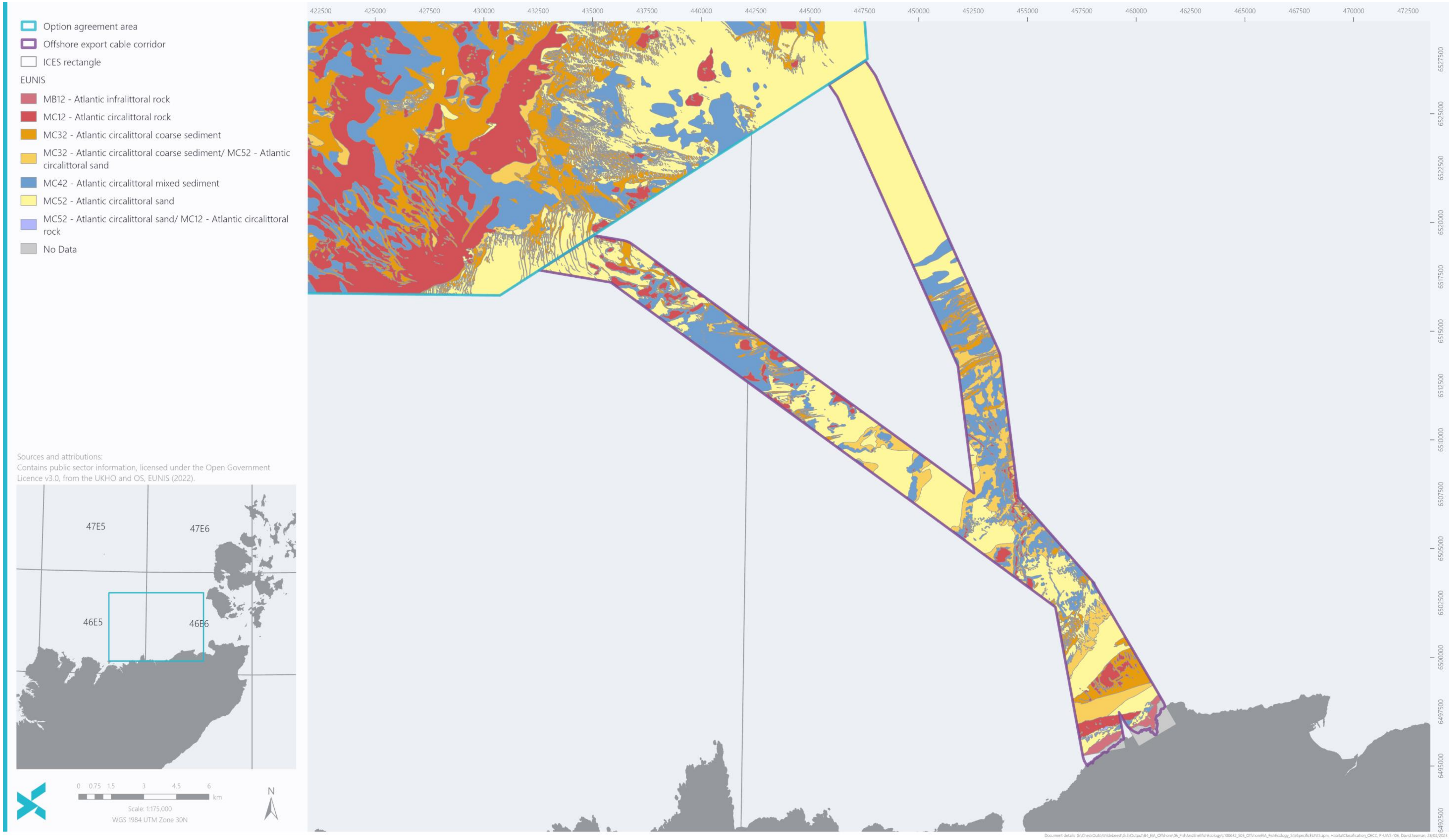

Figure 3-16 Distribution of habitats within the offshore ECC (SS5: Benthic environmental baseline report)

3.5 Diadromous fish and associated features

Diadromous fish are fish that migrate between freshwater and marine environments to fulfil their lifecycle. Diadromy takes several forms, but here a focus is placed on anadromy – where a species migrates from marine waters to freshwater to spawn (salmonids, lamprey) and catadromy – where a species migrates from freshwater to spawn in seas and oceans (European eel).

The eDNA surveys did not identify any diadromous fish as being present at the time of the survey. However, this does not indicate that diadromous fish are absent from the offshore Project area, as the design of the eDNA survey provides a snapshot of the species present at the time of the survey only.

Diadromous fish are exposed to a range of pressures during their migration, including both in riverine and marine environments (e.g. commercial and recreational exploitation, climate change and disease). Furthermore, as diadromous fish perform outward and homing migrations which may rely on specific environmental cues, they are potentially sensitive to any barriers to their migration. Diadromous fish are also potentially sensitive to changes in predator distributions and abundance that may reduce juvenile or adult survival during their migrations, and this was highlighted in the MS-LOT Scoping Opinion and subsequent consultation (MS-LOT, 2022a).

Atlantic salmon and sea trout are potentially susceptible to barotrauma from underwater noise. However, as their swim bladder is not connected to the inner ear, they are sensitive to particle motion, but not sound pressure (Popper *et al.*, 2014). European eel are expected to only be able to detect particle motion, due to the long distance between the swim bladder and the inner ear (Jerkø *et al*., 1989). Therefore, they are not considered to be as sensitive as some other fish species (e.g. herring).

Diadromous fish do not possess specialist magnetic receptor cells. Instead within their skeletal structure contains magnetically sensitive material and they may use EMFs as a navigational tool for migration (Gill and Bartlett, 2010).

3.5.1 Conservation importance

All diadromous fish found in UK waters are protected by conservation legislation and/or are listed on biodiversity action lists. The conservation status of the diadromous fish species potentially present within the fish and shellfish ecology offshore study area is summarised in Table 3-8, as indicated by BEIS (2022a). European smelt (*Osmerus eperlanus*), allis shad (*Alosa alosa)* and twaite shad (*Alosa fallax*) are the other key diadromous fish species in the UK but are rarely recorded in Scottish waters (NatureScot, 2022b; NatureScot, 2022c).

Table 3-8 Conservation status of diadromous fish and associated features

SPECIES	OSPAR	IUCN	BERN CONVENTION	HABITATS REGULATIONS[7]	SALMON ACT[8]	PMF
Atlantic salmon (*Salmo salar*)	✓	Least concern	✓	✓	✓	✓
Sea trout (*Salmo trutta*)		Least concern	-	-	✓	✓
Sea lamprey (*Petromyzon marinus*)	✓	Least concern	✓	✓	-	✓
River lamprey (*Lampetra fluviatilis*)	-	Least concern	✓	✓	-	✓
European eel (*Anguilla anguilla*)	✓	Critically endangered	-	-	-	✓
<Redacted>	-	Endangered	-	✓	-	-

The designated sites protecting Atlantic salmon (*Salmo salar*) and <Redacted> that have potential connectivity with the offshore Project are included in Table 3-9 and Figure 3-17, where connectivity means there is the potential for a qualifying feature of the designated site to overlap with the offshore Project or wider zone of influence associated with the effects of the offshore Project. This list of designated sites was identified as part of the Habitats Regulations Appraisal (HRA) screening process and is presented within the West of Orkney Windfarm Offshore HRA Screening Report (OWPL, 2022) and response from MS-LOT, Fisheries Management Scotland, Caithness DSFB, Northern DSFB, North and West DSFB, NatureScot and the Royal Society for the Protection of Birds Scotland (RSPB Scotland) was received in November 2022 (MS-LOT, 2022b). Typically, an assessment of the potential effects of the offshore Project on the designated sites themselves would form part of the HRA process. However, as outlined in the Offshore Report to Inform Appropriate Assessment (RIAA), feedback from NatureScot stipulated that impacts on Atlantic salmon and <Redacted> should be considered within the EIA only and not as part of the HRA. Furthermore, potential connectivity with designated sites with sea lamprey (*Petromyzon marinus*) and river lamprey (*Lampetra fluviatilis*) as qualifying features were screened out through the HRA screening process. Therefore, the Offshore EIA Report will assess any effects on Atlantic salmon, <Redacted> and lamprey species in EIA terms, but not on the designated sites themselves as agreed with MS-LOT in their response to the Offshore HRA Screening Report and subsequent consultation (MS-LOT, 2022b).

The only potential pathway for an effect on <Redacted> will be indirect effects to Atlantic salmon, due to the direct relationship between salmonids and <Redacted> (as described in section 3.5.2). For Special

[7] *The Conservation (Natural Habitats, &c.) Regulations 1994 and the Conservation of Offshore Marine Habitats and Species Regulations 2017*
[8] *The Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003*

Areas of Conservation (SACs) designated for <Redacted> where Atlantic salmon are not listed as a qualifying feature / interest, indirect effects as a result of effects to Atlantic salmon will also be assessed.

Table 3-9 SACs designated for diadromous fish interests with potential connectivity with the offshore Project

SPECIAL AREA OF CONSERVATION (SAC)	QUALIFYING FEATURES
River Thurso SAC	• Atlantic salmon
River Borgie SAC	• Atlantic salmon; and • <Redacted>
River Naver SAC	• Atlantic salmon; and • <Redacted>
Berriedale and Langwell Waters SAC	• Atlantic salmon
Langavat SAC	• Atlantic salmon
North Harris SAC	• Atlantic salmon; and • <Redacted>
River Oykel SAC	• Atlantic salmon; and • <Redacted>
Little Gruinard River SAC	• Atlantic salmon
River Spey SAC	• Atlantic salmon; • <Redacted> and • Sea lamprey.
River Moriston SAC	• Atlantic salmon; and • <Redacted>
River Dee SAC	• Atlantic salmon; and • <Redacted>
River South Esk SAC	• Atlantic salmon; and • <Redacted>
River Tay SAC	• Atlantic salmon; • Brook lamprey; • River lamprey; and • Sea lamprey.
River Teith SAC	• Atlantic salmon; • Brook lamprey; • River lamprey; and • Sea lamprey.
Endrick Water SAC	• Atlantic salmon; • Brook lamprey; and • River lamprey.
River Tweed SAC	• Atlantic salmon; • Brook lamprey; • River lamprey; and • Sea lamprey.
River Bladnoch SAC	• Atlantic salmon

SPECIAL AREA OF CONSERVATION (SAC)	QUALIFYING FEATURES
Foinaven SAC	• <Redacted>
River Evelix SAC	• <Redacted>
Abhainn Clais an Eas and Allt A'mhuilinn SAC	• <Redacted>
Ardnamurchan Burns SAC	• <Redacted>
Mingarry Burn SAC	• <Redacted>
River Kerry SAC	• <Redacted>
River Moidart SAC	• <Redacted>
Ardvar and Loch a' Mhuilinn Woodlands SAC	• <Redacted>
Glen Beasdale SAC	• <Redacted>
Inverpolly SAC	• <Redacted>
Rannoch Moor SAC	• <Redacted>

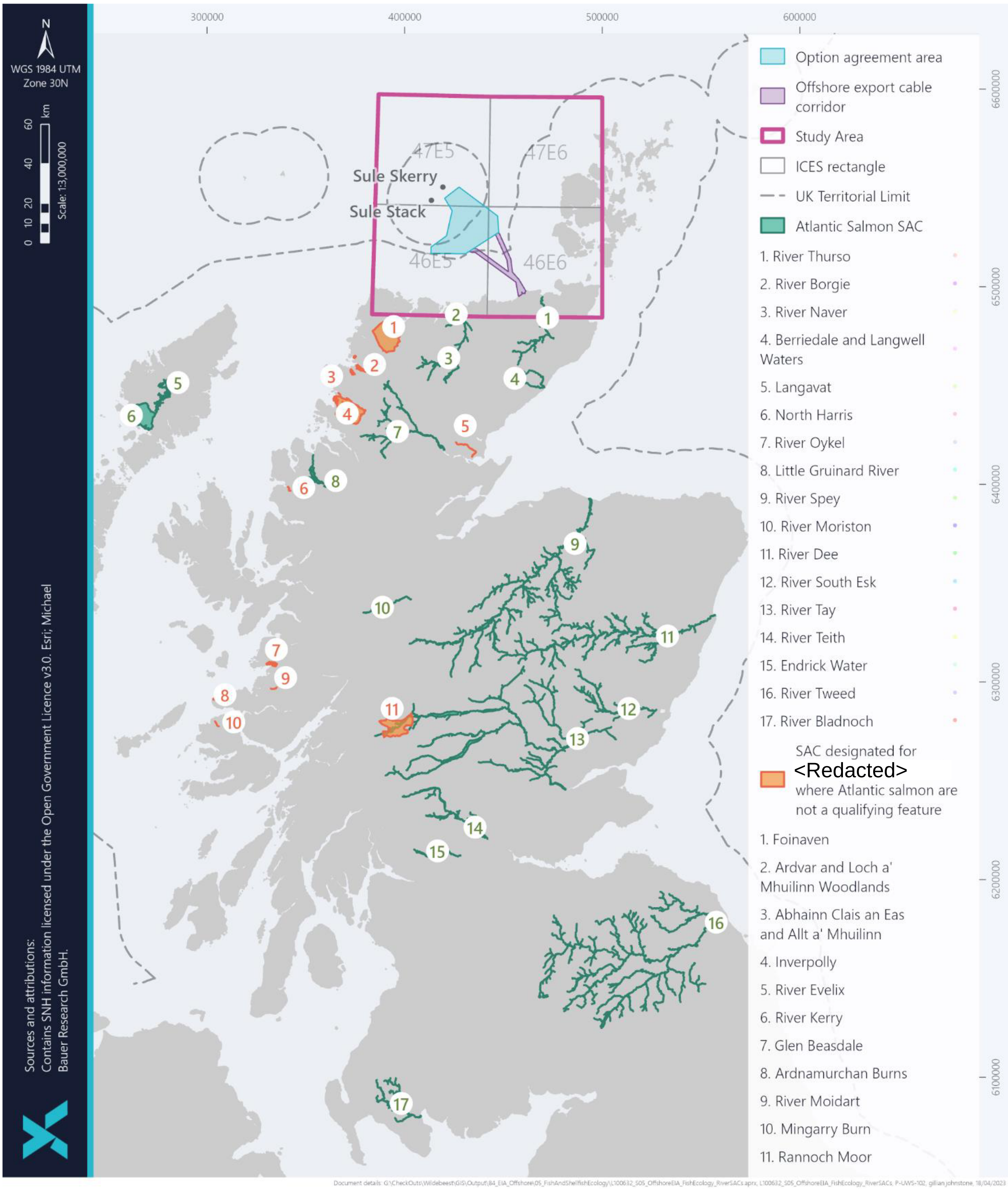

Figure 3-17 SACs designated for Atlantic salmon and <Redacted>

3.5.2 Key species accounts

This section describes the ecology of the key diadromous fish and associated species potentially present within the fish and shellfish ecology offshore study area.

The ecology of the species have been used to inform chapter 11: Fish and shellfish ecology of the Offshore EIA Report. However, it should be noted that for some impacts, species may not be considered on an individual basis but as a 'diadromous fish' functional group.

Atlantic salmon

Life stages

The life cycle of Atlantic salmon is displayed in Figure 3-18, and can be summarised as follows (NatureScot, 2022d; Atlantic Salmon Trust, 2016; Malcom *et al.*, 2010):

1. Atlantic salmon spawn in riverine environments in late autumn / early winter, in areas called redds where adult females release eggs that adult males fertilise;
2. The eggs then hatch and become alevins that feed from a yolk sac, remaining within the redd;
3. Once the yolk sac is absorbed, the alevins leave the redds, swim up and are known as fry;
4. Fry then become parr when the salmon are over a year old and at this stage vertical parr markings develop. Parr remain in rivers for one to five years;
5. When the parr reach approximately 10 cm, the salmon goes through a transformation to enable survival in saline conditions (smoltification) and migrate to the marine environment in April to June;
6. Once in the marine environment, they are known as post-smolts until spring of the following year;
7. Following the migration as post-smolts to offshore feeding grounds, adults can either spend a single winter (i.e. 1 Sea-Winter (1SW) or grilse) or Multiple Winters at Sea (MSW)). Their migration back to freshwater is dictated by hormones and can occur during any month of the year; and
8. Once adult salmon have spawned the majority die at the spawning grounds. A small number (known as kelts) return to the sea, potentially returning again to become repeat spawners.

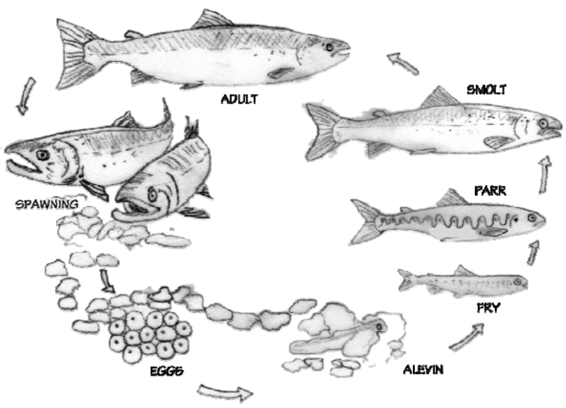

Figure 3-18 Atlantic salmon life cycle (Atlantic Salmon Trust, 2016)

Smolt migratory behaviour

Smolt migration is expected to be triggered by environmental cues, such as changes in current flow or temperature (Simmons *et al.*, 2021). Migration typically occurs in spring and is predominantly nocturnal (Thorstad *et al.*, 2012). Nocturnal migration and a rapid migration through coastal environments are potential mechanisms utilised by post-smolts to reduce exposure to predators (Thorstad *et al.*, 2012; Lilly *et al.*, 2022). Passive drifting is unlikely to be used for the entirety of the migration out to sea, and active directing swimming is likely to be utilised for at least part of the migration (Ounsley *et al.*, 2020; Newton *et al.*, 2017; McIlvenny *et al.*, 2021).

Once in the marine environment, post-smolts conduct an offshore migration towards feeding grounds in the northeast Atlantic. Aggregations of post-smolts along the continental shelf edge and within the northern North Sea have been identified through trawl surveys. Genetic analysis indicates that different stocks may have different distributions, potentially relating to differences in migratory behaviours (Gilbey *et al.*, 2021). Ounsley *et al.* (2020) also theorised that in order to reach the north Atlantic feeding grounds, post-smolts from different river stocks may have to utilise different migratory behaviours and trajectories.

The drivers of post-smolt migratory routes and behaviours, are not well known. A number of studies have attempted to track or model the movement and behaviour of post-smolts from Scottish rivers as they enter the marine environment. Several studies have tracked the initial coastal migration of post-smolts using acoustic transmitters and receivers. For example, studies tracking smolts from the Cromarty Firth and the River Dee indicate a rapid migration in an easterly direction, suggesting an offshore migratory route across the North Sea (Newton *et al.*, 2017, Newton *et al.*, 2021, Main, 2021; River Dee Trust and Marine Scotland Science, 2019). Regional tracking projects include the Atlantic Salmon Trust West Coast[9] and Moray Firth[10] Tracking Projects. These projects aim to improve the knowledge of how Atlantic salmon use river estuarine and marine environments, including both spatially and temporally. Specifically, these research programmes are aiming to identify marine migration routes, understand migratory behaviour and speed and establish the factors that influence migration (Atlantic Salmon Trust, 2022, *personal communication*). The Moray Firth Tracking Project was initiated in spring 2019. Over 340 acoustic receivers were deployed within the inner and outer Moray Firth and 800 salmon post-smolts were tagged with acoustic transmitters. The initial results of this study indicate an easterly migration of post-smolts, suggesting that the 'Dooly current' may be utilised across the North Sea before heading north prior to the Norway coast (Newton *et al.*, 2019).

The West Coast Tracking Project was initiated in 2021, with over 228 acoustic receivers being deployed along the northwest coast of Scotland with over 1,000 smolts being tagged. The initial findings indicate that post-smolts from the west coast of Scotland disperse widely to reach the continental shelf to then travel towards the northeast Atlantic feeding grounds in a west-to-east direction (Atlantic Salmon Trust, 2022). The second and third years of this tracking programme will focus on further understanding the rate of movement and migratory routes of post-smolts, focussing on several sea lochs on the west coast of Scotland (Atlantic Salmon Trust, 2022, *personal communication*).

The potential movement of post-smolt Atlantic salmon within the fish and shellfish ecology offshore study area, and the relative importance of the offshore Project area, is unknown.

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[9] *https://atlanticsalmontrust.org/our-work/the-west-coast-tracking-project/*
[10] *https://atlanticsalmontrust.org/our-work/morayfirthtrackingproject/*

Adult migratory behaviour

1SW salmon return to Scottish rivers in early summer and MSW salmon can enter Scottish rivers over a longer time period (Youngson, 2002). It is expected that returning adult salmon utilise environmental cues obtained during the outward post-smolt migration (Haraldstad *et al*., 2022).

Tagging studies suggest a west-to-east migration of returning Atlantic salmon across the Pentland Firth, as shown on Figure 3-19 (Malcom *et al*., 2010; Youngson, 2017). Furthermore, a combination of genetic assignment and tracking studies show that adults returning to rivers along the north coast of Scotland are not only from local river stocks but also from rivers hundreds of kilometres away (Downie *et al*., 2018). This may result from some individuals taking a convoluted route for migration, entering multiple rivers before selecting the final river to spawn (Cauwelier *et al.*, 2015; Downie *et al.*, 2018; Armstrong *et al.*, 2018).

Adult salmon generally swim at depths between 0 and 5 m below the sea surface, with brief dives into deeper water to approximately 64 m (Godfrey *et al.*, 2015).

It still remains uncertain as to whether homing adults from different river stocks will migrate through the Pentland Firth or around Orkney and Shetland (Malcom *et al*., 2010). Therefore, the potential abundance of homing migrating salmon within the offshore Project area remains unknown.

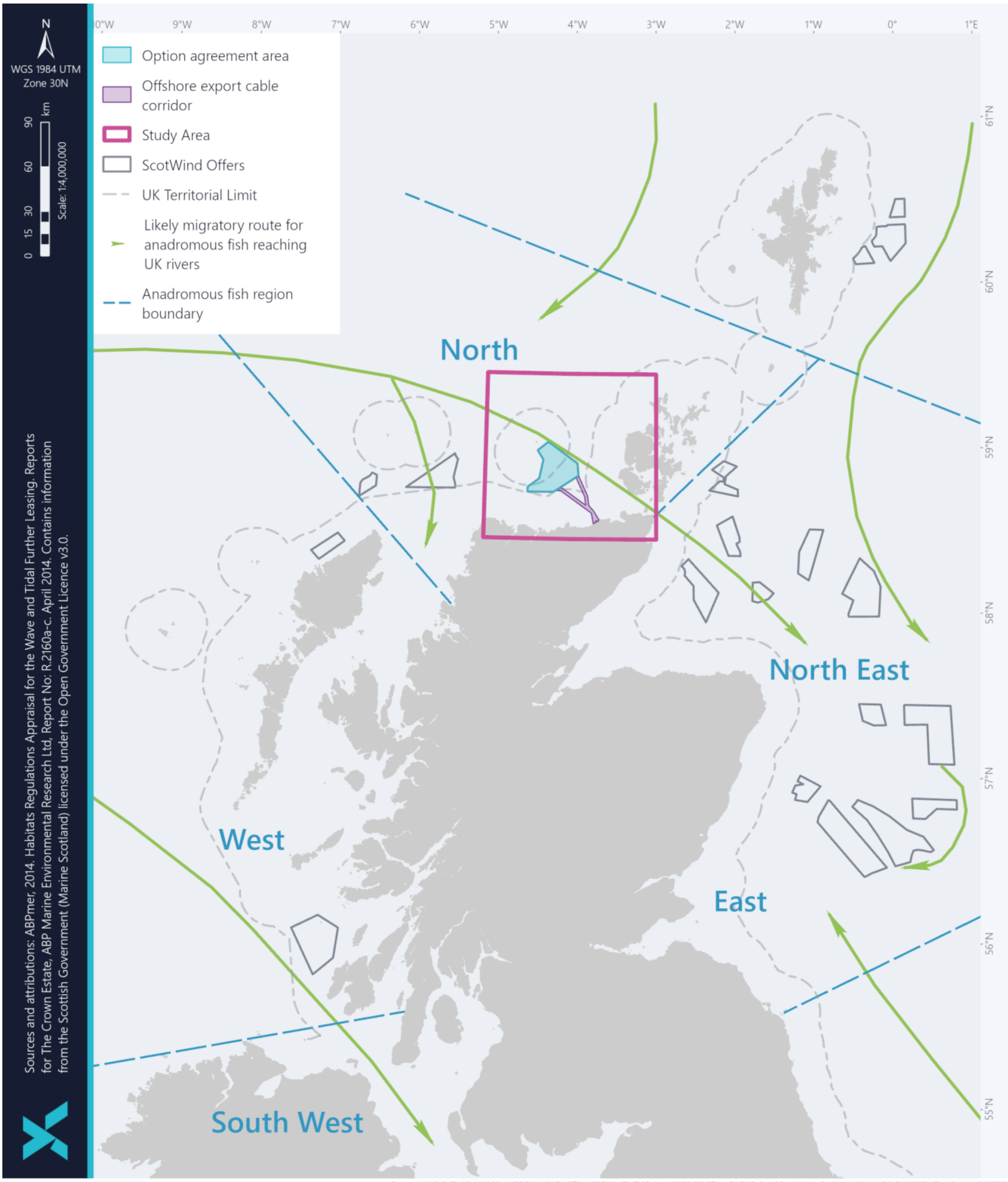

Figure 3-19 Potential migration routes of homing adult Atlantic salmon (ABPmer, 2014, reproduced in Scottish Government, 2020)

Condition of salmon within Scottish rivers

The number of returning salmon in Scotland has declined over the last six decades, and this has impacted the number of salmon spawning in Scottish rivers. As a result, the majority of rivers are now classified as being in poor status (Scottish Government, 2022). Scotland has multiple rivers protected for Atlantic salmon. Due to the location of the offshore Project, there is potential to affect the migratory routes of adult salmon returning to Scottish rivers from the northern Atlantic Ocean and for smolts of salmon leaving the rivers and entering the ocean. The Caithness District Salmon Fishery Board publish yearly electrofishing reports surveying juvenile salmonids (2013-2021) (Youngson, 2022). The River Thurso and the River Forss Water, which are located in the vicinity of the offshore Project are included within these reports. The River Forss Water is adjacent to the Crosskirk landfall option. In 2020, the River Thurso was found to be performing well, with salmon fry density often exceeding the 0.8 fry per m^2 target at all six of the survey sites (Youngson, 2022) and it is expected that juvenile salmon production in the River Thurso will remain 2022.healthy in the short term. Recent electrofishing data from the Forss (2020 and 2021) suggest a major decline in the production of juvenile Atlantic salmon in the river (Youngson, 2022). This has been caused by low spawning effort, potentially driven by adult mortality during migration or within early stages of freshwater return.

<Redacted>

There is a direct relationship between salmonids and <Redacted> because, in their first year, during the glochidial stage of their life cycle, <Redacted> live on the gills of Atlantic salmon or sea trout as parasites (NatureScot, 2022e).

As adults, <Redacted> inhabit freshwater environments only. As a result, the offshore Project only has the potential to impact <Redacted> indirectly through effects on Atlantic salmon or brown trout. <Redacted> are declining in Scotland and are under threat due to poor water quality, illegal <Re fishing and damage to their habitat. There has been a decline in the number of rivers in Scotland that can support <Redacte d> and the species is extirpated from several rivers (NatureScot, 2022e).

Anadromous brown trout (sea trout)

Sea trout (*Salmo trutta*) are the anadromous form of brown trout. They have a similar life cycle to Atlantic salmon, conducting outward marine migrations as smolts and returning to native rivers to spawn as adults, following a period at sea (NatureScot, 2022f).

Smolts typically migrate out to the marine environment between April and June (Ferguson *et al.*, 2019). However, the age at which sea trout smolt varies by latitude, with sea trout in more northerly latitudes smolting later than in the south. Most sea trout in Scotland become smolts at one to four years of age, although this may be longer for some populations (Klemetsen *et al.*, 2003; Thompson, 2014). Sea trout migrations are generally more localised than Atlantic salmon, however, migratory routes of hundreds of kilometres have been observed from rivers on the East coast of Scotland (Malcom *et al.*, 2010). Sea trout utilise areas closer to the coast for their outward migration relative to Atlantic salmon (River Dee Trust and Marine Scotland Science, 2019).

There is considerable variation in the timing and duration of marine migrations for sea trout. Some individuals, known as 'finnock', return to their native rivers in July and September of the same year as their seaward migration, whereas larger fish known as 'maidens' may return after a migration duration of over 12 months (NatureScot, 2022f). Most finnock are immature and will undertake further seaward migrations before maturing. The timing of the return migration may also vary by river size, with sea trout returning to larger rivers which require a longer ascent earlier than those returning to smaller rivers (Thompson, 2014).

Trout may be present within the rivers along the north Caithness coast, and the Orkney islands also contain important spawning burns for sea trout (Youngson, 2022; Orkney Trout Fishing Association, 2022). As per Atlantic salmon, this species also supports several fisheries in Scotland which have undergone a decline in catches over the last few decades (Moffat *et al.*, 2020).

Lamprey species

There are three species of lamprey, including river, sea, and brook lamprey (*Lampetra planeri*). River and sea lamprey are diadromous, spawning in freshwater environments and migrating out to sea as juveniles. Most adults are parasitic on other fish or marine megafauna (NatureScot, 2022g).

River lamprey typically inhabit coastal and estuarine habitats for approximately one to two years following their migration to sea. Spawning typically occurs in autumn and spring, and migration out to sea occurs from late autumn onwards (Maitland, 2003). Sea lamprey migrate further offshore than river lamprey for approximately 18 to 24 months before returning to rivers in spring / early summer to spawn (NatureScot, 2022g). Unlike salmon and sea trout, lamprey do not display a homing behaviour (Waldman *et al*., 2008). Both sea and river lamprey individuals die after spawning (NatureScot, 2022g).

The at-sea behaviour and migratory behaviour of lamprey remains relatively unknown (Malcom *et al.*, 2010).

European eel

European eel (*Anguilla anguilla*) spend most of their lives in freshwater, migrating to the Sargasso Sea to spawn and die, over a distance of 5,000 to 10,000 km (Aarestrup *et al.*, 2009). A proportion of the total European eel population, at the adult (silver eel) migratory stage, may pass through Scottish coastal waters. Waters bordering the northern coast of mainland Scotland, Orkney, Shetland and the Outer Hebrides are most likely to contain migratory eels from northern continental Europe as well as the UK (Malcom *et al*., 2010).

The number of European eel in Scottish waters has declined drastically since the 1990s (NatureScot, 2022h). The Scottish eel management plan was established in 2010 in response to the Eel Recovery Plan (formed under European Commission Council Regulation No 1100/2007) with the aim of improving the European eel stocks (Defra, 2010).

A recent tagging study of silver eels in the Azores archipelago, an area *en route* to the Sargasso Sea from the northeast Atlantic, has shed light on European eel spawning migrations (Wright *et al*., 2022). Eel migrations to the Sargasso Sea were tracked for the first time, supporting previous studies suggesting Sargasso Sea is of importance for European eel spawning. Importantly, this study builds on previous evidence of European eel migration and further improves the understanding of the migratory routes used by this species (Wright *et al*., 2022).

Once the eggs hatch in the Sargasso Sea, larvae drift eastwards towards Europe. Most eels on the coast of Scotland are expected to be glass eels (juvenile eels prior to entering freshwater) destined for Scottish rivers (NatureScot, 2022h).

Migratory patterns of eels in Scottish waters remains poorly understood and the distribution or abundance of European eel within the offshore Project area is unclear.

3.6 Future baseline

The fish and shellfish baseline will continue to evolve over time as a result of a number of factors. Key drivers of change include climate change, predator-prey interactions, and fishing activities. Evidence of changes in the fish and shellfish distribution as a result of increased warming has already been observed, including northward shifts of population boundaries for a number of species (Perry *et al.*, 2005; Wright *et al.*, 2020).

Increasing sea surface temperatures may result in a regional shift of fish species into deeper and colder waters. Declines in recruitment may occur if these environments do not contain the specific habitat requirements of some species (e.g. sandeel spawning grounds). Shifts in migratory timings, or other life history stages, that are influenced by environmental cues such as temperature, may also occur (BEIS, 2022a; Wright *et al.*, 2020).

As a result of natural variation, there is limited confidence in attributing climate change to observed changes in fish and shellfish communities (Wright *et al.*, 2020). It is also extremely difficult to predict climate change impacts on fish and shellfish populations, and therefore, an accurate future baseline for the fish and shellfish ecology offshore study area cannot be provided.

Changes in fishing patterns may also alter the fish and shellfish populations within the fish and shellfish ecology offshore study area. Elasmobranchs that have a slow growth rate and low fecundity are particularly sensitive to overfishing. It should be noted that there have been some improvements in some stocks in recent years which may continue (BEIS, 2022a).

4 SUMMARY AND CONCLUSION

4.1 Fish and shellfish ecology baseline

The desk-based review and site-specific survey data indicate that a range of demersal and pelagic marine finfish, shellfish, elasmobranchs and diadromous fish species are likely to be present in the vicinity of the offshore Project and within the wider fish and shellfish ecology offshore study area. There are several spawning and nursery grounds that overlap the offshore Project area, and spawning grounds for herring, sandeel and flapper skate were further investigated to understand the potential suitability of the habitat at the offshore Project area for spawning by these species. There are areas within the OAA and offshore ECC which may be favourable for the spawning of these species. The North West Orkney NCMPA, located approximately 11 km from the OAA, is designated for sandeel.

A number of marine finfish species were identified as potentially being present within the fish and shellfish ecology offshore study area. The eDNA surveys identified that mackerel and gadoid species such as cod and haddock were present with the highest DNA sequence reads, and this is also generally consistent with these species contributing to some of the highest average live weights in the commercial landings for the fish and shellfish ecology offshore study area. Brown crab and scallops are considered to be the key shellfish species for the offshore Project area, and these species contribute to the highest average live weights in the commercial landings for the fish and shellfish ecology offshore study area.

There are a range of elasmobranch species identified as potentially being present in the fish and shellfish ecology offshore study area, as indicated by the sightings database maintained by the Shark Trust. The key species is considered to be flapper skate, as the waters around Orkney support high numbers of this critically endangered species.

Atlantic salmon (and <Redacted> in association), anadromous brown trout, lamprey species and European eel were identified as the key diadromous fish species. There are also several SACs designated for Atlantic salmon and <Redacted> that were identified as having potential connectivity with the offshore Project.

4.2 Species taken forward for assessment

Table 4-1 outlines the key species taken forward for assessment within the Offshore EIA Report. However, for some impacts the Offshore EIA Report has considered the wider functional groups of marine finfish, shellfish, elasmobranchs, and diadromous fish. Where a species is particularly vulnerable or sensitive, individual species have been considered.

Table 4-1 Species taken forward for assessment

SPECIES	JUSTIFICATION
Marine finfish	
Mackerel	• One of the most frequently recorded species in the eDNA analysis;

SPECIES	JUSTIFICATION
	• Important prey species; • Listed as PMF; • Important commercial species; and • High and low intensity nursery grounds overlap the offshore Project area.
Herring	• Detected during the eDNA analysis (albeit only at three locations); • Important prey species; • Listed as PMF; • Important commercial species; • Spawning grounds overlap the offshore Project area and further analysis indicates that there are areas within the OAA which may be suitable for spawning of this species; • Low intensity nursery grounds overlap the offshore Project area; and • Sensitive to seabed disturbance and underwater noise.
Sprat	• Frequently detected during the eDNA analysis; • Spawning grounds overlap with the offshore Project area; and • Sensitive to underwater noise.
Sandeel	• Sandeel DNA was detected during the eDNA analysis and there were visual observations of this species during the benthic surveys; • Important prey species; • Listed as PMF and a protected feature of the North West Orkney NCMPA, 11 km from the OAA; • Spawning grounds overlap the offshore Project area and further analysis indicates that there are areas within the OAA and offshore ECC which may be suitable for spawning of this species; • Low intensity nursery grounds overlap the offshore Project area and probable presence of buried sandeel in the nearshore areas of the offshore ECC and east of OAA; and • Sensitive to seabed disturbance.
Haddock	• One of the most frequently detected species in the eDNA analysis; • Areas of the offshore Project area categorised as being of low to moderate importance for haddock spawning; • Important commercial species; • Low intensity nursery grounds overlap the offshore Project area with moderate to high probability of 0-group fish; and • Sensitive to underwater noise.
Cod	• Detected during the eDNA analysis; • Areas of the offshore Project area categorised as being of rare or occasional cod spawning grounds; • Listed as a PMF, on the OSPAR list of threatened and/or declining species and habitats and as 'Vulnerable' on the IUCN red list of threatened species; • Important commercial species; • Low intensity nursery grounds overlap the offshore Project area with low probability of 0-group fish; and • Sensitive to underwater noise.

SPECIES	JUSTIFICATION
Whiting	• Detected during the eDNA analysis; • Spawning grounds overlap with the offshore Project area with a low to moderate importance for spawning whiting; • Areas of the offshore Project area categorised as being of rare or occasional cod spawning grounds; • Listed as a PMF; • Important commercial species; • Low intensity nursery grounds overlap the offshore Project area with moderate to probability of 0-group fish; and • Sensitive to underwater noise.
Norway pout	• Detected during the eDNA analysis; • Spawning and nursery grounds overlap the offshore Project area with a moderate to high probability of 0-group fish; and • PMF species.
Monkfish/Anglerfish	• Detected during the eDNA analysis at one sample location; • High intensity nursery grounds overlap the offshore Project area with a low to moderate probability of 0-group fish; • Important commercial species; and • PMF species.
Saithe	• Species not detected during eDNA analysis, but the higher taxonomic group of Gadidae spp. was frequently recorded; • Low intensity nursery grounds overlap the offshore Project area; • Important commercial species; • PMF species; and • Sensitive to underwater noise.
Lemon sole	• Detected during eDNA analysis; and • Spawning and nursery grounds overlap the offshore Project area.
Shellfish	
Brown crab	• Important commercial species; • Likely to be present based on desk-based data and commercial landings; and • Sensitive to seabed disturbance and EMF.
Scallops	• Detected during eDNA analysis and benthic surveys; • Important commercial species; and • Likely to be present based on desk-based data and commercial landings.
Velvet crab	• Important commercial species.
Whelk	• Important commercial species.
Squid	• Important commercial species, although less likely to be important in the local area.
Elasmobranchs	
Flapper skate	• Low intensity grounds overlap the offshore Project area and potential egg laying habitat is present in the offshore Project area;

SPECIES	JUSTIFICATION
	• Detected during the benthic surveys; • Listed as a PMF, on the OSPAR list of threatened and/or declining species and habitats and as 'Critically endangered' on the IUCN red list of threatened species; and • Sensitive to seabed disturbance and EMF.
Thornback ray	• Low intensity nursery grounds overlap the offshore Project area; • Detected during benthic surveys; • Listed on the OSPAR list of threatened and/or declining species and habitats; and • Sensitive to seabed disturbance and EMF.
Spotted ray	• Low intensity nursery grounds overlap the offshore Project area; • Listed as a PMF species, on the OSPAR list of threatened and/or declining species and habitats; and • Sensitive to seabed disturbance and EMF.
Other skates and rays	• Several species are less likely to be present in the vicinity of the offshore Project but are of conservation importance, including sandy ray, blue skate and white skate; and • Sensitive to seabed disturbance and EMF.
Tope shark	• Low intensity nursery grounds overlap the offshore Project area; and • Listed as critically endangered on the IUCN red list of threatened species.
Spurdog	• Low intensity nursery grounds overlap the offshore Project area; • Listed as a PMF, on the OSPAR list of threatened and/or declining species and habitats and as 'Vulnerable' on the IUCN red list of threatened species; and • Sensitive to EMF.
Other sharks	• Several species are less likely to be present in the vicinity of the offshore Project but are of conservation importance, including blue shark, porbeagle, Portuguese dogfish and gulper shark; and • Sensitive to EMF.
Diadromous fish	
Atlantic salmon	• Listed as a PMF species, on the OSPAR list of threatened and/or declining species and habitats, on The Convention on the Conservation of European Wildlife and Natural Habitats ('BERN') convention, and protected under the Salmon Act; • Listed as an Annex II species on the Habitats Regulations and as a qualifying feature to several designated sites in the vicinity of the offshore Project; • Likely to migrate through the offshore Project area based on desk-based data; and • Sensitive to underwater noise, EMF, changes in prey distribution and abundance and migratory barriers.
<Redacted>	• Listed as 'Endangered' on the IUCN red list of threatened species; and • Listed as an Annex II species on the Habitats Regulations and as a qualifying feature to several designated sites in the vicinity of the offshore Project.
Anadromous brown trout (sea trout)	• Listed as a PMF species and protected under the Salmon Act; • May potentially migrate through the offshore Project area based on desk-based data; and • Sensitive to underwater noise, EMF, changes in prey distribution and abundance and migratory barriers.

SPECIES	JUSTIFICATION
Lamprey species	• Sea lamprey is listed as a PMF species, on the OSPAR list of threatened and/or declining species and habitats, on the BERN convention, and protected under the Salmon Act; • Annex II species on the Habitats Regulations; and • Sea lamprey may migrate through the offshore Project area, less likely for River lamprey.
European eel	• Listed as a PMF species, on the OSPAR list of threatened and/or declining species and habitats, and as 'Critically endangered' on the IUCN red list of threatened species; • May migrate through the offshore Project area; and • Sensitive to underwater noise, EMF, changes in prey distribution and abundance and migratory barriers.

4.3 Key data limitations and uncertainties

The key data limitations and uncertainties for the fish and shellfish ecology baseline characterisation are described in Table 4-2. This has been informed by the ScotMER publication on "*Fish and fisheries research to inform ScotMER evidence gaps and future strategic research in the UK: review*" (Xoubanova and Lawrence, 2022).

It is acknowledged that data limitations and uncertainties exist for the fish and shellfish baseline characterisation. The key data uncertainties are considered to be diadromous fish migratory patterns and routes in the offshore Project area, and this relates to a wider lack of understanding of the migratory patterns and behaviours at-sea of diadromous fish. These data uncertainties have been considered when assessing the potential effects of the offshore Project within the Offshore EIA Report and will also inform future monitoring proposals.

Table 4-2 Data gaps and limitations

SPECIES / FUNCTIONAL GROUP	DATA LIMITATIONS AND/OR UNCERTAINTIES
Spawning and nursery grounds	The Coull *et al.* (1998) and Ellis *et al.* (2012) spawning and nursery grounds are indicative and the data used to delineate these areas requires updating. The spawning areas and timing also represent the maximum spatial extents and durations, and in reality, these may be smaller and shorter, respectively. Information from a number of sources, including Aires *et al.* (2014), Gonzales and Wright (2016a,b), Gonzalez and Wright (2017) and IHLS survey and site-specific data (PSA data) have been used in conjunction with Coull *et al.* (1998) and Ellis *et al.* (2012) data to further understand the potential for spawning / nursery grounds at the offshore Project area at a finer scale. It should be noted that the site-specific PSA data indicates the potential presence of suitable sandeel and herring spawning habitat, rather than actual locations of sandeel and herring spawning, which may depend on other biotic and abiotic factors.
Marine finfish	There is a good understanding of the key marine finfish species in the regional area. Landings data, ICES surveys reports and the eDNA surveys have been used to improve the

SPECIES / FUNCTIONAL GROUP	DATA LIMITATIONS AND/OR UNCERTAINTIES
	understanding of the marine finfish assemblage within the fish and shellfish ecology offshore study area. However, there are limitations to this data, relating to the specificity of the survey methods employed for ICES surveys and the fishing gears used. For instance, non-commercial species will be underrepresented in commercial landings data and the species targeted by specific fishing gears may be overrepresented. Landings data are also skewed towards commercial species (with non-commercial species being discarded at sea) and will also be influenced by fisheries legislation and controls. The eDNA surveys represent a 'snapshot' of the marine finfish assemblage at the time of the survey and do not reflect the seasonal and annual variation in marine finfish communities. The identification of taxa to species level is also dependent on the completeness of the reference databases.
Elasmobranchs	As above for marine finfish, there is relatively good understanding of the elasmobranch species present in the wider region. eDNA surveys and sightings data available through Shark Trust have been used to understand the presence of elasmobranchs at a more local scale. These data cannot be used to determine density / distribution within the offshore Project area itself but greatly improve the understanding of the key species relevant to the offshore Project. The sightings data is also subject to survey effort, and therefore cannot be used to provide a quantitative assessment of the distribution of species. As mentioned for marine finfish, the eDNA surveys also represent a 'snapshot' of the elasmobranch assemblage at the time of the survey and do not reflect the seasonal and annual variation in elasmobranch communities.
Shellfish	There is a good understanding of the key shellfish species in the regional area. The brown crab tagging studies around Orkney improve the understanding of the migratory patterns of crab in the region. However, these data now require updating, and the relative importance of the offshore Project area for migrating crab remains unknown. Knowledge gaps remain around brown crab migratory behaviour, and there has also been little consideration of mapping shellfish habitat areas when compared with marine finfish. Landings data are skewed towards commercial species and will be influenced by fisheries legislation and controls, and the eDNA surveys provide a 'snapshot' of the shellfish assemblage at the time of the survey.
Diadromous fish	There is no empirical data for the offshore Project area itself with the exception of the eDNA surveys which did not detect diadromous fish DNA at the time of the survey. Tagging studies are available for Atlantic salmon on the north coast of Scotland, including those for adults and smolts. However, the majority of studies have been conducted in coastal environments, providing an indication of smolt behaviour / movement from freshwater to coastal environments or providing an indication of the origins / destinations of adult migrating salmon at the coast. There is limited information on sea trout, European eel and sea lamprey migration.

SPECIES / FUNCTIONAL GROUP	DATA LIMITATIONS AND/OR UNCERTAINTIES
	Key uncertainties for diadromous fish include: • Migratory routes for Atlantic salmon, sea trout, European eel and sea lamprey juveniles and adults; • Specific timing of migrations; • The abundance / proximity of migratory fish to the offshore Project; • Post-smolt migratory behaviour (beyond the coastal environment) and migratory routes; and • Genetic origin of diadromous fish within the offshore Project area.

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6 ABBREVIATIONS

TERM	DEFINITION
1SW	One Sea-Winter
BERN	The Convention on the Conservation of European Wildlife and Natural Habitats
BRUV	Baited Remote Underwater Video
CES	Crown Estate Scotland
DDV	Drop Down Video
DSFB	District Salmon Fishery Board
ECC	Export Cable Corridor
eDNA	Environmental DNA
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
FIP	Fishery Improvement Project
GAM	Generalised Additive Model
HRA	Habitats Regulations Appraisal
IBTS	International Bottom Trawl Survey
ICES	International Council for Exploration of the Sea
IHLS	International Herring Larvae Survey
IUCN	International Union for the Conservation of Nature
km	Kilometre
MarLIN	Marine Life Information Network
MMO	Marine Management Organisation
MSC	Marine Stewardship Council
MSW	Multiple Winters at Sea
MSY	Maximum Sustainable Yield
MS-LOT	Marine Scotland Licensing Operations Team
NCMPA	Nature Conservation Marine Protected Area
nm	Nautical mile
OESEA	Offshore Energy Strategic Environmental Assessment
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
OWF	Offshore Wind Farm
OWPL	Offshore Wind Power Limited
PCR	Polymerase Chain Reaction

TERM	DEFINITION
PMF	Priority Marine Feature
PO	Plan Option
PSA	Particle Size Analysis
PSU	Practical Salinity Unit
RIAA	Report to Inform Appropriate Assessment
ROV	Remotely Operated Vehicle
RSPB	Royal Society for the Protection of Birds Scotland
SAC	Species Area of Conservation
TAC	Total Allowable Catch
VMS	Vessel Monitoring System

APPENDIX A MMO LIVE WEIGHTS (2017 – 2021) (TONNES)

ROW LABELS	46E5	46E6	47E5	47E6	GRAND TOTAL
Marine finfish					
Mackerel	4.9	7.0	2,180.0	254.0	2,445.9
Haddock	242.2	451.0	367.6	316.7	1,377.6
Herring	557.6	0.1	138.4	21.8	717.9
Cod	16.5	212.8	67.1	365.0	661.4
Monks or Anglers	5.1	77.9	63.3	334.3	480.6
Whiting	7.9	64.3	43.3	141.8	257.3
Saithe	19.8	9.0	188.9	33.4	251.1
Megrim	1.8	9.4	25.6	66.1	103.0
Plaice	5.4	25.7	27.3	28.3	86.6
Ling	8.2	3.5	51.5	17.3	80.5
Gurnards - Grey	2.9	6.2	28.5	22.5	60.1
Lemon Sole	1.5	3.7	16.2	18.1	39.4
Hake	0.7	10.3	12.1	8.2	31.4
Witch	0.0	1.5	0.8	22.2	24.4
Gurnards - Red	1.3	1.0	8.8	7.0	18.1
Gurnard and Latchet	0.5	0.3	9.8	6.2	16.8
Ballan Wrasse	0.0	4.4	0.0	1.8	6.2
Pollack	0.1	0.8	2.3	1.7	4.8
Turbot	0.2	0.7	1.4	2.5	4.8
Halibut	0.0	0.4	0.2	1.9	2.5
John Dory	0.3	0.5	0.8	0.6	2.2
Dabs	0.4	0.0	0.6	0.3	1.3
Torsk (Tusk)	0.0	0.1	0.4	0.3	0.8
Brill	0.1	0.2	0.2	0.0	0.5
Conger Eels	0.0	0.0	0.0	0.4	0.4
Black Scabbard Fish	0.4	0.0	0.0	0.0	0.4
Horse Mackerel	0.0	0.2	0.0	0.2	0.4

ROW LABELS	46E5	46E6	47E5	47E6	GRAND TOTAL
Blue Ling	0.1	0.0	0.1	0.0	0.2
Redfishes	0.0	0.0	0.1	0.1	0.2
Argentines	0.0	0.0	0.1	0.0	0.1
Greater Forked Beard	0.1	0.0	0.0	0.0	0.1
Halibut - Greenland	0.0	0.0	0.1	0.0	0.1
Wrasses	0.0	0.1	0.0	0.0	0.1
Sole	0.0	0.0	0.0	0.0	0.0
Forkbeard	0.0	0.0	0.0	0.0	0.0
Pilchards	0.0	0.0	0.0	0.0	0.0
Corkwing wrasse	0.0	0.0	0.0	0.0	0.0
Conger eel	0.0	0.0	0.0	0.0	0.0
Norway Pout	0.0	0.0	0.0	0.0	0.0
Sprats	0.0	0.0	0.0	0.0	0.0
Red Mullet	0.0	0.0	0.0	0.0	0.0
Roughead Grenadier	0.0	0.0	0.0	0.0	0.0
Capelin	0.0	0.0	0.0	0.0	0.0
Long-nosed Skate	0.0	0.0	0.0	0.0	0.0
Roundnose Grenadier	0.0	0.0	0.0	0.0	0.0
Leerfish	0.0	0.0	0.0	0.0	0.0
Lumpfish	0.0	0.0	0.0	0.0	0.0
Snake Mackerel	0.0	0.0	0.0	0.0	0.0
Bluemouth (Blue Mouth Redfish)	0.0	0.0	0.0	0.0	0.0
Surmullet	0.0	0.0	0.0	0.0	0.0
Shellfish					
Crabs (C.P.Mixed Sexes)	357.6	557.2	155.7	429.9	1,500.4
Scallops	93.6	144.0	9.4	7.4	254.3
Crabs - Velvet (Swim)	6.1	75.4	0.0	46.5	128.0
Whelks	0.9	90.4	0.0	5.4	96.8
Squid	43.9	10.1	9.4	11.4	74.7
Lobsters	7.9	43.0	0.2	6.0	57.2

ROW LABELS	46E5	46E6	47E5	47E6	GRAND TOTAL
Nephrops (Norway Lobster)	8.6	4.0	0.5	11.8	24.9
Green Crab	1.4	19.7	0.0	2.4	23.4
Queen Scallops	0.0	10.7	0.0	0.6	11.2
Mixed Squid and Octopi	1.5	0.2	0.7	1.0	3.3
Razor Clam	1.1	0.0	0.0	0.0	1.1
Mixed Clams	0.0	0.6	0.0	0.0	0.6
Periwinkles	0.0	0.4	0.0	0.0	0.4
Octopus	0.0	0.0	0.1	0.1	0.2
Surf Clams	0.0	0.1	0.0	0.0	0.1
Crawfish	0.0	0.0	0.0	0.0	0.0
Brown Shrimps	0.0	0.0	0.0	0.0	0.0
Mussels	0.0	0.0	0.0	0.0	0.0
Cuttlefish	0.0	0.0	0.0	0.0	0.0
Lobster - Squat	0.0	0.0	0.0	0.0	0.0
Elasmobranchs					
Lesser Spotted Dog	0.9	3.1	11.7	27.5	43.3
Spotted Ray	2.4	5.2	13.5	8.5	29.6
Thornback Ray	3.2	3.8	7.0	9.3	23.3
Cuckoo Ray	0.1	0.9	4.4	2.0	7.4
Skates and Rays	0.5	0.3	1.6	0.6	2.9
Nursehound	0.1	0.1	0.3	0.7	1.2
Catfish	0.0	0.1	0.1	0.1	0.3
Common Skate (Blue/Grey)	0.0	0.0	0.1	0.1	0.3
White Skate	0.0	0.0	0.1	0.1	0.2
Starry Ray	0.0	0.0	0.0	0.0	0.1
Blonde Ray	0.0	0.0	0.0	0.0	0.0
Unidentified Dogfish	0.0	0.0	0.0	0.0	0.0
Gulper Shark	0.0	0.0	0.0	0.0	0.0

APPENDIX B PSA ANALYSIS FOR SANDEEL AND HERRING HABITAT SUITABILITY

B.1 Sandeel habitat suitability

STATION ID	% MUDS	% SANDS	FOLK SEDIMENT UNIT	SANDEEL HABITAT SUITABILITY
OI_164_GR_ENV_OAA_S01	1.59	97.51	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S03	0.57	87.91	Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S05	1.45	42.99	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S06	0.39	91.81	Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S07	0.47	44.85	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S09	0.42	51.13	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_OAA_S12	0.32	94.82	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S13	0.26	48.54	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S14	0.22	37.45	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S16	2.15	53.98	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_OAA_S17	0.42	80.34	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S19	1.49	45.86	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S20	0.50	98.36	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S21	0.44	51.52	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_OAA_S25	0.26	35.14	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S26	0.40	28.47	Sandy Gravel	Unsuitable

STATION ID	% MUDS	% SANDS	FOLK SEDIMENT UNIT	SANDEEL HABITAT SUITABILITY
OI_164_GR_ENV_OAA_S27	0.00	99.84	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S28	0.32	97.85	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S29	0.00	88.13	Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S30	0.66	98.97	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S31	0.61	65.31	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_OAA_S32	0.73	95.49	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S33	0.00	99.76	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S34	1.11	60.53	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_OAA_S35	0.69	90.09	Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S36	0.14	20.72	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S38	0.90	98.86	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S40	0.00	99.90	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S42	0.48	99.37	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_OAA_S43	0.51	60.11	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_OAA_S44	0.22	31.27	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S46	0.31	27.78	Sandy Gravel	Unsuitable
OI_164_GR_ENV_OAA_S49	0.91	98.99	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_ECW_S51	0.96	98.85	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_ECW_S54	1.09	26.04	Sandy Gravel	Unsuitable

STATION ID	% MUDS	% SANDS	FOLK SEDIMENT UNIT	SANDEEL HABITAT SUITABILITY
OI_164_GR_ENV_ECW_S55	2.28	93.41	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S56	2.85	52.95	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_ECW_S57	3.75	56.19	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_ECW_S58	2.73	87.12	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S60	5.09	94.76	Slightly Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S61	5.09	81.47	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S62	6.58	93.34	Slightly Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S63	4.16	95.78	Slightly Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S64	2.78	96.96	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S66	1.94	92.04	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S67	1.57	97.47	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S68	1.36	97.98	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S69	0.00	100.00	Sand	Prime
OI_164_GR_ENV_ECW_S70	1.33	98.34	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S71	0.45	77.31	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S73	0.30	94.48	Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_ECE_S76	8.24	91.37	Slightly Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECE_S77	7.19	92.68	Slightly Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECE_S78	3.74	92.09	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S79	1.17	41.03	Sandy Gravel	Unsuitable

STATION ID	% MUDS	% SANDS	FOLK SEDIMENT UNIT	SANDEEL HABITAT SUITABILITY
OI_164_GR_ENV_ECE_S80	1.86	97.35	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S82	2.10	76.56	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S83	3.02	89.48	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S84	2.13	96.25	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S85	1.81	96.21	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S86	2.93	86.74	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S89	1.91	89.37	Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S90	1.50	97.77	Slightly Gravelly Sand	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S91	1.09	52.06	Sandy Gravel	Suitable (marginal)
OI_164_GR_ENV_ECE_S93	0.05	99.86	Slightly Gravelly Sand	Prime (preferred)
OI_164_GR_ENV_ECE_S94	0.00	100.00	Sand	Prime (preferred)

B.2 Herring habitat suitability

STATION ID	% MUDS	% GRAVEL	FOLK SEDIMENT UNIT	HERRING SPAWNING POTENTIAL
OI_164_GR_ENV_OAA_S01	1.59	0.90	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S03	0.57	11.52	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_OAA_S05	1.45	55.55	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S06	0.39	7.80	Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S07	0.47	54.67	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S09	0.42	48.45	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S12	0.32	4.86	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S13	0.26	51.21	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S14	0.22	62.33	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S16	2.15	43.86	Sandy Gravel	Sub-prime (preferred)

STATION ID	% MUDS	% GRAVEL	FOLK SEDIMENT UNIT	HERRING SPAWNING POTENTIAL
OI_164_GR_ENV_OAA_S 17	0.42	19.24	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_OAA_S 19	1.49	52.65	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S 20	0.50	1.14	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 21	0.44	48.04	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S 25	0.26	64.59	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S 26	0.40	71.13	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S 27	0.00	0.16	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 28	0.32	1.83	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 29	0.00	11.87	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_OAA_S 30	0.66	0.36	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 31	0.61	34.08	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S 32	0.73	3.78	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 33	0.00	0.24	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 34	1.11	38.37	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S 35	0.69	9.21	Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 36	0.14	79.14	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S 38	0.90	0.24	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 40	0.00	0.10	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_OAA_S 42	0.48	0.15	Slightly Gravelly Sand	Unsuitable

STATION ID	% MUDS	% GRAVEL	FOLK SEDIMENT UNIT	HERRING SPAWNING POTENTIAL
OI_164_GR_ENV_OAA_S 43	0.51	39.38	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_OAA_S 44	0.22	68.51	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S 46	0.31	71.91	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_OAA_S 49	0.91	0.10	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 51	0.96	0.19	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 54	1.09	72.86	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_ECW_S 55	2.28	4.31	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 56	2.85	44.20	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S 57	3.75	40.06	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_ECW_S 58	2.73	10.14	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S 60	5.09	0.15	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 61	5.09	13.44	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S 62	6.58	0.08	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 63	4.16	0.05	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 64	2.78	0.27	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 66	1.94	6.02	Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 67	1.57	0.96	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 68	1.36	0.67	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S 69	0.00	0.00	Sand	Unsuitable

STATION ID	% MUDS	% GRAVEL	FOLK SEDIMENT UNIT	HERRING SPAWNING POTENTIAL
OI_164_GR_ENV_ECW_S70	1.33	0.33	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECW_S71	0.45	22.24	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECW_S73	0.30	5.22	Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S76	8.24	0.39	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S77	7.19	0.13	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S78	3.74	4.16	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S79	1.17	57.79	Sandy Gravel	Prime (preferred)
OI_164_GR_ENV_ECE_S80	1.86	0.79	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S82	2.10	21.34	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECE_S83	3.02	7.50	Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S84	2.13	1.62	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S85	1.81	1.98	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S86	2.93	10.33	Gravelly Sand	Suitable (marginal)
OI_164_GR_ENV_ECE_S89	1.91	8.72	Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S90	1.50	0.73	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S91	1.09	46.85	Sandy Gravel	Sub-prime (preferred)
OI_164_GR_ENV_ECE_S93	0.05	0.09	Slightly Gravelly Sand	Unsuitable
OI_164_GR_ENV_ECE_S94	0.00	0.00	Sand	Unsuitable