NORTH FALLS

Offshore Wind Farm

PRELIMINARY ENVIRONMENTAL INFORMATION REPORT

Chapter 11 Fish and Shellfish Ecology

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Contents

Tables

Figures (Volume II)

Appendix (Volume III)

Glossary of Acronyms

AC	Alternating Current
B	Magnetic
BEIS	Department for Business, Energy and Industrial Strategy
BMM	Brown and May Marine Ltd
BOEM	Bureau of Ocean Energy Management
Cefas	Centre for Environment, Fisheries and Aquaculture
CEA	Cumulative Effects Assessment
CP-EGGS	North Sea Cod and Plaice Egg Surveys
CPUE	Catch Per Unit Effort
DATRAS	The Database of Trawl Surveys
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
E	Electric
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
ES	Environmental Statement
EPP	Evidence Plan Process
ETG	Expert Topic Group
GBS	Gravity Based Structure
GGOW	Greater Gabbard Offshore Wind Farm
GWF	Galloper Offshore Wind farm
HDD	Horizontal Directional Drilling
HRA	Habitat Regulations Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICES	International Council for the Exploration of the Sea
iE	Induced Electric
IBTS	North Sea International Bottom Trawl Survey
IHLS	International Herring Larval Survey
INNS	Invasive Non-native Species
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
IMARES	Institute for Marine Resources and Ecosystem Studies
KEIFCA	Kent and Essex Inshore Fisheries and Conservation Authority
MarESA	Marine Evidence based Sensitivity Assessment
MCZ	Marine Conservation Zone
MPA	Marine Protected Area
MMO	Marine Management Organisation
NFOW	North Falls Offshore Wind Farm Limited

NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
O&M	Operation and Maintenance
OSP	Offshore Substation Platform
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PEMP	Project Environmental Management Plan
PINS	Planning Inspectorate
PSA	Particle Size Analysis
SA	Sandeel Assessment
SAC	Special Area of Conservation
SELcum	Cumulative Sound Exposure Level
SPA	Special Protection Area
SPL	Sound pressure level
SSC	Suspended Sediment Concentration
TAC	Total Allowable Catch
TTS	Temporal Threshold Shift
UXO	Unexploded Ordnance
WTG	Wind Turbine Generators
ZSL	Zoological Society of London

Glossary of Terminology

Array areas	The two distinct offshore wind farm areas (including the ‘northern array area’ and ‘southern array area’) which together comprise the North Falls offshore wind farm.
Array cables	Cables which link the wind turbine generators with each other and the offshore substation platform(s).
Beam trawl	A trawl net whose lateral spread during trawling is maintained by a beam across its mouth.
Benthic	Relating to, or occurring at the sea bottom.
Bioelectric	Relating to electricity or electrical phenomena produced within living organisms.
Bony fish	Any of a major taxon (class Osteichthyes or superclass Teleostomi) comprising fishes with a bony rather than a cartilaginous skeleton.
Clupeid	Any of various fishes of the family Clupeidae, which includes the herrings, sprats, sardines and shads.
Crustacean	An arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp, or barnacle.
Demersal	Living on or near the seabed.
Diadromous	Migrating between fresh and salt water.
Elasmobranch	Any cartilaginous fish of the subclass Elasmobranchii which includes the sharks, rays and skates.
Electro-receptive	Ability to perceive electrical stimuli.
Epibenthic	Relative to the flora and fauna living on the surface of the sea bottom.
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA and information to support HRA.
Gadoid	A bony fish of an order (Gadiformes) that comprises the cods, hakes, and their relatives.
Geomagnetic field	The Earth's magnetic field.
Gravid	Carrying eggs or young.
Horizontal directional drill	Trenchless technique to bring the offshore cables ashore at the landfall. The technique will also be used for installation of the onshore export cables at sensitive areas of the onshore cable route.
Interconnector cable	Cable between the northern and southern array areas
Interconnector cable corridor	The corridor of the seabed between the northern and southern array areas
Landfall	The location where the offshore cables come ashore.
Landfall search area	Locations being considered for the landfall, comprising the Essex coast between Clacton-on-Sea and Frinton-on-Sea.
Offshore cable corridor	The corridor of seabed from array areas to the landfall within which the offshore export cables will be located.
Offshore export cables	The cables which bring electricity from the offshore substation platform(s) to the landfall.
Offshore project area	The overall area of the array areas and the offshore cable corridor.
Offshore substation platform(s)	Fixed structure(s) located within the array areas, containing electrical equipment to aggregate the power from the wind turbine generators and convert it into a more suitable voltage for export to shore via offshore export cables.

Otter trawl	A trawl net fitted with two 'otter' boards which maintain the horizontal opening of the net.
Ovigerous	Carrying or bearing eggs.
Pelagic	Living in the water column.
Piscivorous	Feeding on fish.
Safety zones	A marine zone outlined for the purposes of safety around a possibly hazardous installation or works / construction area
Scour protection	Protective materials to avoid sediment being eroded away from the base of the wind turbine generator foundations and offshore substation platform foundations as a result of the flow of water.
Swim bladder	A gas-filled sac present in the body of many bony fish, used to maintain and control buoyancy.
The Applicant	North Falls Offshore Wind Farm Limited (NFOW).
The Project Or 'North Falls'	North Falls Offshore Wind Farm, including all onshore and offshore infrastructure.
Wind turbine generator	Power generating device that is driven by the kinetic energy of the wind.

11 Fish and Shellfish Ecology

11.1 Introduction

1. This chapter of the Preliminary Environmental Information Report (PEIR) considers the likely significant effects of the North Falls offshore wind farm (hereafter "North Falls" or "the Project") on fish and shellfish ecology. The chapter provides an overview of the existing environment for the offshore project area, followed by an assessment of the likely significant effects for the construction, operation, maintenance, and decommissioning phases of the Project.
2. This chapter has been written by Brown and May Marine Ltd (BMM) with the assessment undertaken with specific reference to the relevant legislation and guidance, of which the primary source are the National Policy Statements (NPS). Details of these and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Effects Assessment (CEA) are presented in Section 11.4.
3. The assessment should be read in conjunction with following linked chapters:
   - Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I);
   - Chapter 9 Marine Water and Sediment Quality (Volume I);
   - Chapter 10 Benthic and Intertidal Ecology (Volume I);
   - Appendix 12.2 Underwater Noise Modelling (Volume III); and
   - Chapter 14 Commercial Fisheries (Volume I).
4. Additional information to support the fish and shellfish ecology assessment includes:
   - Appendix 11.1 Fish and Shellfish Ecology Technical Report (Volume III).

11.2 Consultation

5. Consultation with regard to fish and shellfish ecology has been undertaken in line with the general process described in Chapter 6 EIA Methodology (Volume I). The key elements to date have included scoping and the ongoing technical consultation via the Seabed Expert Topic Group (ETG). The feedback received has been considered in preparing the PEIR. Table 11.1 provides a summary of how the consultation responses received to date have influenced the approach that has been taken.
6. This chapter will be updated following the consultation on the PEIR in order to produce the final assessment that will be submitted with the Development Consent Order (DCO) application. Full details of the consultation process will also be presented in the Consultation Report alongside the DCO application.

Table 11.1 Consultation responses

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
Planning Inspectorate (PINS)	August 2021/ Scoping Opinion	The Scoping Report states that long term habitat loss will be considered as part of the operation phase assessment and is not considered in the construction and decommissioning phase assessment to avoid duplication. This is reflected in Table 2.16. The Inspectorate is satisfied with this approach and for long-term habitat loss to be scoped out of the construction and decommissioning phase assessment.	Noted. Long term loss of habitat is addressed under the assessment of the potential impacts during operation (Section 11.6.2).
		The Scoping Report states that potential impacts from electromagnetic fields (EMFs) from operational cables will be considered as part of the ES. Table 2.16 shows that this matter will be assessed as part of the operation phase assessment and scoped out for the construction and decommissioning phases. The Inspectorate is satisfied with this approach and for EMF impacts to be scoped out of the construction and decommissioning phase assessment	Noted. Impacts from EMFs are addressed under the assessment of the potential impacts during operation (Section 11.6.2).
		The Scoping Report states that the North Falls impact assessment will be undertaken taking account of the distribution of fish stocks and populations irrespective of national jurisdictions. Therefore, the Applicant considers that a specific assessment of transboundary effects is unnecessary. The Inspectorate agrees that the distribution of fish species is independent of national geographical boundaries and consequently have no objection that a specific assessment of transboundary effects is unnecessary in relation to fish ecology. On this basis and given that transboundary impacts will be assessed in regard to commercial fisheries as part of the construction, operation and decommissioning phases of the Proposed Development, the Inspectorate is satisfied that this matter can be scoped out of the assessment.	Noted. A specific assessment of potential transboundary impacts in respect of fish and shellfish ecology has not been undertaken. Transboundary impacts on commercial fisheries are assessed in Chapter 14 Commercial Fisheries (Volume I).
		The Inspectorate notes that Paragraph 214 references European eel as a protected and migratory fish species that may be present within the offshore project area. However, no reference is made within the Scoping Report to the Eel Regulations 2009 nor Eel Recovery Plans. The ES should include reference to the Eel Regulations and any relevant requirements. The Applicant should agree the approach to meeting the requirements of the Eels Regulations	Reference to the Eel Regulations 2009 is included in Appendix 11.1 (Volume III). Given the offshore location of the Project requirements under the Eels Regulations in respect of eel surveys or provision of fish pass facilities are not considered applicable.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		with the EA and other relevant bodies, including any requirements for eel survey and the provision of eel and other fish pass facilities.	
		The Inspectorate considers the potential for protected and migratory fish species to occur within the vicinity of the Proposed Development, including species that move between both freshwater and marine environments (such as European eel and River lamprey) which may be functionally linked to other nearby protected sites. The ES should establish the presence of such species and assess impacts associated with the construction and operation of the Proposed Development, including the potential for the development to impede / create a barrier to fish migration. The ES should also consider the potential of the Proposed Development to have long-term impacts on fish stocks, where significant effects are likely to occur.	Due consideration has been given in this chapter to the potential impact of the Project on European eel and lampreys. These species have been included as receptors throughout the assessment together with other diadromous species, potentially transiting the area of the offshore project area (Section 11.5.5.1 and 11.5.7).
		The Scoping Report does not provide information regarding the presence and location of shellfish water protected areas, nor does it address the potential of the Proposed Development to impact native oysters / native oyster beds. The Inspectorate considers that there are offshore areas within proximity to the Proposed Development where native oysters may be present and that are designated for native oyster production / protection, including the Blackwater, Crouch, Roach and Colne Estuary MCZ [Marine Conservation Zone]. The ES should establish the presence of any native oysters / native oyster habitat and include an assessment of impacts, where significant effects are likely to occur. The ES should describe the location of relevant shellfish water protected areas and depict their location on a figure(s). Furthermore, if the Proposed Development is to be located in proximity to the shellfish protected areas and where likely significant effects are identified, a full assessment should be conducted to determine the resultant effects on the commercial shellfish trade. Where significant effects are likely, the ES should include detailed mitigation measures to address effects on designated sites and shellfish water protected areas, including any proposed measures to ensure that sediment and water quality does not deteriorate to the detriment of protected and/ or commercial fish and shellfish species. Cross-reference should be made to	Reference to the presence and location of Shellfish Water Protected Areas is included in Appendix 11.1 (Volume III). Due consideration has been given in this chapter to the potential impact of the Project on native oysters. This species has been included as a receptor throughout the assessment.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		relevant assessments of the ES [Environmental Statement], e.g., Marine Water and Sediment Quality and Commercial Fisheries.	
		The Scoping Report states that there is potential for the introduction and spread of marine INNS via vessel traffic and / or the introduction of hard substrate. The ES should assess the potential for such activities and vessel movements to facilitate the spread of INNS, e.g. via ballast water and through accidents and spillages. The ES should describe any necessary mitigation and / or biosecurity precautions required to prevent the spread of INNS. Any measures relied upon in the ES should be discussed with relevant consultation bodies, including NE and the EA, in effort to agree the approach. Measures relied upon in the ES should be adequately secured e.g. through a Construction Environmental Management Plan (CEMP).	Impacts from Invasive Non-Native Species (INNS) are addressed in Chapter 10 Benthic and Intertidal Ecology (Volume I).
		Specific mitigation measures to avoid or reduce any potential impacts on fish and shellfish receptors should be described in the ES. When devising mitigation measures, the Applicant should consider any relevant conservation objectives and ongoing management measures associated with those designated sites identified as having potential to be impacted by the Proposed Development. The ES should include details of the proposed mitigation measures to be included in the Project Environment Management Plan (PEMP).	Mitigation has been presented in Section 11.3.3
		The Scoping Report does not state whether the Applicant intends to control the time of the proposed construction and / or operational activities to avoid key and sensitive periods to species, such as fish spawning seasons and fish migration periods. The ES should assess the duration of impacts in relation to the ecological cycles (e.g. life cycles, breeding and spawning seasons, etc.) of the receptors being assessed. The ES should also consider the potential of the Proposed Development to disrupt fishing and recreational activities (including restriction of access) during both the construction and operational phases and any likely significant effects should be reported within the relevant assessments of the ES (e.g. 'Socio-economics' and 'Tourism and recreation').	Consideration has been given in this assessment to fish species with known spawning and nursey grounds in areas relevant to the Project (Table 11.12). The potential impact of the Project on commercial fisheries is addressed in Chapter 14 Commercial Fisheries (Volume I).

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		The Scoping Report does not address potential impacts on fish feeding grounds or over-wintering areas for crustaceans. The ES should assess these impacts where significant effects are likely to occur.	Reference to feeding grounds and overwintering areas for crustaceans is included in Section 11.5.7 and included in Appendix 11.1 (Volume III).
		The Scoping Report does not address potential impacts from direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish, or sedentary shellfish species, resulting from the Proposed Development. The ES should assess these impacts where significant effects are likely to occur.	The potential impact of the Project on fish and shellfish receptors has been assessed for construction (Section 11.6.1), operation (Section 11.6.2) and decommissioning (Section 11.6.3).
		The Scoping Report does not address potential impacts from accidental pollution on shellfish and fish receptors. The ES should include information to explain the extent of the likely impact and assess any likely significant effects. The ES should include details of any proposed mitigation measures to be included in the PEMP. The ES should also explain how such measures will be secured.	Consideration has been given in this Chapter to the re-mobilisation of contaminated sediments during construction (Section 11.6.1.3), operation (Section 11.6.2.4) and decommissioning (Section 11.6.3). Chapter 9 Marine Water and Sediment Quality (Volume I) outlines the embedded mitigation in relation to accidental pollution
Marine Management Organisation (MMO)	August 2021/ Scoping Opinion	The scoping report provides a high-level fish ecology baseline and correctly identifies that the proposed wind farm array and offshore export cable corridor are within or near to spawning grounds for several fish species. The MMO recognise that migratory fish species, European seabass (*Dicentrarchus labrax) and elasmobranchs* (sharks, skates and rays), including thornback ray (*Raja lavate*) have also been discussed and will be further considered within the EIA, which is appropriate.	Noted.
		Relevant impacts on fish receptors and commercial fisheries have been appropriately scoped in. Potential impacts to be considered within the EIA have previously been agreed with The Applicant through the Evidence Plan Process (EPP) ETG meeting on 5th July 2021. Therefore, MMO are content with the fish species and potential impacts scoped in for further assessment.	Noted.
		The MMO are in agreement with the Applicant that the distribution of fish species is independent of national geographical boundaries and consequently have no objection that a specific assessment of transboundary effects is unnecessary in relation to fish ecology. Transboundary impacts will be assessed in regard to commercial fisheries as part of the construction,	Noted. A specific assessment of potential transboundary impacts in respect of fish and shellfish ecology has not been undertaken. Transboundary impacts on commercial fisheries are assessed in Chapter 14 Commercial Fisheries (Volume I).

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		operation, decommissioning which is appropriate.	
		As part of the EPP ETG Meeting held on 5th July 2021 the MMO recommended the use of the latest data series for the International Council for the Exploration of the Sea (ICES) International Herring Larvae Survey (IHLS); to date, up to 2020 data are publicly available through the ICES website. Additionally, it is recommended to access the North Sea International Bottom Trawl Survey (IBTS) data to support the fish characterisation for the project area. The MMO welcome that the approach to data collection proposed to inform the characterisation of fish ecology and fisheries has now incorporated the most relevant and up-to-date data series. This is appropriate. The Applicant may wish to consider that Centre for Environment, Fisheries and Aquaculture (Cefas) also collects herring samples from the greater Thames area and southern North Sea (available here: https://data.cefas.co.uk/view/5) which provides some limited data on biological maturity and age data for the Thames / Blackwater herring stock, as well as stock allocation. This data may provide complementary data on herring spawning times for the Downs and Thames sub-stocks.	Consideration has been given to the latest available IHLS data (December 2012- January 2022). The latest five years of available IBTS data (2017 to 2021) has been used to inform this chapter (Section 11.5.1). The Applicant has reviewed the publicly available data on the Thames/Blackwater herring stock and notes that that the latest year for which this data is available is 2009 and that sampling is undertaken during the spawning period of the Downs herring (November) but outside of the Downs spawning grounds and therefore of limited value to the assessment. The data has been analysed and is presented in Appendix 11.1 (Volume III) for completeness.
		The MMO agree with The Applicant that given the amount of existing data available and the usefulness of sporadic fish surveys undertaken in the area, no site-specific fisheries surveys will be undertaken for North Falls.	Noted.
		Overall, appropriate fish receptors, potential impacts on fish receptors and commercial fisheries have been identified within the scoping report and will be taken forward for assessment. The MMO welcome that previous comments made during the EPP process have been incorporated into the EIA and the latest data available Will be used to inform the fish characterisation for this project.	Noted.
		The Scoping Report lists numerous sources for data which will be used to inform the EIA regarding commercial fisheries, in the main this data comes from relatively recent data sets (up to 2019), however there are several sources listed, especially relating to nursey and spawning ground research, that are older (2010/11). Given the changes that have been seen in fish	Noted, Coull et al (1998) and Ellis et al (2010) provide a broad scale overview of the potential extent of spawning/nursery grounds and relative intensity and duration of spawning. The limitations of these publications are noted in Appendix 11.1 (Volume III).

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		distribution/quantities in the North Sea, with subsequent changing trends in species landed and the likely impacts on spawning/nursery ground it may be advisable that more recent studies (if available) be used as the reliability of these older studies may be questionable.	
		The MMO consider that in view of the scope of proposals, the approach provided should be sufficient to fully identify and assess the potential impacts to shellfish populations.	Noted.
		In addition to the impacts identified, the MMO would expect to see the impacts of direct mortality (removals from the fishery) assessed. Direct mortality poses a problem for shellfish as a number of species are sedentary and therefore unable to move to avoid danger.	The potential impact of the Project on fish and shellfish receptors has been assessed for construction (Section 11.6.1), operation (Section 11.6.2) and decommissioning (Section 11.6.3). Consideration has been given in this chapter to the impact of commercial fishing on fish and shellfish receptors. Information on relevant fisheries is included in Appendix 11.1 (Volume III) with further information provided in Chapter 14 Commercial Fisheries (Volume I).
		Site specific data is available for the proposed site however the data collected during Galloper Offshore Wind Farm (GWF) and Greater Gabbard Offshore Wind Farm (GGOW) is now considered dated and must be used with caution as it may not represent the current species composition of the site. The baseline presented should be comprised primarily of data obtained with the last 5 years.	Noted. Recent data from the IBTS has been used to inform the baseline characterisation. The results of the fish survey work carried out in the GWF and GGOW have been included as additional site-specific information for reference.
		The Applicant notes that the proposed area is commercially important for crab and lobster species (Section 2.6.1.2 of the Scoping Report) and that the impact assessment will use noise survey data combined with appropriate guidance to assess the level of potential noise impact upon fish, including shellfish (Section 2.6.4 234 of the Scoping Report). However, currently, there are no established noise criteria for crustaceans; therefore, The Applicant will need to draw on relevant scientific literature to support the impact assessment, and assessment conclusions.	Noted. Relevant scientific literature has been included in the assessment of noise during construction on shellfish receptors in Section 11.6.1.4.4.
		The MMO agree with The Applicant's conclusion to scope in the potential	Noted.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		impact of underwater noise during construction, operation and decommission for both fishes (Section 2.6.3 of the Scoping Report) and marine mammals (Section 2.7.3 of the Scoping Report).	
		In Section 2.6.3.1 of the Scoping Report, unexploded ordnance (UXO) clearance was not mentioned as a potential impact on fish species during construction although it was for marine mammals in Section 2.7.3.1. Additionally, in Section 2.6.3.2 of the Scoping Report, underwater noise was not mentioned as a potential impact during operation despite ongoing vessel maintenance. The MMO would expect both the potential impacts of underwater noise arising from UXO clearance and increased presence of vessel traffic to be considered for both fish and marine mammal species.	Underwater noise and vibration from UXO clearance during construction is assessed in Section 11.6.1.6. The assessment of underwater noise and vibration during operation is provided in Section 11.6.2.5.
		In Section 2.6.1.1 (para 212) of the Scoping Report, The Applicant lists: sea bass (*Dicentrarchus labrax*) and thornback ray (*Rava clavata*) as using the outer Thames Estuary. In Section 2.9.1 (para 286) of the Scoping Report, The Applicant then lists the following fish species: mackerel (*Trachurus trachurus*) and haddock (*Melanogrammus aeglefinus*) as being present, with Twaite shad also recorded during site specific surveys. However, these fishes were not included in Table 2.1.14 of the Scoping Report or the subsequent maps showing spawning/ nursery grounds. The Applicant should clarify why these species were scoped out of this assessment	The key species identified, and the rationale for their inclusion within the assessment is provided in Table 11.14. This includes considerations such as presence/abundance in the study area, commercial importance, distribution of spawning and nursery grounds and conservation status.
		The MMO suggest the Applicant groups fishes according to their potential auditory sensitivity (refer to Popper et al., 2014) in their underwater noise assessment as well as commercial importance. It is expected that some of the identified fishes, i.e., herring, will have higher sensitivity to sound pressure than others given that the swim bladder is also involved in their hearing mechanisms.	Reference has been made to Popper et al (2014) when grouping fishes according to their potential auditory sensitivity in Section 11.6.1.4.
		The MMO would expect potential barrier effects (in relation to migratory species) resulting from underwater noise to be considered and would recommend consultation with the Environment Agency.	Due consideration has been given in this chapter to the potential impact of the Project on migratory species. Diadromous species have been included as receptors throughout the assessment and are considered in reference to underwater noise in Section 11.6.1.4.5.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
		A variety of fishes were identified as having potential spawning and/or nursery grounds within the vicinity of the proposed area and have a variety of different hearing sensitivities (see Popper et al., 2014), therefore it is expected they will have differing responses to underwater noise.	Noted. Reference has been made to Popper et al (2014) when grouping fishes according to their potential auditory sensitivity in Section 11.6.1.4
Natural England	August 2021/Scoping Opinion	The table and accompanying maps of fish spawning areas are useful. Maps are indicative only as the underlying data is now relatively old and spawning locations may change over time.	Noted, Coull et al (1998) and Ellis et al (2010) provide a broad scale overview of the potential extent of spawning/nursery grounds and relative intensity and duration of spawning. The limitations of these publications are noted in Appendix 11.1 (Volume III).
		It is noted that no further survey work is proposed for identification of impacts to fish species. Natural England does not agree with this approach as the existing site specific data is in excess of 12 years old. Fish distribution changes temporally as well as spatially so this data may not be representative of the current fish community. Further survey work to characterise the fish community should be considered. Natural England will continue to engage with the applicant on this point through the Evidence Plan Process.	See below Natural England's June 2022/ Response to North Falls Offshore Wind Farm (NFOWF) Fish Ecology Baseline Characterisation and Survey Data – Briefing note.
		Natural England considers the impacts scoped within Table 2.6 of the Scoping Report to be appropriate.	Noted.
Natural England	August 2021/Late Scoping Opinion on Migratory Fish	The works are very far offshore and are very unlikely to present a barrier to migration to fish traveling to and from spawning rivers in the south-east (e.g. Medway MCZ).	Noted.
		The report has noted the presence of protected species such as smelt and shad within the baseline datasets. These species are caught on occasion, so their presence in the dataset in these low numbers is not of particular concern	Noted.
		In regard to the migratory fish aspects, we are satisfied with the North Falls Scoping Report.	Noted.
		We defer to the Environment Agency on Water Framework Directive and European eel matters.	Noted.
Natural England	June 2022/ Response to North Falls Offshore Wind Farm (NFOWF) Fish Ecology	Natural England welcomes the North Falls Fish Ecology Baseline Characterisation and Survey Data – Briefing Note. We are grateful to North Falls OWF [Offshore Wind Farm] project for providing the Fish Ecology Briefing	Noted.

Consultee	Date / Document	Comment	Response / where addressed in the PEIR
	Baseline Characterisation and Survey Data – Briefing note	note, prior to the ETG meeting on 20 June 2022. In line with our comments in the Seabed ETG meeting, Natural England are now content with the evidence that is being used and compiled in relation to fish. We do not feel that additional surveys would add much weight or usefulness to the information that is already in place. Our previous comments related to the evidence that was used for the Greater Gabbard evidence collation, which are now in excess of 12 years old, however these, coupled with additional data sources and evidence, forms part of the overall picture for fish in the area.	

11.3 Scope

11.3.1 Study area

7. The study area for fish and shellfish ecology has been defined with reference to the International Council for the Exploration of the Sea (ICES) rectangles that overlap with the offshore project area (Figure 11.1, Volume II). The North Falls study area is the combined area of the following ICES rectangles:

- ICES rectangle 32F1, where the majority of the offshore project area is located (including the whole offshore cable corridor and interconnector cable corridor and practically the totality of the array areas);
- ICES rectangle 33F1, where a small section of one of the array areas (northern array area) is located; and
- ICES rectangle 32F2 – where a small section of one of the array areas (southern array area) is located.

8. Where appropriate, however, broader geographic areas have been used to provide information in the wider context of the southern North Sea.

11.3.2 Realistic worst-case scenario

9. The final design of North Falls will be confirmed through detailed engineering design studies that will be undertaken post-consent. In order to provide a precautionary but robust impact assessment at this stage of the development process, realistic worst-case scenarios have been defined in terms of the potential effects that may arise. This approach to EIA, referred to as the Rochdale Envelope, is common practice for developments of this nature, as set out in PINS Advice Note Nine (2018). The Rochdale Envelope for a project outlines the realistic worst-case scenario for each individual impact, so that it can be safely assumed that all other scenarios within the design envelope will have less impact. Further details are provided in Chapter 6 EIA Methodology (Volume I).

10. The realistic worst-case scenarios for the fish and shellfish ecology assessment are summarised in Table 11.2. These are based on North Falls parameters

described in Chapter 5 Project Description (Volume I), which provides further details regarding specific activities and their durations.

Table 11.2 Realistic worst-case scenarios

Impact	Parameter	Notes
Construction		

Impact 1: Temporary habitat loss/ physical disturbance	**Array areas:**
	• Seabed preparation area of for gravity based systems (GBS) of 70m² x 72 wind turbine generators (WTG) = 277,088m².
	• Two offshore substation platforms (OSP) seabed preparation = 6,637m² (2 platforms with 65m preparation diameter)
	• Array/interconnector cable seabed preparation – 228km length with average 24m disturbance width = 5,472,000m²
	• Vessel jack up assuming 6 jack up location per WTG (275m² per jack up leg x 6 legs) = 732,600m²
	• Anchoring during WTG and OSP installation = 344,529m² (based on vessels with 8 anchors; and 5 anchoring events per WTG/OSP)
	• Anchoring during array/interconnector cable installation = 144,077m² (based on 9 anchors per vessel and 264 anchoring events)
	• Boulder clearance – 25 boulders of up to 5m diameter = 491m²
	• Worst case scenario total disturbance footprint in the array areas = 6.9km²
	
	Export cable:
	• Maximum temporary disturbance for seabed preparation within the offshore cable corridor = 6,019,200m² based on:
	  ○ Maximum total export cable trench length of 250.8km.
	  ○ Maximum width of temporary disturbance is approximately 24m
	• Anchor placement = 297,826m²
	• Boulder clearance = 295m² (up to 15 boulders of 5m diameter)
	• Horizontal Directional Drilling (HDD) exit – up to 8 bores (4 cables + 4 contingency). Within the worst-case scenario footprint for the seabed preparation area
	• Total disturbance footprint – 6.32km².
		Temporary disturbance relates to seabed preparation and installation activities.
		
		The persistent/ permanent footprint of infrastructure is assessed as an operation phase impact.

Impact	Parameter	Notes
Impact 2: Increased suspended sediment concentrations and sediment re-deposition	**Array areas:** • Seabed preparation area of for GBS of 70m diameter x 72 WTG x average 5m sediment depth = 1,385,442m³ • Two OSPs seabed preparation x average 5m sediment depth = 33,183m³ Worst case scenario volume for seabed preparation for foundation installation = 1,418,625m³ • Array/interconnector cable seabed preparation – 228km length with average 24m disturbance width x average 5m sediment depth = 27,360,000m³ • Cable burial = 228km length with average 1m trench width x average 1.2m burial depth = 273,600m³ Worst case scenario volume due to array and interconnector cable installation = 27,633,600m³ • Drill arisings at 10% of largest WTGs = 38,132.7m³ (based on 42 of the largest turbines which is the worst case scenario) • Drill arisings at 1 x monopile OSPs = 10,687.7m³ (based on 50% of the OSPs needing drilling) Worst case scenario drill arising volume due to foundation installation = 48,820.3m³ NB, drill arising would not occur in the event that the GBS is used and therefore this parameter cannot be added to the maximum seabed levelling for GBS described above. **Export cable:** • Export cable sandwave levelling = 250.8km length with average 24m disturbance width x average 5m sediment depth = 30,096,000m³ • Export cable burial = 250.8km length with average 1m trench width x average 1.2m burial depth = 300,960m³ Worst case scenario volume due to export cable installation = 30,396,960m³	Seabed preparation (dredging using a trailing suction hopper dredger and installation of a bedding and levelling layer) may be required up to a sediment depth of 5m. The worst-case scenario assumes that sediment would be dredged and returned to the water column at the sea surface during disposal from the dredger vessel. Sandwave levelling may be required prior to offshore cable installation. Any excavated sediment due to sandwave levelling would be disposed of within the North Falls offshore project area, meaning there will be no net loss of sediment from the site. Sediment will be disposed of within the boundary of the offshore project area. Assumes drilling at up to 10% WTG locations. The offshore HDD exit location will be subtidal in 1 to 8m water depth. Sediment displacement is included in the totals for the export cable.

Impact	Parameter	Notes
Impact 3: Re-mobilisation of contaminated sediments	Maximum suspension of sediments as described above. No significant contaminated sediments were recorded in the offshore project area. See Chapter 9 Marine Water and Sediment Quality (Volume I) for more detail.	This represents the maximum total seabed disturbance and therefore the maximum amount of contaminated sediment that may be released into the water column during construction activities.
Impact 4: Underwater noise and vibration associated with piling for foundation installation	**Spatial worst case:** Mortality/potential mortal injury (fleeing and stationary receptor) and temporary threshold shift (TTS) and behavioural impacts (stationary receptor): • Installation of up to 74 monopiles (72 WTG and 2 OSPs) with a maximum pile diameter of 17m using a hammer energy of 6,000kJ. • Sequential installation of two monopiles. • Up to two simultaneous piling events. TTS and behavioural impacts (fleeing receptor): • Installation of up to 288 pin piles with a maximum pile diameter of 6m, using a hammer energy of 3,000kJ. • Installation of up to 12 pin piles with a maximum pile diameter of 3.5m, using a hammer energy of 3,000kJ for two OSPs. • Sequential installation of 4 pin piles • Up to two simultaneous piling events. **Temporal worst case:** • Installation of up to 300 pin piles using a hammer energy of 3,000kJ. • Piling time per WTG foundation: ○ Monopiles - Maximum of 450 minutes (7.5 hours) of active piling time per monopile Or ○ Pin piles - Maximum of 270 minutes (4.5 hours) of active piling time per pile • Piling time per OSP: ○ Monopiles - Maximum of 450 minutes (7.5 hours) of active piling time per monopile Or	The spatial worst case would result in largest spatial noise impact ranges at a given time and hence in the maximum impact on fish and shellfish receptors. Consideration has also been given to the worst-case scenario in terms of piling duration. This would be associated with the installation of the maximum number of piles.

Impact	Parameter	Notes
	○ Pin piles - Maximum of 270 minutes (4.5 hours) of active piling time per pile Total active piling time for both WTGs and OSPs: • Monopiles ○ Maximum of 540 hours (22.5 days) of active piling time for all WTGs, plus ○ Maximum of 15 hours (less than one day) of active piling time for both OSPs Or • Pin piles: ○ Maximum of 1,296 hours (54 days) of active piling time for all WTGs, plus ○ Maximum of 54 hours (less than 2.5 days) of active piling time for all OSPs	
Impact 5: Underwater noise and vibration from other construction activities	**Underwater noise and vibration from construction activities other than piling, including:** • Cable installation (cable laying vessel noise, trenching, etc.) • Seabed preparation • Rock placement • Construction vessels noise Maximum number of vessels on site at any one time: 35 Indicative construction vessel movements: 3,090 over three year offshore construction period (average of 1,030 movements per year; 3 movements per day)	This would result in the greatest noise impacts as a result of project construction activities other than piling for foundation installation.
Impact 6: Underwater noise from UXO clearance	Maximum equivalent charge weight for the potential UXO devices that could be present in the offshore project area has been estimated to be 698kg. Worst case number of UXO: • Up to 24 UXO The worst-case is an estimate. Actual UXO numbers would be determined by a pre-construction UXO survey.	This would result in controlled detonations with the greatest potential associated noise impacts.
Impact 7: Changes in fishing activity	See Chapter 14 Commercial Fisheries (Volume I)	

Impact	Parameter	Notes
Operation and Maintenance		
Impact 8: Temporary habitat loss/ physical disturbance	Unplanned repairs and reburial of cables may be required during O&M, the following estimates are included: • Reburial of c. 5km of array/interconnector cable is estimated over the life of the Project (24m disturbance width) = 120,000m^2 • Reburial of c. 5km of export cable is estimated over the life of the Project (24m disturbance width) = 120,000m^2 • Five array/interconnector cable repairs are estimated over the Project life. 600m section removed x 24m disturbance width = 72,000m^2 • Four export cable repairs are estimated over the Project life. 600m section removed x 24m disturbance width = 57,600m^2 Anchored vessels placed during the no. of cable repairs included above = 4,914m^2 Maintenance of offshore infrastructure would be required during O&M. An estimated 180 major component replacement activities may be required per year, using jack up vessels and/or anchoring = 297,000m^2	This represents the maximum estimated total area of seabed disturbance from unplanned repairs and reburial of cables that may be required during operation and maintenance (O&M). Persistent/ permanent habitat loss as a result of infrastructure decommissioned in situ is assessed as an operational impact because the impact begins when the operation phase starts once the wind farm infrastructure is in place.
Impact 9: Long term habitat loss	**Array areas:** WTGs: ○ Total worst case WTG foundation footprint with scour protection, based on 72 x 65m GBS diameter = 238,918m^2 ○ Scour protection **-** assumes all turbines have scour protection of up to 83,774m^2 (excluding turbine foundation footprint) = 6,031,728m^2 • Array/interconnector cable protection - Up to 45.6km of cable protection may be required in the unlikely event that array/interconnector cables cannot be buried (based on 20% of the length) x 6m cable protection width = 273,600m^2 • Two OSPs with scour protection = 149,012m^2 (74,506m^2 each) • Worst case scenario total persistent footprint in the array areas = 6.69km^2 **Export cable:**	This would result in the maximum area of seabed habitat loss for fish and shellfish receptors in respect of North Falls infrastructure.

Impact	Parameter	Notes
	Export cable protection - Up to 25km of cable protection may be required in the unlikely event that export cables cannot be buried (based on 10% of the length) x 6m cable protection width = 150,480m^2	
Impact 10: Increased suspended sediment concentrations (SSC) and re-deposition	Unplanned repairs and reburial of cables may be required during O&M, the following estimates are included: • Reburial of c. 5km of array/interconnector cable is estimated over the life of the Project (24m disturbance width) x average 1.2m depth = 144,000m^3 • Reburial of c. 5km of export cable is estimated over the life of the Project (24m disturbance width) x average 1.2m depth = 144,000m^3 • Five array/interconnector cable repairs are estimated over the Project life. 600m section removed x 24m disturbance width x average 1.2m depth = 86,400m^3 • Four export cable repairs are estimated over the Project life. 600m section removed x 24m disturbance width x average 1.2m depth = 69,120m^3	This would result in the highest potential levels of SSCs and subsequent sediment re-deposition. Each O&M activity would be relatively short term and it is likely that the requirements for maintenance would be spread over the Project life, with suspended sediments becoming rapidly redeposited.
Impact 11: Re-mobilisation of contaminated sediments	Re-mobilisation of contaminated sediments as a result of seabed disturbance from unplanned repairs and reburial of cables during O&M, area as described above for temporary increases in suspended sediment concentrations.	The ‘worst-case’ scenario is represented by that which could result in the maximum volume of arisings (and therefore, maximum volume of contaminated sediment that could be brought into suspension).
Impact 12: Underwater noise and vibration	**Underwater noise and vibration during operation:** • WTG - mechanically generated vibration and noise • Cable repairs and reburial (cable laying vessel noise, etc) • Maintenance vessels noise Maximum number of vessels on site at any one time: 22 Indicative O&M vessel trips to port per year: 1,460 round trips of small vessels and 127 round trips of large vessels (1,587 in total).	This results in the maximum potential for noise disturbance on fish and shellfish receptors during the O&M phase.

Impact	Parameter	Notes
Impact 13: Electromagnetic Fields (EMFs)	Array/interconnector cables: • Maximum cable length: 228km • Maximum voltage: 132kV • Minimum burial depth: 0.5m (average burial depth: 1.2m) • Up to 20% of total array/interconnector cable length requiring protection (up to 45.6 km) Export cables: • Up to 4 cable circuits with 3x unbundled power cables per circuit. • Maximum offshore cable length: 250.8km • Maximum voltage: up to 400 KV • Minimum burial depth: 0.5m (average burial depth 1.2m) • Up to 10% of total export cable length requiring protection (up to 25.1km)	The maximum length of cables and the minimum burial depth would result in the greatest potential for EMF related effects.
Impact 14: Introduction of hard substrate	Based on the long-term habitat loss (Impact 9) as a result of permanent infrastructure detailed for O&M • 72 WTG and 2 OSP • Volume of array/interconnector cable protection = 383,040m^3 • Volume of export cable protection = 210,672m^3	This would result in the greatest introduction of hard substrate and therefore in the greatest extent of impacts on fish and shellfish receptors
Impact 15: Changes in fishing activity	See Chapter 14 Commercial Fisheries (Volume I)	
Decommissioning		
Impact 16: Temporary habitat loss/ physical disturbance	• Vessel jack up assuming 6 jack up locations per wind turbine (275m^2 per jack up leg x 6 legs x 6 locations) = 712,800m^2 • Jack up vessel footprints for OSPs = 19,800m^2 • Anchoring - 60.7m^2 anchor footprint x 8 anchors per vessel x 264 placements during array/interconnector cable removal (if required) = 144,077m^2 • Anchoring - 116.4m^2 anchor footprint x 9 anchors per vessel x 5 placements per wind turbine/OSP installation = 344,529 m^2 • Anchor placement for export cable removal (if required) = 297,826m^2	For the purposes of the worst-case scenario, it is anticipated that the impacts will be no greater than those identified for the construction phase. No decision has yet been made regarding the final decommissioning policy for the offshore project infrastructure. It is also recognised that legislation and industry best practice change over time. However, the following infrastructure is likely be removed, reused or recycled where practicable: • WTGs including monopile, steel jacket and GBS foundations;

Impact	Parameter	Notes
Impact 17: Re-mobilisation of contaminated sediments	Maximum suspension of sediments as described above. No significant contaminated sediments were recorded in the offshore project area. See Chapter 9 Marine Water and Sediment Quality (Volume I) for more detail.	• OSPs including topsides and steel jacket foundations; and • Offshore cables may be removed or left *in situ* depending on available information at the time of decommissioning. The following infrastructure is likely to be decommissioned *in situ* depending on available information at the time of decommissioning: • Scour protection; • Offshore cables may be removed or left *in situ*; and • Crossings and cable protection. The detail and scope of the decommissioning works will be determined by the relevant legislation and guidance at the time of decommissioning and will be agreed with the regulator. Decommissioning arrangements will be detailed in a Decommissioning Plan, which will be prepared in accordance with the Energy Act 2004.
Impact 18: Underwater noise and vibration	WTG operational noise as described in Appendix 12.2 (Volume III).	
Impact 19: Changes in fishing activity		

11.3.3 Summary of mitigation embedded in the design

11. This section outlines the embedded mitigation relevant to the fish and shellfish ecology assessment, which has been incorporated into the design of North Falls. Where other mitigation measures are proposed, these are detailed in the impact assessment (Section 11.6).

Table 11.3 Embedded mitigation measures

Parameter	Mitigation measures embedded into North Falls design
Cable burial	The Applicant is committed to burying offshore cables where practicable to a minimum burial depth of 0.5m. Cable burial reduces the strength of EMFs to which fish and shellfish species may be exposed as it constitutes a physical barrier, with fish and shellfish species not able to transit the immediate proximity of cables where EMFs are strongest. In addition, cable burial minimises the amount of hard substrate which may be required and associated potential changes to seabed habitat.
Cable protection	Where cables cannot be buried to the minimum depth, appropriate surface laid cable protection will be used
Duration of construction activities	During construction, overnight working practices would be employed offshore where appropriate so that construction activities could be 24 hours, thus reducing the overall period for potential impacts to fish communities near the offshore project area.
Construction noise	A soft start and ramp-up protocol will be used for pile driving. This would allow mobile species to move away from the area of highest noise impact during installation of foundations.
Pollution prevention	As outlined in Chapter 9 Marine Sediment and Water Quality (Volume I), the Applicant is committed to the use of best practice techniques and due diligence regarding the potential for pollution throughout all construction, O&M, and decommissioning activities. An outline PEMP will be developed and submitted alongside the DCO application to set out the details of the measures that will be taken in relation to accidental pollution events. The final PEMP would be agreed with the MMO prior to construction.

11.4 Assessment methodology

11.4.1 Legislation, guidance and policy

11.4.1.1 National Policy Statements

12. The assessment of potential impacts upon fish and shellfish ecology has been made with specific reference to the relevant NPS. These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Project and fish and shellfish ecology are:

- NPS for Renewable Energy Infrastructure (EN-3) (Department of Energy and Climate Change (DECC), 2011); and
- Draft NPS for Renewable Energy Infrastructure (EN-3) (Department for Business, Energy and Industrial Strategy (BEIS), 2021a).

13. The UK Government announced a review of the existing NPSs within its December 2020 Energy White Paper (HM Government, 2020) and issued a draft version of NPS for Renewable Energy Infrastructure EN-3, Overarching NPS for Energy EN-1, and NPS for Electricity Networks Infrastructure EN-5 for consultation on 6th September 2021 (BEIS, 2021a; BEIS, 2021b; BEIS, 2021d). At the time of writing this PEIR chapter, final versions of the revised NPSs are not available.

14. The specific assessment requirements for fish and shellfish ecology as detailed in the NPS, are summarised in Table 11.4 together with an indication of the section of the PEIR chapter where each is addressed.

Table 11.4 NPS assessment requirements

NPS Requirement	NPS Reference	PEIR Reference
NPS for Renewable Energy Infrastructure (EN-3)		
There is the potential for the construction and decommissioning phases, including activities occurring both above and below the seabed, to interact with seabed sediments and therefore have the potential to impact fish communities, migration routes, spawning activities and nursery areas of particular species. In addition, there are potential noise impacts, which could affect fish during construction and decommissioning and to a lesser extent during operation.	Paragraph 2.6.73	Section 11.6
The Applicant should identify fish species that are the most likely receptors of impacts with respect to: spawning grounds; nursery grounds; feeding grounds; over-wintering areas for crustaceans; and migration routes.	Paragraph 2.6.74	Section 11.5.7
Where it is proposed that mitigation measures of the type set out in paragraph 2.6.76 below are applied to offshore export cables to reduce electromagnetic fields (EMF) the residual effects of EMF on sensitive species from cable infrastructure during operation are not likely to be significant. Once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement.	Paragraph 2.6.75	The mitigation measures proposed in paragraph 2.6.76 of EN-3 is included as an embedded mitigation measure for the Project. As described in Table 11.3, cables will be buried where practicable to a minimum burial depth of 0.5m (average burial depth 1.2m).
EMF during operation may be mitigated by use of armoured cable for inter-array and export cables which should be buried at a sufficient depth. Some research has shown that where cables are buried at depths greater than 1.5m below the sea bed impacts are likely to be negligible. However sufficient depth to mitigate impacts will depend on the geology of the sea bed.	Paragraph 2.6.76	As described in Table 11.3, cables will be buried where practicable to a minimum depth of 0.5m (average burial depth 1.2m).
During construction, 24 hour working practices may be employed so that the overall construction programme and the potential for impacts to fish communities is reduced in overall time.	Paragraph 2.6.77	As described in Table 11.3, the proposed embedded mitigation measures include consideration of 24 hour working practices.
Draft NPS for Renewable Energy Infrastructure (EN-3)		
Fish in the context of this NPS also includes elasmobranchs (sharks and rays) and shellfish (e.g., crabs). There is the potential for the construction and decommissioning phases, including activities occurring both above and below the seabed, to impact fish communities, migration routes, spawning activities and nursery areas of particular species. There are potential impacts associated with energy emissions into the environment (e.g. noise or EMF), as well as potential interaction with seabed sediments.	Paragraph 2.26.1	Section 11.6
The Applicant should identify fish species that are the most likely receptors of impacts with respect to:	Paragraph 2.26.2	Section 11.5.7

NPS Requirement	NPS Reference	PEIR Reference
• spawning grounds • nursery grounds • feeding grounds • over-wintering areas for crustaceans • migration routes • protected areas (e.g. HRA [Habitat Regulations Assessment] sites and MCZs)		
The assessment should also identify potential implications of underwater noise from construction and unexploded ordnance (both sound pressure and particle motion) and EMF on sensitive fish species.	Paragraph 2.26.3	Underwater noise is considered in Section 11.6.1.4, Section 11.6.1.5 and 11.6.1.6. The potential effects of EMF on sensitive species are considered in Section 11.6.2.6.
Review of up-to-date research should be undertaken and all potential mitigation options presented. EMF in the water column during operation, is in the form of electric and magnetic fields, which are reduced by use of armoured cables for interarray and export cables. Burial of the cable increases the physical distance between the maximum EMF intensity and sensitive species. However, what constitutes sufficient depth to reduce impact will depend on the geology of the seabed. It is unknown whether exposure to multiple cables and larger capacity cables may have a cumulative impact on sensitive species. Therefore monitoring EMF emissions may provide the evidence to inform future EIAs. In the case of floating wind, the cables may hang freely in the water and thus potentially require alternative monitoring and mitigation.	Paragraph 2.26.4	Impacts from EMFs are addressed under the assessment of the potential impacts during operation (Section 11.6.2.6). As described in Table 11.3, cables will be buried where practicable to a minimum burial depth of 0.5m (average burial depth 1.2m).
Construction of specific elements can also be timed to reduce impacts on spawning or migration. Underwater noise mitigation can also be used to prevent injury and death of fish species.	Paragraph 2.26.5	Consideration has been given in this assessment to fish species with known spawning and nursery grounds in areas relevant to the Project (Table 11.12). As described in Table 11.3, soft start and ramp-up mitigation will be used for pile driving to allow mobile species to move away from the area of highest noise impact during installation of foundations.
The use of rock armouring as mitigation does have advantages in reducing EMF for individual cables on fish species. However, the Secretary of State should also consider any negative impacts from rock armouring on benthic habitats and a balance between protection of various receptors must be made, with all mitigation and alternatives to rock armouring reviewed.	Paragraph 2.26.6	The presence of cable protection has no effect on reducing EMF but enforces a minimum physical distance between the receptor and the EMF. The effect of cable protection on benthic receptors is discussed in Chapter 10 Benthic and Intertidal Ecology (Volume I).
Draft NPS for Electricity Networks Infrastructure (EN-5)		
Draft EN-5 contains relevant policy in relation to the assessment of electricity networks infrastructure, however there is no information specific to this chapter.		

11.4.1.2 *Other legislation, policy and guidance*

15. In addition to the NPS, policy and guidance applicable to the assessment of fish and shellfish ecology is set out in the East Inshore and East Offshore Marine Plans and the South East Marine Plan. Relevant policies outlined in these marine plans are listed in Table 11.5.

16. Further detail on legislation, policy and guidance is provided in Chapter 3 Policy and Legislative Context (Volume I).

Table 11.5 Marine Plans Policies of Relevance to Fish and Shellfish Ecology

Marine Plan	Policy	Reference	PEIR Reference
East Inshore and East Offshore Marine Plans	Proposals should demonstrate, in order of preference: a) that they will not have an adverse impact upon spawning and nursery areas and any associated habitat b) how, if there are adverse impacts upon the spawning and nursery areas and any associated habitat, they will minimise them c) how, if the adverse impacts cannot be minimised they will be mitigated d) the case for proceeding with their proposals if it is not possible to minimise or mitigate the adverse impacts	FISH2	Section 11.6
South East Marine Plan	Proposals that enhance essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes should be supported. Proposals that may have significant adverse impact on essential fish habitat, including spawning, nursery and feeding grounds, and migratory routes, must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate Adverse impacts so they are no longer significant.	SE-FISH-1	Section 11.6

11.4.2 Data sources

17. The characterisation of the fish and shellfish ecology baseline on which to base the impact assessment, has been informed through a desktop review of available data and information. This has included information from fish surveys carried out at offshore wind farm projects in the proximity of the Project, namely the Greater Gabbard Offshore Wind Farm (GGOW) and Galloper Wind Farm (GWF), available data from ICES on the results of fish surveys which cover the study area and analysis of fisheries landings statistics.

18. In addition, the results of the sediment Particle Size Analysis (PSA) from grab samples collected in the offshore area during the benthic baseline characterisation survey carried out for the Project (Fugro 2021) have been used where appropriate to characterise the distribution of suitable habitat for species such as herring *Clupea harengus* and sandeels.

19. A description of the key sources of data and information used is provided in Table 11.6.

20. As agreed with the Seabed ETG during the meeting held on 20th June 2022 as part of the EPP, given the available data and information on the distribution of fish and shellfish species in the study area, the undertaking of site-specific surveys to aid the baseline characterisation in respect of the Project is not considered necessary.

Table 11.6 Other available data and information sources

Data Set	Spatial Coverage	Year	Notes
MMO UK Landings Data (weight) by species (MMO, 2021)	ICES rectangles in the study area (33F1, 32F1 and 32F2), and adjacent rectangles (34F0, 34F1, 34F2, 34F3, 33F2, 33F3, 32F0,31F1, 31F1, 31F2)	2016 -2020	Provides an indication of the principal species targeted around the Project.
Benthic Baseline Characterisation Survey (Fugro, 2021)	Offshore project area	2021	PSA data from grab samples collected across the offshore project area analysed to assess seabed suitability as sandeel and spawning herring habitat.
ICES International Bottom Trawl Survey (IBTS) data	ICES rectangles in the study area (33F1, 32F1 and 32F2) and wider North Sea	2017 -2021	IBTS data has been accessed via the ICES Data Portal (DATRAS, the Database of Trawl Surveys: http://datras.ices.dk). The data has been presented as catch per unit effort (CPUE) (individuals caught per hour) for the period 2017-2021
ICES International Herring Larvae Survey (IHLS) data	Sothern North Sea and English Channel (Downs herring)	December 2012 to January 2022	IHLS data has been accessed via the ICES Data Portal (http://eggsandlarvae.ices.dk). The IHLS surveys routinely collect information on the size, abundance and distribution of herring eggs and larvae (and other species) in the North Sea.
North Sea Cod and Plaice Egg (CP-EGGS) Surveys in the North Sea	North Sea	2003 – 2004, 2008 - 2009	CP-EGGS data has been accessed via the ICES Data Portal (http://eggsandlarvae.ices.dk). CP-EGGS aim to studying fish egg and larval distributions in the North Sea.
Cefas Blackwater Herring Survey	Thames Estuary	1989 - 2009	Cefas data has been accessed via the Cefas data portal: (https://data.cefas.co.uk/view/10094) Aims to assess the state of herring (*Clupea harengus*) stocks through measurements of length samples and by ageing a stratified selection of fish.
Distribution of Spawning and Nursery Grounds as defined in Coull et al. (1998) and in Ellis et al (2010, 2012)	UK territorial waters and the North Sea	Coull et al., 1991 - 1996 Ellis et al., varies by species but generally includes data between 1983 and 2008	Coull et al (1998) and Ellis et al (2010, 2012) are the standard references that provide broad scale overviews of the potential spatial extent of nursery grounds, spawning grounds and the relative intensity and duration of spawning. Both Coull et al (1998) and Ellis et al (2010, 2012) are based on a compilation of a variety of data sources.

Data Set	Spatial Coverage	Year	Notes
Galloper Offshore Wind Farm Adult and Juvenile Fish Surveys (BMM, 2009)	GWF array area, cable corridor and adjacent locations.	October/November 2008 and April 2009	Baseline adult and juvenile fish surveys undertaken for the GWF using a commercial otter trawl and a 2-m scientific beam trawl, respectively.
Greater Gabbard Offshore Wind Farm Epibenthic Surveys (CMACS, 2014)	GGOW array area, export cable corridor and adjacent locations.	2009 and 2013	Epibenthic baseline and post-construction surveys undertaken as part of the monitoring of benthic communities following construction of the GGOW. Dataset includes information on the principal fish species recorded in 2-m scientific beam trawl samples.
Greater Gabbard Offshore Wind Farm Elasmobranch survey (BMM, 2014)	GGOW array area, export cable corridor and adjacent locations.	2014	Post-construction surveys carried out using longlines to determine the distribution and abundance of elasmobranch species in and around the wind farm.

21. In addition to the data sources described above, the following resources have been accessed to inform this report:

- Kent and Essex Inshore Fisheries Conservation Authority (KEIFCA) publications;
- Centre for Environment, Fisheries and Aquaculture Science (Cefas) publications;
- Joint Nature Conservation Committee (JNCC) publications;
- Institute for Marine Resources and Ecosystem Studies (IMARES) publications;
- ICES publications; and
- Other relevant peer-reviewed publications.

11.4.3 Impact assessment methodology

22. Chapter 6 EIA Methodology (Volume I) explains the general impact assessment methodology applied to North Falls. The following sections confirm the methodology used to assess the potential impacts on fish and shellfish ecology.

11.4.3.1 Definitions

23. For each effect, the assessment identifies receptors sensitive to that effect and implements a systematic approach to understanding the impact pathways and the level of impacts on given receptors. The definitions of sensitivity and magnitude for the purpose of the fish and shellfish ecology assessment are provided in Table 11.7 and Table 11.8.

Table 11.7 Definition of sensitivity for a fish and shellfish ecology receptor

Sensitivity	Definition
High	Individual* receptor (species or stock) has very limited or no capacity to avoid, adapt to, accommodate or recover from the anticipated impact.

Sensitivity	Definition
Medium	Individual* receptor (species or stock) has limited capacity to avoid, adapt to, accommodate or recover from the anticipated impact.
Low	Individual* receptor (species or stock) has some tolerance to accommodate, adapt or recover from the anticipated impact.
Negligible	Individual* receptor (species or stock) is generally tolerant to and can accommodate or recover from the anticipated impact.

*In this case individual receptor does not refer to an individual organism but refers to the population or stock of a species

Table 11.8 Definition of magnitude for a fish and shellfish ecology receptor

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the particular receptors character or distinctiveness.
Medium	Considerable, permanent / irreversible changes, over the majority of the receptor, and / or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Low	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (for part of the project duration) change, or barely discernible change for any length of time, over a small area of the receptor, and / or slight alteration to key characteristics or features of the particular receptors character or distinctiveness.

11.4.3.2 Significance of effect

24. In basic terms, the potential significance of an effect is a function of the sensitivity of the receptor and the magnitude of the impact (see Chapter 6 EIA Methodology (Volume I) for further details). The determination of significance is guided by the use of an impact significance matrix, as shown in Table 11.9. Definitions of each level of significance are provided in Table 11.10.

25. Potential effects identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. Appropriate mitigation has been identified, where practicable, in consultation with the regulatory authorities and relevant stakeholders. The aim of mitigation measures is to avoid or reduce the overall effect in order to determine a residual effect upon a given receptor.

Table 11.9 Significance of effect matrix

		Negative Magnitude				Beneficial Magnitude			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	*Major*	*Major*	*Moderate*	*Minor*	*Minor*	*Moderate*	*Major*	*Major*
	Medium	*Major*	*Moderate*	*Minor*	*Minor*	*Minor*	*Minor*	*Moderate*	*Major*
	Low	*Moderate*	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 11.10 Definition of effect significance

Significance	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision making process.
Negligible	No discernible change in receptor condition.
No change	No impact, therefore no change in receptor condition.

11.4.4 Cumulative effects assessment (CEA) methodology

26. The CEA considers other plans, projects and activities that may impact cumulatively with North Falls. Chapter 6 EIA Methodology (Volume I) provides further details of the general framework and approach to the CEA.

27. For fish and shellfish ecology these activities include other OWFs, subsea cables and pipelines, oil and gas exploration and aggregate extraction. As a general rule, other activities are only screened into the CEA where there is a spatial and/or temporal overlap in effects such that a cumulative effect would be possible.

11.4.5 Transboundary impact assessment methodology

28. For fish and shellfish ecology, the potential for transboundary effects has been scoped out for assessment. As described in the Scoping Report (Royal HaskoningDHV, 2021), the fish and shellfish impact assessment has been undertaken taking account of the distribution of fish stocks and populations irrespective of national jurisdictions. Therefore, the Applicant considers that a specific assessment of transboundary effects in relation to fish and shellfish ecology is unnecessary. The suitability of this approach has been confirmed by the MMO and PINS in their Scoping Opinion (see Table 11.1).

11.4.6 Assumptions and limitations

29. The characterisation of the existing environment in respect of fish and shellfish receptors has been undertaken using a wide a range of sources of data and information. Key data sources used, including their sensitivities and limitations are described in detail in Appendix 11.1 (Volume III).

11.5 Existing environment

30. This section includes a summary of the fish and shellfish ecology baseline for the Project and identifies key fish and shellfish receptors requiring assessment. Further detailed information on the fish and shellfish ecology baseline can be found in Appendix 11.1 (Volume III).

31. Fish and shellfish ecology receptors have been identified taking account of the following parameters:

- Presence/abundance in the study area;
- Location of spawning and nursery grounds relative to the Project;
- Conservation importance;
- Commercial importance; and
- Role within the North Sea's food-web.

32. In addition, in identifying key fish and shellfish receptors, due consideration has been given to the feedback received in the Scoping Opinion of relevance to fish and shellfish ecology and the consultation undertaken with the Seabed ETG on fish and shellfish ecology issues as part of the EPP.

11.5.1 International Bottom Trawl Survey (IBTS)

33. Recent data from the IBTS (2017 - 2021) have been analysed to help characterise the fish and shellfish community in the study area and are presented in Appendix 11.1 (Volume III).

34. The demersal bony fish species recorded in the study area by the IBTS in greatest numbers was whiting. Other species found in relatively high numbers included dab, bib, poor cod, plaice and Dover sole. Species such as lesser weever, grey gurnard *Eutrigla gurnardus*, lemon sole and stripped red mullet *Mullus surmuletus* were also relatively abundant but for the most part their catches were concentrated in rectangle 32F2, with relatively low numbers found in 32F1, where the majority of the offshore project area is located. The remaining species of demersal bony fish were all recorded in relatively low numbers.

35. Small spotted catshark was the elasmobranch found in greatest numbers, followed by thornback ray and smoothhounds.

11.5.2 Species of commercial importance in the study area

36. The principal commercial fish and shellfish species targeted in the study area have been identified through the analysis of landings statistics of UK vessels by weight by ICES rectangle presented in Appendix 11.1 (Volume III). Additional information on activities from UK vessels and from vessels of other nationalities known to be active in the study area is provided in Chapter 14 Commercial Fisheries (Volume I).

37. The species of commercial importance from the study area are considered to be sole *Solea solea*, whelk *Buccinum undatum*, bass *Dicentrarchus labrax*, thornback ray *Raja clavata*, horse mackerel *Trachurus trachurus*, herring *Clupea harengus,* cod *Gadus morhua* and plaice *Pleuronectes platessa*.

38. The principal species landed by weight by UK vessels from the study area are molluscs, predominantly cockle *Cerastoderma edule* and whelk *B. undatum.* However, cockles are not fished in the vicinity of the offshore cable corridor, as any cockle grounds that do overlap have been closed under the Cockle Fishery Flexible Permit Byelaw for the last 10 years. The active cockle fishery is in the southwest corner of ICES rectangle 32F1, and is therefore not considered further.

39. In ICES rectangle 32F1, where the majority of the offshore project area is located, the species of highest commercial importance are considered to be sole, whelk, bass and thornback ray. Local vessels to the offshore cable corridor are reported as targeting species such as bass, sole, skate, herring, turbot, brill, lobster and crab from a mix of trawling, netting and potting.

40. Further detailed information on landings statistics is provided in Appendix 11.1 (Volume III) and in Chapter 14 Commercial Fisheries (Volume I).

11.5.3 Surveys undertaken in the Galloper and Greater Gabbard Offshore Wind Farms

41. Various fish surveys have been undertaken in the GGOW and GWF. These are outlined in Table 11.11. Whilst these surveys have not been carried out in recent years, some of the stations sampled are within or in close proximity to the offshore project area and are therefore of relevance to the Project. A summary of the results of these surveys is provided below. For additional detail see Appendix 11.1 (Volume III).

Table 11.11 Surveys undertaken in the Galloper and Greater Gabbard Offshore Wind Farms

Survey	Gear Type	Survey Area	Sampling Effort	Time of Surveys
Adult and Juvenile Fish Survey (BMM, 2009)	Otter trawl and 2-m scientific beam trawl	GWF array areas, export cable corridor and adjacent areas	15 x 25-minute otter trawls 18 x 5-minute beam trawls	October/November 2008 and April 2009
Epibenthic Survey (CMACS, 2014)	2-m scientific beam trawl	GGOW array area, export cable corridor and adjacent areas	21 x 300m tows	Spring/Summer 2009
			26 x 300m tows	Spring/Summer 2013
Elasmobranch Survey (BMM, 2014)	Longlines	GGOW array, export cable corridor and adjacent locations	14 x 300m longlines (100 hooks per line, 3 m apart)	May 2014

42. In the surveys carried out using otter trawl gear at GWF (BMM 2009), whiting *Merlangius merlangus*, cod and small-spotted catshark *Scyliorhinus canicula* were the species caught in higher numbers, with other demersal species such as dab *Limanda limanda*, bib *Trisopterus luscus*, plaice *Pleuronectes platessa*, thornback ray, starry smoothhound *Mustelus asterias*, poor cod *Trisupterus minutus*, lemon sole *Microstomus kitt* and tub gurnard *Chelidonichthys lucernus* also caught in relatively high numbers.

43. In the surveys undertaken using 2-m scientific beam trawl in the GWF and GGOW (BMM, 2009; CMACS, 2014) the main fish species recorded included various species of goby, Dover sole, Northern rockling *Ciliata septentrionalis*, dragonet *Callionymus lyra*, bib, poor cod, lesser weever *Echiichthys vipera*, sea snail *Liparis liparis*, dab, small spotted cat-shark, lemon sole, pogge *Aganus cataphractus* and whiting.

44. Small spotted catshark was the principal elasmobranch species recorded during the longline elasmobranch survey carried out in the GGOW (BMM, 2014),

followed by thornback ray and spurdog. Other species, such as smoothhounds *Mustelus sp. and tope Galeorhinus galeus* were also reported from this survey but in much lower numbers (eleven and one individuals, respectively*).*

45. Further details on the results of these surveys are provided in Appendix 11.1 (Volume III).

11.5.4 Spawning and nursery grounds

46. Species for which spawning or nursery grounds have been defined in areas that overlap with the array areas, offshore cable corridor and/or interconnector corridor are listed in Table 11.12 based on information provided in Coull et al (1998) and Ellis et al (2010, 2012).

47. As shown, spawning grounds for herring, lemon sole, plaice, sandeel (*Ammodytidae spp*.), Dover sole, sprat, whiting and cod have all been defined in the offshore project area.

48. Nursery grounds for the species mentioned above as well as mackerel, thornback ray, and tope have also been defined within the offshore project area. It should be noted that in the case of thornback ray and tope, there is currently insufficient data on the occurrence of egg-cases or egg-bearing females in the spawning season with which to define spawning grounds. In the case of thornback ray, it is considered that these are likely to broadly overlap with nursery grounds (Ellis et al., 2012).

49. Most of the species listed in Table 11.12 are pelagic spawners, which release their eggs in the water column. Exceptions to this are herring and sandeel, which are substrate specific demersal spawners. Thornback ray also lay eggs on benthic substrates although they are not known to have the same degree of substrate-specific spawning requirements as herring and sandeels.

50. Further detailed information on the distribution of spawning and nursery grounds of the species described above, together with information relating to their ecology, is provided in Appendix 11.1 (Volume III).

Table 11.12 Species with spawning and/or nursery grounds in the offshore project area (Coull et al.,1998; Ellis et al., 2010)

Species	Spawning Season (month)												Spawning Intensity			Nursery Intensity		
	1	2	3	4	5	6	7	8	9	10	11	12	AA	OCC	ICC	AA	OCC	ICC
Herring														n/a	n/a			
Lemon Sole																		
Plaice	*	*																
Sandeel																		
Dover sole				*														
Sprat					*	*												
Whiting																		
Mackerel					*	*	*						n/a	n/a	n/a			
Cod		*	*															
Tope	Gravid females found all year												n/a	n/a	n/a			
Thornback ray				*	*	*	*						n/a	n/a	n/a			

Spawning times and intensity colour key: orange = high intensity spawning/nursery grounds, yellow= low intensity spawning/nursery grounds, blue= spawning/ nursery intensity not defined, grey= spawning period, * = peak spawning, n/a= no overlap with spawning/nursery grounds. AA = array areas, OCC = offshore cable corridor, ICC = interconnector cable corridor.

11.5.5 Species of conservation importance

51. Fish and shellfish species of conservation importance which have the potential to be found in the study area are outlined in the following sections including:

- Diadromous migratory species;
- Elasmobranchs; and
- Other species with designated conservation status.

52. Detailed information on the ecology, conservation status and the use that these species may make of the offshore project area or areas in its proximity is provided within Appendix 11.1 (Volume III).

53. The offshore project area overlaps with the Southern North Sea Special Area of Conservation (SAC) and is located in close proximity to the Margate and Long Sands SAC. The southern array area overlaps with the Kentish Knock East MCZ and the inshore section of the offshore cable corridor overlaps with the Outer Thames Estuary Special Protection Area (SPA). The inshore section of the export cable corridor is in the proximity of the Blackwater, Crouch, Roach and Colne Estuaries MCZ of which protected features include native oyster *Ostrea edulis* and native oyster beds.

54. The assessment of impacts on seabed and benthic features is detailed within (Volume I); Chapter 8 Marine Geology, Oceanography and Physical Processes and Chapter 10 Benthic and Intertidal Ecology. The assessment on marine mammals is presented in Chapter 12 Marine Mammal Ecology (Volume I) and the assessment on ornithology receptors in Chapter 13 Offshore Ornithology (Volume I).

55. With the exception of the Blackwater, Crouch, Roach and Colne Estuaries MCZ, where shellfish species (native oyster/oyster beds) are protected features for designation, the Marine Protected Areas (MPAs) mentioned above are not designated for the protection of fish or shellfish species, per se. These MPAs, however, provide habitat and support a wide range of crustaceans and fish and in some cases include foraging areas of importance for marine mammals and birds.

11.5.5.1 Diadromous species

56. Various diadromous species have the potential to transit parts of the offshore project area, during certain periods of their life cycle. These include:

- European eel *Anguilla anguilla*;
- Shads (*Alosa alosa* and *Alosa fallax*);
- River and sea lampreys (*Lampetra fluviatilis* and *Petromyzon marinus*);
- Atlantic salmon *Salmo salar*;
- Sea trout *Salmo trutta*; and
- Smelt *Osmerus eperlanus*.

57. The occurrence of species such as European eel, shad, sea trout and lampreys has been documented from the Blackwater, Crouch and Colne Estuaries and the Thames (APEM, 2018; Graham et al., 2021; Maitland, 2003; Zoological Society of London (ZSL), 2016; ZSL, 2018; ZSL, 2021). These and the remaining species listed above may be occasionally recorded in MMO commercial landings statistics, however, with the exception of twaite shad, none of these species were recorded at surveys undertaken in the GWF and GGOW or during recent IBTS surveys (Appendix 11.1, Volume III).

58. For the most part these species, if present in the area, would be expected in coastal areas (i.e. in inshore areas possibly in the proximity of the offshore cable corridor) rather than in the array areas.

11.5.5.2 Elasmobranchs

59. Elasmobranchs (sharks, skates and rays) are considered particularly vulnerable to anthropogenic pressures due to their slow growth rates, late age at maturity and low reproductivity, resulting in slow increases in their population (Ellis et al., 2008; Sguotti et al., 2016). Stock levels of many elasmobranch species are considered low and are therefore the focus of conservation efforts including international advice and management measures (Dulvy et al., 2017; ICES, 2021). Those potentially present in the study area are listed in Table 11.13.

60. Thornback ray, blonde ray, small spotted catshark, smoothhounds, spurdog and tope were recorded in either the GWF or GGOW fish ecology surveys. Similar species presence was recorded in the IBTS in addition to spotted ray, noting that spurdog was not recorded in recent IBTS sampling. Further detailed information on survey and IBTS sampling results is provided in Appendix 11.1 (Volume III).

Table 11.13 Principal elasmobranch species potentially found in areas of relevance to the offshore project area

Common Name	Scientific name
Sharks	
Basking shark	*Cetorhinus maximus*
Starry smoothhound	*Mustelus asterias*
Smoothhound	*Mustelus mustelus*
Spurdog	*Squalus acanthias*
Thresher shark	*Alopias vulpinus*
Tope	*Galeorhinus galeus*
Skates and rays	
Blonde ray	*Raja brachyura*
Cuckoo ray	*Leucoraja naevus*
Common skate complex	*Dipturus intermedius/ Dipturus flossada*
Spotted ray	*Raja montagui*
Thornback ray	*Raja clavata*

Common Name	Scientific name
Undulate skate	*Raja undulata*
White skate	*Rostroraja alba*

11.5.5.3 Other species of conservation importance

61. In addition to diadromous fish and elasmobranchs, a number of fish and shellfish species found in the study area are of conservation interest, being listed as species of principal importance under the UK Post-2010 Biodiversity Framework and Section 41 of the Natural Environment and Rural Communities Act 2006 (England). In addition, some fish and shellfish species are protected features in MCZs. These are presented in Appendix 11.1 (Volume III), along with other conservation designations (e.g. Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR; Oslo/Paris Convention) and International Union for Conservation of Nature (IUCN) listings). It should be noted that many of these species are commercially exploited in the area, either directly or indirectly as by-catch.

11.5.6 Prey species and food web linkages

62. Various fish species found in the study area, particularly sandeels (*Ammodytidae spp.*), and clupeids (e.g. herring *Clupea harengus* and sprat *Sprattus sprattus*), play an important role in the North Sea's food web as prey to predators such as birds, marine mammals and piscivorous fish (ICES, 2019).

63. Sandeels, herring and sprat were present in surveys carried out in GGOW and GWF and, whilst the main focus of the IBTS is on demersal fish sampling, shoaling pelagic species, particularly sprat and to a lesser extent herring were recorded in relatively high numbers over the 2017 to 2021 period. It is also of note that while herring and sprat are commercially exploited in the study area, sandeels are not currently directly targeted.

64. The ecology of these prey species is described in further detail within Appendix 11.1 (Volume III).

11.5.7 Key fish and shellfish species

65. In order to identify key species, due regard has been given to the feedback provided by stakeholders on fish and shellfish ecology related issues in the Scoping Opinion issued by PINS (PINS, 2021) and during ETG meetings as part of the EPP.

66. The key species identified, and the rationale for their inclusion within the assessment is provided in Table 11.14. This includes considerations such as presence/abundance in the study area, commercial importance, distribution of spawning and nursery grounds and conservation status.

67. Detailed information regarding the ecology of these species and the use that they may make of the study area is provided in Appendix 11.1 (Volume III).

Table 11.14 Principal Fish and Shellfish Species in the Study Area

Relevant Fish and Shellfish Species	Rationale
Principal Demersal Bony Fish	
Cod	• Common in the study area • Species of conservation interest (Principal Importance, OSPAR, IUCN) • Commercially important in the study area • Low intensity spawning and nursery areas overlap with offshore project area
Whiting	• Common in the study area • Species of Principal Importance • Low intensity spawning and nursery areas overlap with the offshore project area
Dover sole	• Common in the study area • Species of Principal Importance • Commercially important in the study area • High intensity spawning area overlaps with the offshore project area • High intensity nursery area overlaps with the inshore section of the offshore cable corridor; low intensity nursery area overlaps with the array areas and the interconnector cable corridor
Plaice	• Common in the study area • Species of Principal Importance • Commercially important in the study area • High intensity spawning area and low intensity nursery area overlap with the offshore project area
Lemon sole	• Common in the study area • Undefined intensity spawning area and nursery area overlaps with the offshore project area
Sea bass	• Common in the study area • Of importance to commercial and recreational fisheries in the study area • Sea bass fishing heavily regulated due to stock concerns
Other Species (i.e. dab, gobies, gurnards)	• Species characteristic of the southern North Sea fish assemblage • Common species in the study area • Possible prey items for fish, bird and marine mammal species
Ammodytidae (Sandeels)	
Lesser sandeel Small sandeel Greater sandeel	• Found in the study area • Species of Principal Importance • Key prey species for fish, birds and marine mammals • Low intensity spawning and nursery areas overlap with the offshore project area
Principal Pelagic Fish Species	
Herring	• Common in the study area • Species of Principal Importance • Commercially important in the study area • Spawning grounds of Downs herring located in areas adjacent to the southern array area • Spawning grounds of Blackwater herring located in the proximity of the inshore section of the offshore cable corridor. • High intensity nursery area overlaps with the offshore project area. • Key prey species for fish, birds and marine mammals
Sprat	• Common in the study area • Low commercial importance in the study area • Undefined intensity spawning grounds and nursery grounds overlap with the offshore project area • Key prey species for fish, birds and marine mammals

Relevant Fish and Shellfish Species	Rationale
Horse Mackerel	• Common in the study area • Species of Principal Importance • Commercial importance in the study area
Mackerel	• Found in the study area • Species of Principal Importance • Low commercial importance in the study area • Low intensity nursery area overlaps with the offshore project area
Elasmobranchs	
Thornback ray	• Abundant in the study area • Commercially important in the study area • Conservation importance (‘Near Threatened’ IUCN status and OSPAR list) • Low intensity nursery area overlaps with the offshore project area
Other Rays, Skates and Sharks (e.g. spotted ray, common skate, blonde ray, small spotted catshark, smoothhounds, spurdog, tope)	• Present in the vicinity of the study area • Some species are Species of Principal Importance or OSPAR listed, and several are classified Endangered or Critically Endangered on the IUCN Red List with landings restricted or prohibited • Some species are of commercial importance in the study area • Tope have low intensity nursery grounds overlapping with the offshore project area
Diadromous Fish Species	
European eel	• Present in rivers in the proximity of the study area • Species of conservation importance (Species of Principal Importance, OSPAR list, listed as ‘Critically Endangered’ by IUCN) • May transit/feed in the study area during marine migration
European smelt	• Populations of smelt reported from estuaries in the proximity of the offshore project area • Species of Principal Importance • May transit/feed in vicinity of the inshore section of offshore cable corridor
Twaite shad Allis shad	• Species of conservation interest (Species of Principal Importance, protected under Bern Convention, Wildlife and Countryside Act, Habitats Regulations and included in OSPAR list (allis shad). • May transit/feed in vicinity of the study area during marine phase. • Caught in surveys carried out in the GWF
River lamprey Sea lamprey	• Species of conservation interest (Species of Principal Importance, protected under the Habitats Regulations, the Bern Convention and listed by OSPAR as declining and/or threatened (sea lamprey only). • May transit/feed in vicinity of the study area during marine migration
Atlantic salmon	• Species of conservation interest (Species of Principal Importance, protected under the Habitats Regulations, the Bern Convention, listed by OSPAR as declining and/or threatened and classified as “vulnerable” by IUCN. • May occasionally transit/feed in the study area during marine migration
Sea trout	• Reported from estuaries in the proximity of the offshore project area • Species of Principal Importance • May transit/feed in the study area during marine migration
Shellfish species	
Cockle	• Commercially important in the study area • Managed by the Cockle Flexible Permit Byelaw and the Thames Estuary Cockle Fisheries Order 1994
Whelk	• Commercially important in the study area • Managed by the Whelk Fishery Flexible Permit Byelaw

Relevant Fish and Shellfish Species	Rationale
Native oyster	• Species of Principal Importance and protected in the Blackwater, Crouch, Roach and Colne Estuaries MCZ • Managed by Native Oyster Fishery Flexible Permit Byelaw
Lobster	• Commercial importance in the study area
Crab	• Commercial importance in the study area • May overwinter within the study area and the wider area

11.5.8 Future trends in baseline conditions

68. The existing baseline conditions within the study area described above are considered to be relatively stable in terms of fish and shellfish receptors. Multiple sources of fish and shellfish data are available at different spatial resolutions for varying time periods that exhibit similar trends in species presence and abundance. The fish and shellfish baseline environment of the southern North Sea is however influenced by environmental factors and commercial fishing activity and therefore subject to change.

69. Species distribution shifts during the last decades have been documented at varying scales across oceans and taxonomic groups (Sorte et al., 2010). Chapter 10 Benthic and Intertidal Ecology (Volume I) highlights that North Sea benthic communities are under significant pressure from climate change and that a north westerly shift in geographical distribution is predicted for benthic communities. Fish communities are also likely to follow this trend.

70. Commercial fishing activity is subject to multiple factors including variations in target species abundance, changes in the quotas of pressure stock species, the imposition of conservation measures including spatial restrictions, local byelaws, effort limits and vessel and gear regulations. Economics effects as well as national and international politics may also result in changes at local, regional and national scales.

71. It is anticipated that the baseline will continue to evolve as a result of global trends which include the effects of climate change as well as trends at the European level such as changes in fisheries regulations and policies.

11.6 Potential impacts

11.6.1 Potential impacts during construction

72. The potential impacts of the Project on fish and shellfish receptors during construction are assessed below. As outlined in Table 11.2, these include the following:

- Impact 1: Physical disturbance and temporary habitat loss;
- Impact 2: Increased SSCs and sediment re-deposition;
- Impact 3: Re-mobilisation of contaminated sediments
- Impact 4: Underwater noise from piling for foundation installation
- Impact 5: Underwater noise from other construction activities

- Impact 6: Underwater noise from UXO clearance
- Impact 7: Changes in fishing activity

11.6.1.1 Impact 1: Physical disturbance and temporary habitat loss

11.6.1.1.1 Magnitude of impact

73. During the construction phase of the Project, activities such as foundation installation of WTGs and OSPs as well as array, interconnector and export cable installation have the potential to result in physical disturbance and/or temporary loss of habitat to fish and shellfish receptors. Similarly, the presence of machinery on the seabed (i.e. jack up vessel legs, vessel anchors) could also result in physical disturbance or temporary habitat loss.

74. Offshore works are anticipated to be carried out over an indicative 3-year construction programme. As described in Table 11.2, the total area disturbed during construction within the North Falls array areas would be 6.9km^2. This would account for a small percentage of the total area of the arrays (approx. 4.6%). Similarly, the maximum area of disturbance associated with construction activities in the export cable corridor would also be relatively small (total disturbance footprint = 6.32km^2).

75. Physical disturbance/ loss of habitat would occur at localised discrete locations (i.e. in the immediate proximity of infrastructure/machinery) at any given time as construction works progress and would be temporary and short term. Most of the fish species that are found in the study area are highly mobile with wide distribution ranges, whilst benthic species (e.g. demersal shellfish species) present in the study area are considered to be characteristic of highly disturbed environments and will therefore recover rapidly from disturbance as a result of construction (see Chapter 10 Benthic and Intertidal Ecology (Volume I)).

76. While the inshore section of the offshore cable corridor area overlaps with two cockle harvest areas it is understood from consultation with KEIFCA that there is no overlap between cockle beds that are being commercially targeted and the offshore cable corridor. Similarly, while the offshore cable corridor is in the proximity (c.4.5km) of the Blackwater, Crouch, Roach and Colne Estuaries MCZ (specifically designated for the protection of native oysters/oyster beds) there is no overlap with the offshore cable corridor and therefore no direct loss of this habitat/receptor predicted.

77. Given the small area of disturbance, the generally wide distribution ranges (or no direct overlap of habitats with construction activities) of fish and shellfish species, and that the seabed is anticipated to quickly recover to its original condition the magnitude of the impact of physical disturbance/temporary habitat loss to fish and shellfish receptors in general is considered to be low.

11.6.1.1.2 Sensitivity of receptor

78. Most of the fish species that are found in the study area are highly mobile with wide distribution ranges as adults and juveniles and would be able to make use of suitable undisturbed areas in the vicinity of works. The sediment and benthic species around the offshore project area are considered to be characteristic of highly disturbed environments and would be expected to return to its original condition over a relatively short time frame once construction activities have ceased in a given area. As such no significant impacts on the benthic community

are anticipated in relation to disturbance during construction (impact assessed as negligible in Chapter 10 Benthic and Intertidal Ecology (Volume I)).

79. In the context of the small areas where physical disturbance and temporary habitat loss may occur being characteristic of highly disturbed environments in general terms, fish and shellfish species are therefore considered receptors of low sensitivity.

80. Species that depend on specific substrates for burrowing or spawning and species of life stages of reduced mobility, may however be more susceptible to the impact of physical disturbance/temporary habitat loss. In the study area, these include the following:

- Herring: require specific substrates on which to lay their eggs (demersal spawners)
- Sandeels: require specific substrates on which to burrow as well as for spawning (demersal spawners);
- Elasmobranch species with spawning grounds in the offshore project area that lay egg cases on the seabed (i.e. thornback ray); and
- Shellfish species: have lower mobility in comparison to fish species and in some cases carry their eggs or lay them on the seabed.

81. A separate assessment of sensitivity is provided for these species/species groups below. Additional species-specific information on magnitude, is also included, where relevant, to provide context to the assessment of sensitivity.

Herring

82. Herring are demersal spawners and require the presence of suitable coarse substrate on which to lay their eggs. Therefore, physical disturbance to the seabed and temporary habitat loss associated with construction works could result in detrimental impacts on herring spawning.

83. As discussed in Appendix 11.1 (Volume III), there are two distinct herring populations of relevance in the study area. These are the Downs herring and the Blackwater herring.

84. Defined spawning grounds for the Downs herring are located immediately to the east of the southern array area with limited overlap with the offshore project area (Figure 11.2, Volume II). In line with this, analysis of sediment samples collected during benthic investigations carried out for the Project (Fugro, 2021) (Figure 11.3, Volume II) indicate that for the most part the offshore project area is unsuitable as herring spawning habitat. An exception to this may be the discrete section of the eastern edge of the southern array area which shows overlap with the defined Downs herring spawning grounds. It is noted that within this discrete area no benthic samples were collected during benthic surveys (Figure 11.2 and Figure 11.3, Volume II). Therefore, whilst limited, as there may be some overlap between spawning grounds and the offshore project area, the Downs herring is considered a receptor of medium sensitivity.

85. In the case of the Blackwater herring, spawning grounds are located in inshore areas around the Blackwater Estuary and Herne Bay at considerable distance from the offshore project area (Figure 11.2, Volume II). As such, while

Blackwater herring sensitivity would be the same as for Downs herring, it is considered a receptor of low sensitivity in the context of negligible magnitude.

Sandeels

86. Sandeels depend on the presence of an appropriate sandy substrate in which to burrow and lay their eggs on the seabed (demersal spawners). Therefore, physical disturbance to the seabed and temporary habitat loss associated with construction works could result in detrimental impacts on this species.

87. As shown in Figure 11.4 (Volume II), the offshore project area overlaps with the large low intensity sandeel (*Ammodytidae* spp.) spawning and nursery grounds defined by Ellis et al. (2012) that cover the majority of the southern North Sea. The closest high intensity sandeel spawning areas are found in the Dogger Bank at a considerable distance from the offshore project area.

88. In line with this, analysis of IBTS data for lesser sandeel, the species of sandeel that is most abundant in the North Sea, shows low CPUE values in the study area, with other areas within Sandeel Assessment (SA) area 1r, particularly the Dogger Bank, recording considerably higher CPUEs values (Figure 11.5, Volume II).

89. Whilst sandeels are expected to be found in some numbers in the study area, available information from the IBTS (Figure 11.5, Volume II), the distribution of defined spawning and nursery grounds (Figure 11.4, Volume II), known sandeel grounds and fishing areas (Figure 11.6, Volume II) and the result of analysis of sediment samples collected in the offshore project area (Figure 11.7, see Appendix 11.1, Volume III), all suggest that the offshore project area is not a key sandeel area.

90. It is therefore expected that the extent of sandeel habitat, affected by physical disturbance/temporary habitat loss as a result of construction works will be small.

91. With this in mind but recognising sandeels' dependence on the presence of suitable habitat for burrowing and spawning, they are considered receptors of medium sensitivity.

Elasmobranchs – Thornback ray

92. Thornback rays lay egg cases on the seabed and therefore have increased sensitivity to the effect of physical disturbance. However, they are not known to have the same degree of substrate-specific spawning requirements as species such as herring and sandeels.

93. The offshore project area overlaps with low intensity nursery grounds identified for thornback ray, with spawning and nursery grounds considered to broadly overlap for this species (Ellis et al., 2012). Considering the overall extent of their spawning grounds (Figure 11.8, Volume II), thornback ray is considered a receptor of low sensitivity.

Shellfish

94. Shellfish are much less mobile than fish species and may be less able to avoid areas where construction activity is occurring and therefore be more vulnerable to physical disturbance and temporary loss of habitat. Mobile shellfish species

such as crab and lobster have adopted a reproductive strategy of high egg production to compensate for losses during egg extrusion and the extended incubation period (McQuaid et al., 2009). Females are ovigerous, with the eggs remaining attached to the abdomen until hatching. In the case of crabs, females may remain buried in sediments when bearing eggs for periods ranging from four to nine months. Other species such as whelks lay demersal egg cases which are often found attached to subtidal rocks, stones or shells (Ager, 2008).

95. Sedentary/sessile shellfish species such as cockles and oysters would be expected to be the most vulnerable to physical disturbance; oysters are identified as having a high sensitivity to disturbance (Perry et al., 2017). While the inshore section of the offshore cable corridor area overlaps with two cockle harvest areas (area 18 and 20), from consultation with KEIFCA it is understood that there is no overlap between cockle beds that are being commercially targeted and the offshore cable corridor. Similarly, while the offshore cable corridor is in the proximity of the Blackwater, Crouch, Roach and Colne Estuaries MCZ (specifically designated for the protection of native oysters/oyster beds) there is no overlap with the offshore cable corridor and therefore no direct loss of this habitat/receptor predicted. With this in mind, native oysters/cockles are considered receptors of medium sensitivity.

96. Both adults and egg masses (pre-hatching) of shellfish receptors could be vulnerable to physical damage during construction activities. It is of note, however, that no significant impacts on the benthic community are anticipated in relation to disturbance during construction (impact assessed as negligible in Chapter 10 Benthic and Intertidal Ecology, Volume I) as the benthic species around the offshore project area are considered to be characteristic of highly disturbed environments. Based on outcomes of benthic chapter it is therefore considered that the shellfish receptor sensitivity in general is considered to be low.

11.6.1.1.3 Significance of effect

97. Taking account of the identified magnitude of impact (low) and receptor sensitivity (low), effects associated with physical disturbance and temporary habitat loss during construction are considered to result in an impact of negligible significance for the majority of fish and shellfish species.

98. Of the receptors that were assessed separately, Blackwater herring was assessed as low sensitivity given the lack of overlap of spawning grounds, resulting in negligible significance whereas Downs herring, sandeels and oysters/cockles were considered to be receptors of medium sensitivity which results in an impact of minor significance.

11.6.1.2 Impact 2: Increased SSCs and sediment re-deposition

11.6.1.2.1 Magnitude of impact

99. An expert-based assessment of the potential increase in SSCs and associated sediment re-deposition resulting from the construction of the Project (including seabed preparation and installation of offshore infrastructure) is given in detail within Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I). Relevant information included in the assessment is summarised here and has been used to inform the definition of the magnitude of the impact.

100. Activities associated with the construction phase that have potential to result in increased SSCs and sediment re-deposition include the following:

- Seabed preparation and drilling for foundation installation; and
- Cable installation (export cables and array/interconnector cables).

101. The maximum design scenario associated with increases in SSC is given in Table 11.2. As described in Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I), coarse sand seabed sediments are most prevalent in the northern array, with mostly medium to coarse sand sediments present in the southern array. Therefore, disturbed sediment in the arrays is likely to settle rapidly back to the seabed within minutes or tens of minutes and within tens of metres along the axis of tidal flow from the point at which it was released. The small proportion of fine sand and mud would stay in suspension for longer and form a passive plume. This plume (tens of mg/l) would be likely to exist for around half a tidal cycle (i.e. approximately 6 hours). Sediment would settle to the seabed within a few hundred metres up to approximately 1km along the axis of tidal flow from the location at which it was released. These deposits would be very thin (millimetres).

102. Fine sands and mud are most prevalent along the offshore cable corridor where mud-sized sediments would be advected further distances and persist in the water column for hours to days, before depositing a thin layer on the seabed. Plume modelling simulations carried out for GWF showed a maximum dispersion distance of 15km for coarse silt and indicated that fine sands would result in the greatest bed thickness changes, however the worst-case level sediment smothering and deposition is approximately <1mm (see Chapter 8 Geology, Oceanography and Physical Processes, Volume I).

103. Although SSCs will be elevated they are likely to be lower than concentrations that would develop in the water column during storm conditions, that are likely to drive greater changes to the seabed than the changes that would occur due to the presence of the wind farm infrastructure. Also, tidal currents are likely to rapidly disperse the suspended sediment (i.e. over a period of a few hours). It is likely that the increase in concentrations would be greatest in the shallowest sections of the offshore cable corridor, but in these locations the background concentrations are also greater than in deeper waters.

104. Overall changes from SSC and deposition of fine sands and mud-sized sediment will not be measurable due to prevailing hydrodynamic conditions with high wave activity agitating the seabed regularly.

105. Taking account of the anticipated levels of increase in SSCs and the expected level of sediment deposition, the magnitude of the impact taking account of construction activities for the whole project is considered to be negligible.

11.6.1.2.2 Sensitivity of receptor

106. In general terms, adult and juvenile fish, being mobile, would be expected to rapidly redistribute to undisturbed areas within their habitat range. Given that the SSCs are likely to be within the range of natural variability for these species, they are therefore considered receptors of low sensitivity.

107. It is recognised that species and life stages of relatively low mobility, and those highly dependent on the presence of specific substrates may have increased

sensitivity to the impact of SSCs and sediment deposition. For instance, eggs and early larval stages may drift passively in the water column or be present on benthic substrates. This results in reduced capacity to avoid areas impacted by increased SSCs and re-deposition of sediments and an increased susceptibility to the potential negative effects of the impact. Similarly, shellfish species, having lower mobility in comparison to most fish species, may be more susceptible as they may not be able to avoid areas affected by increased SSCs and re-deposition.

108. Separate assessments are given below for species highly dependent on the characteristics of the substrate, early life stages (eggs and larvae) and shellfish, as follows:

- Sandeels (demersal spawners);
- Herring (demersal spawners);
- Other species with known spawning grounds in the offshore project area; and
- Shellfish species.

109. A separate assessment of sensitivity is provided separately for these species/species groups below. Additional species-specific information on magnitude is also included, where relevant, to provide context to the assessment of sensitivity.

Sandeels

110. Sandeels spend a significant proportion of their life cycle buried within the seabed and are demersal spawners. Therefore, increased SSCs and sediment re-deposition associated with the Project may have increased potential to adversely impact this species group.

111. Sandeels deposit eggs on the seabed in the vicinity of their burrows. Grains of sand may become attached to the adhesive egg membranes. Tidal currents can cover sandeel eggs with sand to a depth of a few centimetres, however, experiments have shown that the eggs are capable of developing normally and hatch as soon as currents uncover them again (Winslade., 1971).

112. Research by Behrens et al. (2007) on the oxygenation in the burrows of sandeel *A. tobianus* found that the oxygen penetration depth at the sediment interface was only a few millimetres. Sandeels were typically buried in anoxic sediments at depths of 1-4cm. In order to respire, they appear to induce an advective transport through the permeable interstice to form an inverted cone of porewater with 93% oxygen saturation.

113. In addition to direct effect on adults and early life stages, increased SSCs and redeposition associated with construction activity could also result in a change in the substrate characteristics causing a change/loss of habitat to sandeels. It should be noted, however, that for the most part any sediment re-deposited would be similar to that in the surrounding seabed and therefore no significant change in seabed sediment type is to be expected (Chapter 8 Marine Geology Oceanography and Physical Processes, Volume I).

114. From the above, it is apparent that sandeel early life stages and adults are relatively tolerant to SSCs and sediment re-deposition. In addition, there is little

potential for significant changes in the characteristics of the seabed sediment type to occur. As described previously for assessment of impacts in respect of temporary disturbance/loss of habitat, available information from the IBTS (Figure 11.5, Volume II), the distribution of defined spawning and nursery grounds (Figure 11.4, Volume II), known sandeel grounds and fishing areas (Figure 11.6, Volume II) and the result of analysis of sediment samples collected in the offshore project area (see Appendix 11.1, Volume III), all suggest that the offshore project area is of comparatively low importance to this species. With the above in mind but recognising their limited mobility and substrate dependence, they are considered receptors of medium sensitivity.

Herring

115. Herring are demersal spawners requiring the presence of a coarse substrate on which to lay their eggs. Therefore, increased SSCs and sediment re-deposition associated with the Project may have increased potential to adversely impact this species.

116. Laboratory studies have established that herring eggs are tolerant to elevated SSCs as high as 300mg/l and can tolerate short term exposure at levels up to 500mg/l (Kiørboe et al., 1981). These studies concluded that dredging and other similar operations are not likely to result in harmful effects to herring spawning grounds. Herring eggs have been recorded to successfully hatch at SSCs up to 7,000mg/l (Messieh et al., 1981).

117. In addition to impacts on early life stages, increased SSCs and sediment redeposition associated with the Project could result in an impact on herring spawning grounds by means of changes in the characteristics of the substrate. As previously described, however, there is little potential for significant changes in the characteristics of the seabed sediment type to occur as a result of construction activities.

118. As described previously for assessment of impacts in respect of temporary disturbance/loss of habitat defined spawning grounds for the Downs and Blackwater herring, Downs herring are located immediately to the east of the southern array area with limited overlap with the offshore project area (Figure 11.2, Volume II). However, analysis of sediment samples indicate that the majority of the offshore project area is unsuitable as herring spawning habitat. An exception to this may be the discrete section of the eastern edge of the southern array area which shows overlap with the defined Downs herring spawning grounds.

119. In light of the relative tolerance of herring eggs to increases in SSCs such as those associated with the construction of the Project and the potential overlap between spawning grounds and the Project, the Downs herring is considered a receptor of medium sensitivity. In the case of the Blackwater herring, spawning grounds are located in inshore areas around the Blackwater Estuary and Herne Bay at considerable distance from the offshore project area (Figure 11.2, Volume II). As such, Blackwater herring is considered a receptor of low sensitivity.

Other species with known spawning grounds

120. As described in Section 11.5.4, there are a number of other fish species with defined spawning grounds located in areas relevant to the offshore project area. These include lemon sole, plaice, sole, sprat, whiting, cod and thornback ray.

121. Most of the species listed in Table 6.8 are pelagic spawners, which release their eggs in the water column. The exception is thornback ray, which lay eggs on benthic substrates although they are not known to have the same degree of substrate-specific spawning requirements as species such as herring and sandeels.

122. Given that the SSCs are likely to be within the range of natural variability for these species, they are therefore considered receptors of low sensitivity.

Shellfish

123. Marine Evidence based Sensitivity Assessment (MarESA) has been used in Chapter 10 Benthic and Intertidal Ecology (Volume I) to determine sensitivity of specific biotopes and dominant macrofauna, including shellfish species which is of relevance to shellfish receptors. Crabs are considered to have a low sensitivity to suspended sediments and smothering, however, they are likely to avoid areas of increased suspended sediment concentration as they rely on visual acuity during predation (Neal and Wilson, 2008). This assessment is based on shellfish species being able to escape from under silt and migrate away from an area.

124. While there is no MarESA available for lobster, there is for the spiny lobster (*Nephropidae*) which belong to the same taxonomic family and can provide a relevant comparison given the physiological similarities between these species. The MarESA concludes that spiny lobster is tolerant and not sensitive to increased SSCs and smothering.

125. In line with the above, in a review of the effects of elevated SSCs, Wilber and Clark (2001) reported that in studies examining the tolerance of adult crustaceans, the majority of mortality was induced by concentrations exceeding 10,000mg/l (considerably higher than those generated by construction activities associated with the installation of foundations and offshore cables).

126. Berried crustaceans (e.g. crab and lobster) are likely to be more vulnerable to increased SSC as the eggs carried by these species require regular aeration. Increased SSC along the offshore cable corridor (potential habitat for egg bearing and spawning crab and lobster in the fish and shellfish study area) will only affect a small area at any one time and will be temporary in nature, with sediments settling to the seabed quickly following disturbance as detailed in Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I). Crab and lobster are therefore considered to have low sensitivity

127. There is limited information on the sensitivity of the common whelk to increased SSCs and deposition. The MarESA for the dog whelk *Nucella lapillus* (which belongs to the same taxonomic order (Neogastropoda)), however, indicates that the species is not sensitive to increased SSCs and smothering (Tyler-Walters, 2007). This is in line with a reported preference for soft substrates (Ager, 2008). Given that the SSCs are likely to be within the range of natural variability for this species, it is considered to have low sensitivity

128. Sedentary/sessile filter feeders such as cockles and oysters are amongst the most vulnerable to increased SSCs and smothering effects from sediment re-deposition (BERR, 2008). However, oysters and cockles habitats are subjected to a degree of natural variation in suspended sediments, given their location in typically nearshore, shallow banks. In Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I), it was assessed that SSCs from nearshore offshore cable installation works, while elevated above prevailing conditions, would likely remain within the range of background nearshore levels (which will be high close to the coast because of increased wave activity) and lower than those concentrations that would develop during storm events.

129. Given the prevailing hydrodynamic conditions and the relative tolerance of shellfish species to SSCs and smothering in the context of the small increases in SSCs and low level of re-deposition expected during the construction of the Project, shellfish in general, are considered receptors of low sensitivity, with oysters and cockles considered to have a medium sensitivity.

11.6.1.2.3 Significance of effect

130. In general terms, adult and juvenile fish, being mobile, would be expected to rapidly redistribute to undisturbed areas within their habitat range. Given that the SSCs are likely to be within the range of natural variability for these species, they are therefore considered receptors of low sensitivity. This, in combination with the negligible magnitude of the impact associated with the Project, would result in an impact of negligible significance.

131. Of the receptors that were assessed separately, Downs herring and sandeels are considered to be receptors of medium sensitivity which results in an impact of minor significance. Shellfish receptors and other species with known spawning grounds are assessed as low to medium sensitivity, which results in an impact of negligible to minor significance.

11.6.1.3 Impact 3: Re-mobilisation of contaminated sediments

11.6.1.3.1 Magnitude of impact

132. As a result of construction activities within both the subtidal and intertidal region there is the potential for contaminants in the sediments to be re-suspended and to have adverse effects on fish and shellfish receptors. Impacts to water quality as receptors are assessed in Chapter 9 Marine Water and Sediment Quality (Volume I).

133. As outlined in Chapter 10 Benthic and Intertidal Ecology (Volume I) benthic samples collected during the offshore site investigation were analysed for contaminants. A comparison of levels of sediment contamination against recognised sediment quality guidelines is given in Chapter 9 Marine Water and Sediment Quality (Volume I).

134. The assessment of subtidal sediment contamination (see Chapter 10: Benthic and Intertidal Ecology, Volume I), concluded that sediment contamination levels were generally at levels that would not be of concern to the marine environment.

135. There is therefore, negligible magnitude of risk to fish and shellfish ecology receptors from re-mobilisation of contaminated sediments

11.6.1.3.2 Sensitivity of receptor

136. Fish and shellfish receptor sensitivity to re-mobilised contaminated sediments will vary depending on a range of factors including species and life stage. Adult fish are less likely to be affected by contaminants due to their increased mobility.

137. Receptors with sessile life history (e.g. cockles and oysters) or life stages that are planktonic (fish eggs and larvae) are likely to be more vulnerable to toxic effects from marine pollutants. Given the prevailing hydrodynamic conditions released sediment bound contaminants would be expected to be dispersed quickly therefore the level of effect is predicted to be small.

138. Given the levels of contaminants found are within environmental protection standards, all receptors are assessed as not sensitive (negligible sensitivity) to changes that remain within these standards.

11.6.1.3.3 Significance of effect

139. The overall worst-case effect is considered to be of negligible significance from the remobilisation of contaminated sediments given the negligible magnitude and negligible sensitivity to the existing contaminant levels found in the area.

11.6.1.4 Impact 4: Underwater noise and vibration from piling for foundation installation

140. During the construction phase, activities associated with foundation for turbines and OSPs would result in underwater noise and vibration.

141. As a worst case, it is assumed that all foundations will be installed using pile driving as this would result in the greatest noise impacts.

142. The assessment presented in this section is supported by the underwater noise modelling carried out for the Project in respect of piling noise (see Appendix 12.2 (Volume III)).

11.6.1.4.1 Impact Criteria

143. The noise impact criteria used for assessment of piling noise on fish are shown in Table 11.15. These are based on the Popper et al. (2014) study, which provides a summary of the latest research and represents current best available guidance on fish exposure to sound.

144. Popper et al. (2014) groups fish species into four categories for analysing the effects of sounds on them. Three of these categories are defined on the basis of whether or not fish species have a swim bladder and whether it is involved in hearing, with a fourth separate category focused on fish eggs and larvae, as follows:

- Fish species with no swim bladder or other gas chamber (e.g. dab and other flat fish species). These species are less susceptible to barotrauma and only detect particle motion, not sound pressure. However, some barotrauma may result from exposure to sound pressure;
- Fish species with swim bladder in which hearing does not involve the swim bladder or other gas volume (e.g. Atlantic salmon). These species are susceptible to barotrauma although hearing only involves particle motion, not sound pressure;

- Fish species in which hearing involves a swim bladder or other gas volume (e.g. cod, herring and relatives). These species are susceptible to barotrauma and detect sound pressure as well as particle motion; and
- Fish eggs and larvae.

145. As shown in Table 11.15, in some cases, the noise levels used to define the criteria are the same for multiple effects. This is because data available to create the criteria is limited and most criteria are defined as “greater than” (>), with a precise threshold not identified. Impact ranges associated with criteria defined as “>”, are therefore somewhat conservative.

146. For behavioural effects on fish, given that the best research available is limited to very specific studies on species often under artificial conditions. Popper et al. (2014) does not recommend the use of a quantitative approach for assessment. Instead, Popper et al. (2014) describes behavioural criteria in a qualitative manner on the basis of the relative risk (high, moderate, low) to the animal at various distances from the source of noise (near (N), intermediate (I) and far (F)). For the purposes of this assessment, and in line with the definitions proposed by Popper et al. (2014), these distances are considered as follows:

- Near: within tens of metres
- Intermediate: within hundreds of metres; and
- Far: within thousands of metres.

Table 11.15 Fish noise impact criteria for pile driving (Popper et al. 2014)

Fish Category	Mortality and potential mortal injury	Recoverable injury	TTS	Behaviour
No swim bladder (particle motion detection)	>219 dB SEL cum or >213 dB peak	>216 dB SEL cum or >213 dB peak	>>186 dB SEL cum	(N) High (I) Moderate (F) Low
Swim bladder is not involved in hearing (particle motion detection)	210 dB SEL cum or >207 dB peak	203 dB SEL cum or >207 dB peak	>186 dB SEL cum	(N) High (I) Moderate (F) Low
Swim bladder involved in hearing (primarily pressure detection)	207 dB SEL cum or >207 dB peak	203 dB SEL cum or >207 dB peak	186 dB SEL cum	(N) High (I) High (F) Moderate
Eggs and larvae	>210 dB SEL cum or >207 dB peak	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
(N) within tens of metres; (I) within hundreds of metres; (F) within thousands of metres				

147. Despite increasing research on the impact of underwater noise on invertebrates in recent years (i.e. Tidau and Briffa, 2016, Edmonds et al., 2016, Solan et al., 2016, Jones et al., 2020), hearing in shellfish species is still poorly understood, and noise exposure criteria similar to those developed for fish (Popper et al.,

2014) are yet to be defined for invertebrates. In the absence of standard criteria, the assessment of piling noise on shellfish has been undertaken through a review of available research on the impact of underwater noise on marine invertebrates.

11.6.1.4.2 Noise Modelling

148. Underwater noise modelling has been carried out at four representative locations (North, East, South and West) covering the extents and various water depths at the array areas. The modelling locations are outlined in Table 11.16.

Table 11.16 Summary of Underwater Noise Modelling Locations

Modelling locations	North	East	South	West
Latitude	52.0085°N	51.7368°N	51.6266°N	51.7703°N
Longitude	001.8905°W	002.0443°W	001.8649°W	001.8262°W
Water depth (m)	27.8	34.7	36.3	35.1

149. Two foundation scenarios were considered for modelling:

- A monopile worst case scenario, installing a 17m diameter pile with a maximum hammer energy of 6,000kJ; and
- A pin pile worst case scenario, installing a 3.5m diameter pile with a maximum hammer energy of 3,000kJ.

150. For SEL_{cum} criteria, the soft start and ramp up of hammer energies along with the total duration of piling and strike rate was considered. This is summarised in Table 11.17 and Table 11.18 for the two piling scenarios.

151. As described in Appendix 12.2 (Volume III), in a 24-hour period, it is expected that up to two monopile foundations or four pin pile foundations can be installed. Scenarios covering a single pile installation, multiple sequential pile installation and simultaneous multiple location installation were all considered as part of the modelling exercise.

Table 11.17 Soft start and ramp-up scenario for monopile worst case modelling

Monopile worst case	900 kJ	1,800 kJ	2,700 kJ	3,700 kJ	4,800 kJ	6,000 kJ
Number of strikes	100	600	600	600	600	10,800
Duration (minutes)	10	30	30	30	30	320
Strike rate (blows/minute)	10	20	20	20	20	~34
13,300 strikes, 7.5 hours per pile/ 26,600 strike, 15 hours for 2 piles						

Table 11.18 Soft start and ramp-up scenario for pin pile worst case modelling

Pin pile worst case	450 kJ	900 kJ	1,400 kJ	1,900 kJ	2,400 kJ	3,000 kJ
Number of strikes	100	100	100	100	100	6,120
Duration (minutes)	10	5	5	5	5	180
Strike rate (blows/minute)	10	20	20	20	20	34

Pin pile worst case	450 kJ	900 kJ	1,400 kJ	1,900 kJ	2,400 kJ	3,000 kJ
6,620 strikes, 3.5 hours per pile/ 26,480 strikes, 14 hours for 4 piles						

152. Both fleeing animal and stationary animal models have been used to cover the SEL_{cum} criteria for fish. As noted in Appendix 12.2 (Volume III), most species are likely to move away from a sound that is loud enough to cause harm, some may seek protection in the sediment and others may dive deeper in the water column. For species that flee, the speed used for the modelling of $1.5ms^{-1}$, is relatively slow in relation to data from Hirata (1999) and therefore considered somewhat conservative.

153. Although it is feasible that some species will not flee, those that are likely to remain are thought more likely to be benthic species or species without a swim bladder, and therefore the least sensitive species to underwater noise.

154. Furthermore, as noted in Appendix 12.2 (Volume III), modelling on a stationary (zero flee speed) receptor, is likely to greatly overestimate the potential risk to fish species, assuming that an individual would remain in the high noise level region of the water column, especially when considering the precautionary nature of the parameters already built into the cumulative exposure calculations.

Modelling Results

155. The results of the modelling carried out using Popper et al. (2014) criteria for fish are given in Table 11.19 to Table 11.34, separately for "fish with no swim bladder", "fish with swim bladder not involved in hearing", "fish with swim bladder involved in hearing" and "eggs/larvae".

156. The largest mortality/potential mortal injury and recoverable injury ranges (207 and 203dB SELcum thresholds) are predicted to be up to 8.4km and 13km respectively, assuming a stationary receptor for two sequentially installed monopiles. Assuming a fleeing receptor, the impact ranges for both mortality/potential mortal injury and recoverable injury are reduced to less than 100m.

157. Maximum TTS ranges (186 dB SELcum threshold) are predicted up to 17km assuming a fleeing animal, increasing to up to 39km when considering a stationary receptor. In terms of TTS ranges, when considering a fleeing animal, the pin pile scenario impact ranges are greater than those predicted for the monopile scenario due to the faster ramp-up to full energy and faster strike rate for the pin pile scenario. For stationary receptors, the increased number of strikes combined with the higher hammer energies from the worst case monopile scenario result in larger impact ranges than the worst-case pin pile scenario.

158. When comparing the impact ranges for a single pile installation and sequential pile installations, the overall increases are negligible when considering a fleeing animal, as by the time subsequent piles are installed the fleeing receptors is at such a distance that the additional exposure is minimal. When considering a stationary animal, the ranges are significantly increased as the receptor is essentially receiving noise from either double or quadruple the number of pile strikes from monopiles and pin piles respectively.

Fish with no swim bladder

Table 11.19 Summary of the unweighted sound pressure level (SPL) peak impact ranges using the Popper et al (2014) criteria for fish with no swim bladder for the monopile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>213 dB	0.04 km^2	120 m	110 m	120 m
	Recoverable injury					
East	Mortality and potential mortal injury	>213 dB	0.05 km^2	120 m	120 m	120 m
	Recoverable injury					
South	Mortality and potential mortal injury	>213 dB	0.05 km^2	120 m	120 m	120 m
	Recoverable injury					
West	Mortality and potential mortal injury	>213 dB	0.05 km^2	120 m	120 m	120 m
	Recoverable injury					

Table 11.20 Summary of unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish with no swim bladder for the pin pile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>213 dB	0.03 km^2	90 m	90 m	90 m
	Recoverable injury					
East	Mortality and potential mortal injury	>213 dB	0.03 km^2	100 m	100 m	100 m
	Recoverable injury					
South	Mortality and potential mortal injury	>213 dB	0.03 km^2	100 m	100 m	100 m
	Recoverable injury					
West	Mortality and potential mortal injury	>213 dB	0.03 km^2	100 m	100 m	100 m
	Recoverable injury					

Table 11.21 Summary of unweighted SELcum (cumulative sound exposure level) impact ranges using Popper et al (2014) pile driving criteria for fish with no swim bladder for the monopile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	150 km^2	9.3 km	5.7 km	6.9 km	150 km^2	9.3 km	5.7 km	6.9 km
	Stationary	Mortality and potential mortal injury	>219 dB	2.9 km^2	980 m	950 m	960 m	6.7 km^2	1.5 km	1.4 km	1.5 km
		Recoverable injury	>216 dB	6.6. km^2	1.5 km	1.4 km	1.5 km	15 km^2	2.2 km	2.1 km	2.2 km
		TTS	>>186 dB	1,400 m^2	16 km	18 km	21 km	190 km^2	30 km	20 km	25 km
East	Fleeing	Mortality and potential mortal injury	>219 dB	<0.1. km^2	< 100 m	< 100 m	< 100 m	<0.1. km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	<0.1. km^2	< 100 m	< 100 m	< 100 m	<0.1. km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	430 km^2	15 km	7 km	11 km	430 km^2	15 km	7 km	11 km
	Stationary	Mortality and potential mortal injury	>219 dB	3.8 km^2	1.2 km	1.1 km	1.1 km	9.1 km	1.8 km	1.6 km	1.7 km
		Recoverable injury	>216 dB	9.1 km^2	1.8 km	1.6 km	1.7 km	21 km^2	2.7 km	2.4 km	2.6 km
		TTS	>>186 dB	2,400 km^2	33 km	20 km	27 km	3,100 km^2	39 km	23 km	31 km
South	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	340 km^2	12 km	7.7 km	10 km	340 km^2	12 km	7.7 km	10 km
	Stationary	Mortality and potential mortal injury	>219 dB	3.7 km^2	1.1 km	1.1 km	1.1 km	8.8 km^2	1.7 km	1.7 km	1.7 km
		Recoverable injury	>216 dB	8.8 km2	1.7 km	1.6 km	1.7 km	20 km2	2.6 km	2.5 km	2.5 km
		TTS	>>186 dB	2,100 km^2	29 km	18 km	25 km	2,600 km^2	33 km	18 km	29 km
West	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	240 km^2	12 km	6 km	8.7 km	240 km^2	12 km	6 km	8.7 km
	Stationary	Mortality and potential mortal injury	>219 dB	3.6 km^2	1.1. km	1.1. km	1.1. km	8.7 km^2	1.7 km	1.6 km	1.7 km
		Recoverable injury	>216 dB	8.7 km^2	1.7 km	1.6 km	1.7 km	20 km^2	2.6 km	2.4 km	2.5 km
		TTS	>>186 dB	1,700 km^2	28 km	16 km	23 km	2,200 km^2	33 km	18 km	26 km

Table 11.22 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish with no swim bladder for the pin pile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	230 km^2	11 km	7.3 km	8.5 km	230 km^2	12 km	7.3 km	8.6 km
	Stationary	Mortality and potential mortal injury	>219 dB	0.7 km^2	500 m	480 m	490 m	4.2 km^2	1.2 km	1.1 km	1.2 km
		Recoverable injury	>216 dB	1.8 km^2	780 m	750 m	770 m	9.4 km^2	1.8 km	1.7 km	1.7 km
		TTS	>>186 dB	830 km^2	20 km	15 km	16 km	1,600 km^2	28 km	19 km	23 km
East	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	560 km^2	16 km	8.7 km	13 km	580 km^2	17 km	8.8 km	13 km
	Stationary	Mortality and potential mortal injury	>219 dB	1 km^2	580 m	230 m	550 m	5.7 km^2	14 km	13 km	14 km
		Recoverable injury	>216 dB	2.3 km^2	900 m	830 m	860 m	13 km^2	2.2. km	2 km	2.1 km

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
		TTS	>>186 dB	1,500 km^2	25 km	16 km	22 km	2,700 km^2	36 km	22 km	29 km
South	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	470 km^2	14 km	9.6 km	12 km	480 km^2	14 km	9.6 km	12 km
	Stationary	Mortality and potential mortal injury	>219 dB	1 km^2	580 m	530 m	560 m	5.6 km^2	1.4 km	1.3 km	1.3 km
		Recoverable injury	>216 dB	2.3 km^2	880 m	850 m	860 m	13 km^2	2.1 km	2 km	2 km
		TTS	>>186 dB	1,300 km^2	23 km	17km	20 km	2,300 km^2	31 km	18 km	27 km
West	Fleeing	Mortality and potential mortal injury	>219 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	>216 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>>186 dB	340 km^2	14 km	7.4 km	10 km	350 km^2	14 km	7.4 km	10 km
	Stationary	Mortality and potential mortal injury	>219 dB	0.9 km^2	580 m	530 m	550 m	5.5 km^2	1.4 km	1.3 km	1.3 km
		Recoverable injury	>216 dB	2.3 km^2	880 m	830 m	860 m	13 km^2	2.1 km	2. km	2 km

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
		TTS	>>186 dB	1,000 km^2	22 km	14 km	18 km	1,900 km^2	31 km	17 km	25 km

Fish with a swim bladder that is not involved in hearing

Table 11.23 Summary of the unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish with a swim bladder that is not involved in hearing for the monopile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>207	0.26 km^2	290 m	290 m	290 m
	Recoverable injury					
East	Mortality and potential mortal injury	>207	0.3 km^2	310 m	310 m	310 m
	Recoverable injury					
South	Mortality and potential mortal injury	>207	0.31 km2	310 m	310 m	310 m
	Recoverable injury					
West	Mortality and potential mortal injury	>207	0.3 km^2	310 m	310 m	310 m
	Recoverable injury					

Table 11.24 Summary of unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish with a swim bladder that is not involved in hearing for the pin pile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>207	0.16 km^2	230 m	230 m	230 m
	Recoverable injury					
East	Mortality and potential mortal injury	>207	0.19 km^2	250 m	250 m	250 m
	Recoverable injury					
South	Mortality and potential mortal injury	>207	0.2 km	250 m	250 m	250 m
	Recoverable injury					
West	Mortality and potential mortal injury	>207	0.19 km^2	250 m	250 m	250 m
	Recoverable injury					

Table 11.25 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish with a swim bladder that is not involved in hearing for the monopile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	150 km^2	9.3 km	5.7 km	6.9 km	150 km^2	9.3 km	5.7 km	6.9 km
	Stationary	Mortality and potential mortal injury	210 dB	31 km^2	3.2 km	3.0 km	3.1 km	60 km^2	4.6 km	4.2 km	4.4 km
		Recoverable injury	203 dB	130 km^2	6.8 km	6.2 km	6.5 km	220 km^2	9.5 km	8.0 km	8.5 km
		TTS	>186 dB	1,400 km^2	16 km	18 km	21 km	1,900 km^2	30 km	20 km	25 km
East	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	430 km^2	15 km	7.0 km	11 km	430 km^2	15 km	7.0 km	11 km
	Stationary	Mortality and potential mortal injury	210 dB	46 km^2	4.1 km	3.6 km	3.9 km	97 km^2	6.0 km	5.0 km	5.5 km
		Recoverable injury	203 dB	220 km^2	9.3 km	7.1 km	8.4 km	390 km^2	13 km	8.7 km	11 km
		TTS	>186 dB	2,400 km^2	33 km	20 km	27 km	3100 km^2	39 km	23 km	31 km
South	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	340 km^2	12 km	7.7 km	10 km	340 km^2	12 km	7.7 km	10 km
	Stationary	Mortality and potential mortal injury	210 dB	45 km^2	3.9 km	3.6 km	3.8 km	91 km^2	5.7 km	5.1 km	5.4 km
		Recoverable injury	203 dB	210 km^2	8.8 km	7.2 km	8.2 km	360 km^2	12 km	9.0 km	11 km
		TTS	>186 dB	2,100 km^2	29 km	18 km	25 km	2,600 km^2	33 km	18 km	29 km
West	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	240 km^2	12 km	6.0 km	8.7 km	240 km^2	12 km	6.0 km	8.7 km
	Stationary	Mortality and potential mortal injury	210 dB	41 km^2	3.8 km	3.5 km	3.6 km	82 km^2	5.5 km	4.8 km	5.1 km
		Recoverable injury	203 dB	180 km^2	8.4 km	7.0 km	7.7 km	310 km^2	11 km	8.8 km	9.9 km
		TTS	>186 dB	1,700 km^2	28 km	16 km	23 km	2,200 km^2	33 km	18 km	26 km

Table 11.26 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish with a swim bladder that is not involved in hearing for the pin pile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km²	< 100 m	< 100 m	< 100 m	< 0.1 km²	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km²	< 100 m	< 100 m	< 100 m	< 0.1 km²	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	230 km²	11 km	7.3 km	8.5 km	230 km²	12 km	7.3 km	8.6 km
	Stationary	Mortality and potential mortal injury	210 dB	9.4 km²	1.8 km	1.7 km	1.7 km	41 km²	3.8 km	3.5 km	3.6 km
		Recoverable injury	203 dB	51 km²	4.2 km	3.9 km	4.0 km	170 km²	7.9 km	7.0 km	7.3 km
		TTS	>186 dB	830 km²	20 km	15 km	16 km	1,600 km²	28 km	19 km	23 km
East	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km²	< 100 m	< 100 m	< 100 m	< 0.1 km²	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km²	< 100 m	< 100 m	< 100 m	< 0.1 km²	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	560 km²	16 km	8.7 km	13 km	580 km²	17 km	8.8 km	13 km
	Stationary	Mortality and potential mortal injury	210 dB	13 km²	2.2 km	2.0 km	2.1 km	66 km²	4.9 km	4.2 km	4.6 km
		Recoverable injury	203 dB	38 km²	5.5 km	4.7 km	5.2 km	290 km²	11 km	7.6 km	9.6 km
		TTS	>186 dB	1,500 km²	25 km	16 km	22 km	2,700 km²	36 km	22 km	29 km
South	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km²	< 100 m	< 100 m	< 100 m	< 0.1 km²	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km²	< 100 m	< 100 m	< 100 m	< 0.1 km²	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	470 km²	14 km	9.6 km	12 km	480 km²	14 km	9.6 km	12 km

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
	Stationary	Mortality and potential mortal injury	210 dB	13 km^2	2.1 km	2.0 km	2.0 km	63 km^2	4.7 km	4.3 km	4.5 km
		Recoverable injury	203 dB	79 km^2	5.3 km	4.8 km	5.0 km	270 km^2	10 km	8.1 km	9.3 km
		TTS	>186 dB	1,300 km^2	23 km	17 km	20 km	2300 km^2	31 km	18 km	27 km
West	Fleeing	Mortality and potential mortal injury	210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	>186 dB	340 km^2	14 km	7.4 km	10 km	350 km^2	14 km	7.4 km	10 km
	Stationary	Mortality and potential mortal injury	210 dB	13 km^2	2.1 km	2.0 km	2.0 km	57 km^2	4.5 km	4.1 km	4.3 km
		Recoverable injury	203 dB	71 km^2	5.1 km	4.5 km	4.8 km	240 km^2	9.7 km	7.8 km	8.7 km
		TTS	>186 dB	1000 km^2	22 km	14 km	18 km	1900 km^2	31 km	17 km	25 km

Fish with a swim bladder involved in hearing

Table 11.27 Summary of the unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish with a swim bladder that is involved in hearing for the monopile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>207 dB	0.26 km^2	290 m	290 m	290 m
	Recoverable injury					
East	Mortality and potential mortal injury	>207 dB	0.3 km^2	310 m	310 m	310 m
	Recoverable injury					
South	Mortality and potential mortal injury	>207 dB	0.31 km^2	310 m	310 m	310 m
	Recoverable injury					
West	Mortality and potential mortal injury	>207 dB	0.3 km^2	310 m	310 m	310 m
	Recoverable injury					

Table 11.28 Summary of unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish with a swim bladder that is involved in hearing for the pin pile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>207 dB	0.16 km^2	230 m	230 m	230 m
	Recoverable injury					
East	Mortality and potential mortal injury	>207 dB	0.19 km^2	250 m	250 m	250 m
	Recoverable injury					
South	Mortality and potential mortal injury	>207 dB	0.2 km^2	250 m	250 m	250 m
	Recoverable injury					
West	Mortality and potential mortal injury	>207 dB	0.19 km^2	250 m	250 m	250 m
	Recoverable injury					

Table 11.29 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish with a swim bladder that is involved in hearing for the monopile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	150 km^2	9.3 km	5.7 km	6.9 km	150 km^2	9.3 km	5.7 km	6.9 km
	Stationary	Mortality and potential mortal injury	207 dB	60 km^2	4.6 km	4.2 km	4.4 km	110 km^2	6.2 km	5.7 km	5.9 km
		Recoverable injury	203 dB	130 km^2	6.8 km	6.2 km	6.5 km	220 km^2	9.5 km	8.0 km	8.5 km
		TTS	186 dB	1,400 km^2	16 km	18 km	21 km	1,900 km^2	30 km	20 km	25 km
East	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	430 km^2	15 km	7.0 km	11 km	430 km^2	15 km	7.0 km	11 km
	Stationary	Mortality and potential mortal injury	207 dB	96 km^2	6.0 km	5.0 km	5.5 km	190 km^2	8.4 km	6.6 km	7.7 km
		Recoverable injury	203 dB	220 km^2	9.3 km	7.1 km	8.4 km	390 km^2	13 km	8.7 km	11 km
		TTS	186 dB	2,400 km^2	33 km	20 km	27 km	3,100 km^2	39 km	23 km	31 km

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
South	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	340 km^2	12 km	7.7 km	10 km	340 km^2	12 km	7.7 km	10 km
	Stationary	Mortality and potential mortal injury	207 dB	91 km^2	5.7 km	5.1 km	5.4 km	170 km^2	7.9 km	6.7 km	7.4 km
		Recoverable injury	203 dB	210 km^2	8.8 km	7.2 km	8.2 km	360 km^2	12 km	9.0 km	11 km
		TTS	186 dB	2,100 km^2	29 km	18 km	25 km	2600 km^2	33 km	18 km	29 km
West	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	240 km^2	12 km	6.0 km	8.7 km	240 km^2	12 km	6.0 km	8.7 km
	Stationary	Mortality and potential mortal injury	207 dB	82 km	5.5 km	4.8 km	5.1 km	150 km^2	7.6 km	6.4 km	7.0 km
		Recoverable injury	203 dB	180 km^2	8.4 km	7.0 km	7.7 km	310 km^2	11 km	8.8 km	9.9 km
		TTS	186 dB	1,700 km^2	28 km	16 km	23 km	2,200 km^2	33 km	18 km	26 km

Table 11.30 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish with a swim bladder that is involved in hearing for the pin pile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	230 km^2	11 km	7.3 km	8.5 km	230 km^2	12 km	7.3 km	8.6 km
	Stationary	Mortality and potential mortal injury	207 dB	20 km^2	2.6 km	2.5 km	2.5 km	78 km^2	5.2 km	4.8 km	5.0 km
		Recoverable injury	203 dB	51 km^2	4.2 km	3.9 km	4.0 km	170 km^2	7.9 km	7.0 km	7.3 km
		TTS	186 dB	830 km^2	20 km	15 km	16 km	1600 km^2	28 km	19 km	23 km
East	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	560 km^2	16 km	8.7 km	13 km	580 km^2	17 km	8.8 km	13 km
	Stationary	Mortality and potential mortal injury	207 dB	30 km^2	3.3 km	2.9 km	3.1 km	130 km^2	7.0 km	5.7 km	6.5 km
		Recoverable injury	203 dB	38 km^2	5.5 km	4.7 km	5.2 km	290 km^2	11 km	7.6 km	9.6 km
		TTS	186 dB	1500 km^2	25 km	16 km	22 km	2700 km^2	36 km	22 km	29 km
South	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Location	Fleeing / stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	470 km^2	14 km	9.6 km	12 km	480 km^2	14 km	9.6 km	12 km
	Stationary	Mortality and potential mortal injury	207 dB	29 km^2	3.2 km	3.0 km	3.1 km	120 km^2	6.7 km	5.8 km	6.3 km
		Recoverable injury	203 dB	79 km^2	5.3 km	4.8 km	5.0 km	270 km^2	10 km	8.1 km	9.3 km
		TTS	186 dB	1300 km^2	23 km	17 km	20 km	2300 km^2	31 km	18 km	27 km
West	Fleeing	Mortality and potential mortal injury	207 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		Recoverable injury	203 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
		TTS	186 dB	340 km^2	14 km	7.4 km	10 km	350 km^2	14 km	7.4 km	10 km
	Stationary	Mortality and potential mortal injury	207 dB	28 km^2	3.1 km	2.9 km	3.0 km	110 km^2	6.4 km	5.5 km	5.9 km
		Recoverable injury	203 dB	71 km^2	5.1 km	4.5 km	4.8 km	240 km^2	9.7 km	7.8 km	8.7 km
		TTS	186 dB	1,000 km^2	22 km	14 km	18 km	1,900 km^2	31 km	17 km	25 km

Eggs and Larvae

Table 11.31 Summary of the unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish eggs and larvae for the monopile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>207 dB	0.26 km^2	290 m	290 m	290 m
East			0.3 km^2	310 m	310 m	310 m
South			0.31 km^2	310 m	310 m	310 m
West			0.3 km^2	310 m	310 m	310 m

Table 11.32 Summary of unweighted SPLpeak impact ranges using the Popper et al (2014) criteria for fish eggs and larvae for the pin pile worst case modelling scenario

Location	Criteria	SPLpeak	Area	Max	Min	Mean
North	Mortality and potential mortal injury	>207 dB	0.16 km^2	230 m	230 m	230 m
East			0.19 km^2	250 m	250 m	250 m
South			0.2 km^2	250 m	250 m	250 m
West			0.19 km^2	250 m	250 m	250 m

Table 11.33 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish eggs and larvae for the monopile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single monopile installation				Sequential monopile installation (2 monopiles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	>210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			31 km^2	3.2 km	3.0 km	3.1 km	60 km^2	4.6 km	4.2 km	4.4 km
East	Fleeing			< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			46 km^2	4.1 km	3.6 km	3.9 km	97 km^2	6.0 km	5.0 km	5.5 km
South	Fleeing			< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			45 km^2	3.9 km	3.6 km	3.8 km	91 km^2	5.7 km	5.1 km	5.4 km
West	Fleeing			< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			41 km^2	3.8 km	3.5 km	3.6 km	82 km^2	5.5 km	4.8 km	5.1 km

Table 11.34 Summary of unweighted SELcum impact ranges using Popper et al (2014) pile driving criteria for fish eggs and larvae for the pin pile worst case modelling scenario assuming both a fleeing and stationary animal

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
North	Fleeing	Mortality and potential mortal injury	>210 dB	< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			9.4 km^2	1.8 km	1.7 km	1.7 km	41 km^2	3.8 km	3.5 km	3.6 km
East	Fleeing			< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			13 km^2	2.2 km	2.0 km	2.1 km	66 km^2	4.9 km	4.2 km	4.6 km
South	Fleeing			< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m

Location	Fleeing / Stationary	Criteria	Unweighted SELcum	Single pin pile installation				Sequential pin pile installation (4 pin piles)			
				Area	Max	Min	Mean	Area	Max	Min	Mean
	Stationary			13 km^2	2.1 km	2.0 km	2.0 km	63 km^2	4.7 km	4.3 km	4.5 km
West	Fleeing			< 0.1 km^2	< 100 m	< 100 m	< 100 m	< 0.1 km^2	< 100 m	< 100 m	< 100 m
	Stationary			13 km^2	2.1 km	2.0 km	2.0 km	57 km^2	4.5 km	4.1 km	4.3 km

11.6.1.4.3 Receptor Groups

159. In order to facilitate the assessment of piling noise on fish, receptors have been grouped into categories depending on their hearing system. In line with Popper et al. (2014) these have been based on whether or not fish have a swim bladder and on whether or not it is involved in hearing (Table 11.35).

Table 11.35 Hearing categories of the fish receptors "(*)" denotes uncertainty or lack of current knowledge with regard to the potential role of the swim bladder in hearing)

Hearing Category	Fish Receptor
Fish with no swim bladder or other gas chamber	• Dover sole • Plaice • Dab • Sandeels • Lemon sole • Mackerel and horse mackerel • Elasmobranchs • River and sea lamprey
Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume	• Atlantic salmon • Sea trout • Smelt (*) • Seabass (*) • Gurnards (*) • Gobies
Fish in which hearing involved a swim bladder or other gas volume	• Herring • Sprat • Cod • Whiting • European eel (*) • Allis and twaite shad

11.6.1.4.4 Assessment of mortality and recoverable injury

Fish with no swim bladder

Magnitude of impact

160. Mortality/potential mortal injury and recoverable injury in fish with no swim bladder has been modelled to have potential to occur at ranges up 1.2km and 1.8 km, respectively. This is based on a stationary receptor scenario for installation of one monopile and would increase to up to 1.8km and 2.7km under a 2 monopile sequential installation scenario. Under a fleeing animal assumption, ranges at which mortality/potential mortal injury and recoverable injury could occur would be reduced to less than 100m, regardless of the scenario under consideration (Table 11.21).

161. Taking the small areas potentially affected under both, stationary and fleeing animal scenarios, and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible.

Sensitivity of receptor

162. The fish receptors included within the group "fish with no swim bladder" (Table 11.35) are mobile and would be expected to vacate the area in which the impact could occur with onset of "soft start" piling. As noted in Appendix 12.2 (Volume

III), although it is feasible that some species will not flee, available evidence suggest that little damage may occur to fish without a swim bladder except at very short ranges, as these are the species less sensitive to noise.

163. Fish with no swim bladder are therefore considered receptors of low sensitivity. In the particular case of sandeels, given their burrowing behaviour and substrate dependence, they may have limited capacity to flee to other areas and are therefore considered receptors of medium sensitivity**.**

Significance of effect

164. Taking account of the identified magnitude of impact (negligible) and receptor sensitivity (minor for species without a swim bladder in general and medium for sandeels), mortality and recoverable injury effects associated with piling noise are considered to result in an impact of negligible significance for species without a swim bladder in general and of minor significance in the case of sandeels.

Fish with a swim bladder that is not involved in hearing

Magnitude of impact

165. Mortality/potential mortal injury and recoverable injury in fish with a swim bladder that is not involved in hearing has been modelled to have potential to occur at ranges up to 4.1km and 9.3km, respectively. This is based on a stationary receptor scenario for installation of one monopile and would increase to up to 6km and 13km respectively under a 2 monopile sequential installation scenario. Under a fleeing animal assumption, ranges at which mortality/potential mortal injury and recoverable injury could occur would be reduced to less than 100m regardless of the scenario under consideration (Table 11.21).

166. Taking the areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible under the fleeing animal scenario and low under a stationary receptor scenario.

Sensitivity of receptor

167. The fish receptors included within the group “fish with a swim bladder that is not involved in hearing” (Table 11.35) are mobile and would be expected to vacate the area in which the impact could occur with onset of “soft start” piling.

168. In general terms, fish with a swim bladder that is not involved in hearing are therefore considered receptors of low sensitivity. Exceptions to this are gobies as they have limited mobility compared to other fish species in this category and therefore limited capacity to escape the greatest noise levels. However, as gobies are abundant over wide areas of the North Sea, any localised impacts from noise would only affect a small proportion of their population. Furthermore, given the relatively short life cycle of goby species (Teal et al., 2009) their population would be expected to recover quickly if subject to localised lethal or injury impacts associated with piling. With the above in mind, gobies are considered receptors of medium sensitivity.

Significance of effect

169. Taking account of the identified magnitude of impact (negligible for fleeing receptor/low for stationary receptor) and receptor sensitivity (low for species

with a swim bladder that is not involved in hearing in general and medium for gobies), mortality and recoverable injury effects associated with piling noise are considered to result in an impact of negligible significance for species with a swim bladder that is not involved in hearing in general and of minor significance in the case of gobies.

Fish with a swim bladder that is involved in hearing

Magnitude of impact

170. Mortality/potential mortal injury and recoverable injury in fish with a swim bladder that is involved in hearing has been modelled to have potential to occur at a range of 6km and 9.3km, respectively. This is based on a stationary receptor scenario for installation of one monopile and would increase to up to 8.4km and 13km respectively under a 2 monopile sequential installation scenario. Under a fleeing animal assumption, ranges at which mortality/potential mortal injury and recoverable injury could occur would be reduced to less than 100m regardless of the scenario under consideration.

171. Taking the areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible under the fleeing animal scenario and low under a stationary receptor scenario.

Sensitivity of receptor

172. The fish receptors included within the group fish with a swim bladder that is involved in hearing (Table 11.35) are mobile and therefore able to move away from the area in which the impact could occur with the onset of “soft start” piling.

173. In general terms, fish with a swim bladder that is involved in hearing are considered receptors of low sensitivity.

Significance of effect

174. Taking account of the identified magnitude of impact (negligible for fleeing receptor/low for stationary receptor) and receptor sensitivity (low), mortality and recoverable injury effects associated with piling noise are considered to result in an impact of negligible significance for species with a swim bladder that is involved in hearing.

Eggs and Larvae

Magnitude of impact

175. Mortality/potential mortal injury in fish eggs and larvae has been modelled to have potential to occur at a range up to 4.1km. This is based on a stationary receptor scenario for installation of one monopile and would increase to up to 6km under a 2 monopile sequential installation scenario. Under a fleeing animal assumption, ranges at which mortality/potential mortal injury and recoverable injury could occur would be reduced to less than 100m regardless of the scenario under consideration.

176. With regard to recoverable injury, quantitative criteria for fish eggs and larvae are not currently available. Popper et al. (2014), however, proposed the following qualitative criteria specific to this receptor group: moderate effects at

distances near the source (tens of metres) and low effects at intermediate and far distances (hundreds of metres to thousands of metres).

177. Taking the areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible under the fleeing animal scenario and low under a stationary receptor scenario.

Sensitivity of receptor

178. Fish eggs and larvae would not be able to flee the vicinity of the foundations during piling, however, prolonged exposure would likely be reduced by the drift of eggs/larvae due to water currents and this may reduce the risk of mortality.

179. In addition, the distribution of fish eggs and larvae extends over wide areas at a given time and therefore, whilst eggs and larvae may not be able to flee the vicinity of piling, the level and frequency of interaction with piling events would be expected to be low. Furthermore, any egg/larval mortality/mortal injury potentially resulting from piling would be expected to be very low in comparison to the natural mortality rates associated with fish egg and larval stages.

180. Eggs and larvae are considered receptors of medium sensitivity.

Significance of effect

181. Taking account of the identified magnitude of impact (negligible for fleeing receptor/low for stationary receptor) and receptor sensitivity (medium), mortality and recoverable injury effects associated with piling noise are considered to result in an impact of minor significance on fish eggs and larvae.

Shellfish

Magnitude of impact

182. There is no specific criteria currently published in respect of mortality or recoverable injury for shellfish species. Decapod crustaceans are thought to be physiologically resilient to noise as they lack gas filled spaces (Popper et al., 2001). In line with this research carried out on lobster *Homarus americanus* has shown no effect on mortality, appendage loss of the ability of animals to regain normal posture after exposure to very high sound levels (> 220dB) (Payne et al., 2007). Similarly, Kosheleva (1992) found no adverse effect on benthic invertebrates, following exposure to a single air gun at a range of 0.5m. However, behavioural changes in mussels were observed in response to simulated pile-driving, with increased filtration rates observed in blue mussels (Spiga et al., 2016).

183. Effects on shellfish species are predicted to be limited, as they are considered to be less sensitive to noise than fish species, though data on sensitivity of these receptors is acknowledged to be scarce. Injury or behavioural effects on shellfish receptors would not be expected beyond the injury response ranges presented for demersal fish species.

184. The potential for piling noise to result in mortality/potential mortal injury or recoverable injury in shellfish species is expected to be very low, being likely limited to very short ranges. As such the magnitude of the impact is considered to be negligible.

Sensitivity of receptor

185. There has been little research into the impact of underwater sound on marine invertebrates (including shellfish) and at present there are no published sensitivity thresholds for this receptor group.

186. Studies on marine invertebrates have shown sensitivity to substrate borne vibration (Roberts et al., 2016). However, many invertebrate species are equipped with a number of receptor types potentially capable of responding to the particle motion component of underwater noise (e.g. the vibration of the water molecules which results in the pressure wave) (Popper et al., 2001 Hawkins et al., 2014, Popper and Hawkins, 2018).

187. Effects on shellfish species are predicted to be limited, as they are considered to be less sensitive to noise than fish species, though data on sensitivity of these receptors is acknowledged to be scarce. The potential for mortality/potential mortal injury or recoverable injury on shellfish receptors are not expected to be beyond the ranges presented for demersal fish species

188. Given the relatively low mobility of shellfish species in comparison to most fish and the commercial importance of some species in the study area, they are considered receptors of medium sensitivity.

Significance of effect

189. Taking account of the identified magnitude of impact (negligible) and receptor sensitivity (medium), mortality and recoverable injury effects associated with piling noise are considered to result in an impact of minor significance on shellfish species.

11.6.1.4.5 Assessment of TTS and behavioural impacts

Magnitude of impact

190. The outputs of the underwater noise modelling for the spatial worst-case scenario indicate that TTS may occur at distances up to 16km and 17km assuming a fleeing animal (single pin pile and sequential pin pile installation), increasing to up to 33km and 39km when considering a stationary receptor (single monopile and sequential monopiles installation). Behavioural responses would be expected within these ranges and potentially in wider areas depending on the hearing ability of the species under consideration.

191. As shown in Table 11.2, in terms of temporal worst case the maximum duration of piling would be equivalent to 44 days (1,075 hours), although this would not be continuous.

192. Taking account of the spatial extent of the impact and the overall short duration of piling and its intermittent nature, the magnitude of the impact is considered to be low.

Sensitivity of receptor

193. Impacts associated with TTS could result in reduced fitness, whilst behavioural impacts could cause changes in distribution, such as moving from preferred sites for feeding and spawning, or alteration of migration patterns. In both cases, any impact would be temporary.

194. The assessment of the impact of TTS and behavioural impacts has been focused on key species, selected on the basis of the presence, known spawning and nursery grounds in the offshore project area, conservation status and commercial value. On this basis, the following species have been taken forward for detailed assessment:

- Dover sole;
- Plaice;
- Lemon sole;
- Mackerel;
- Sandeels;
- Seabass;
- Cod;
- Whiting;
- Sprat;
- Herring;
- Elasmobranchs; and
- Diadromous species.

Dover sole, plaice, lemon sole and mackerel

195. The offshore project area is located within high intensity spawning grounds and low intensity nursery grounds for Dover sole and plaice (Figure 11.9 and Figure 11.10, Volume II). In addition, the offshore project area overlaps with lemon sole spawning and nursery grounds and with mackerel nursery grounds (intensity not defined) (Figure 11.11 and Figure 11.12, Volume II).

196. As illustrated in Figure 11.9 to Figure 11.12 (Volume II), however, the degree of overlap between spawning and nursery grounds and ranges at which TTS may occur would be very small in the context of the total spawning/nursery areas available to these species. All four species lack a swim bladder and according to the criteria for behavioural impacts proposed in Popper et al. (2014) they would be at high risk of behavioural impacts within tens of metres from the piling operation, at moderate risk within hundreds of metres and at low risk when located within thousands of metres from the piling operation (Table 11.15).

197. It should be noted that these four species are pelagic spawners and are therefore not dependent on discrete spawning grounds with specific substrate characteristics on which to lay their eggs.

198. Considering the distribution ranges of these species, including the areas used as spawning/nursery grounds, in the context of the potential zones where TTS and behavioural impacts could occur, plaice, lemon sole and mackerel are considered receptors of low sensitivity. In the case of Dover sole, taking account of its more restricted overall distribution range (see Appendix 11.1, Volume III) and the smaller extent of their spawning and nursery grounds in a North Sea context, they are considered receptors of medium sensitivity.

Sandeels

199. As shown in Figure 11.13 (Volume II), the offshore project area overlaps with low intensity spawning and nursery grounds for sandeels. The degree of overlap between sandeel spawning/nursery grounds and sandeel habitat and areas where TTS may occur would however be very small. In this context it is important to note that important sandeel grounds have not been previously reported from the study area, with no overlap between known sandeel grounds in Sandeel Assessment Area 1r and the offshore project area (Figure 11.6 (Volume II); Jensen et al., 2011). In addition, PSA data from benthic grab samples collected in the offshore project area, indicates that for the most part, the sediment found is either not suitable for sandeels or of marginal suitability as sandeel habitat (Figure 11.7, Volume II).

200. Sandeels lack a swim bladder and according to the criteria for behavioural impacts proposed in Popper et al. (2014) would be at high risk of behavioural impacts within tens of metres from piling operations, at moderate risk when located within hundreds of metres and at low risk if found within thousands of metres from piling operations (Table 11.15).

201. Whilst the level of overlap between sandeel habitat and areas potentially affected by underwater noise would be expected to be small, considering the seabed habitat specificity and burial behaviour of sandeels they are considered receptors of medium sensitivity.

Sea bass

202. Sea bass is a species of commercial importance to local fisheries using the offshore project area and is relatively abundant in the study area, particularly in inshore areas. Since 2017 its commercial and recreational fisheries have been heavily regulated due to conservation concerns over sea bass stocks (Appendix 11.1, Volume III).

203. Various studies have been carried out on the behavioural impact of underwater noise on sea bass. These have reported increases in motility and changes in swimming performance in response to impulsive sounds (Neo et al., 2015). In addition, changes in responsiveness to visual stimulus have also been reported in sea bass exposed to playback piling noise (Everley et al., 2015) and startle responses as a result of exposure to low frequency sounds (Kastelien et al., 2008).

204. Areas where seabass may be affected by TTS may extend up to 39km for a stationary receptor decreasing to up to 17km when considering a fleeing receptor scenario (Table 11.25 and Table 11.26). Sea bass falls within the category of “fish with a swim bladder which is not involved in hearing” (Table 11.35). According to Popper et al. (2014) criteria for behavioural impacts, this species would be at high risk of behavioural impacts within tens of metres from piling operation and at moderate and low risk when within hundreds and thousands of metres, respectively.

205. Sea bass would be expected to be more commonly found in the offshore export cable corridor rather than in the array areas where piling operations will be undertaken. With this in mind, and considering the distribution range of the species and the relatively small areas where TTS and behavioural impacts may occur, sea bass is considered a receptor of low sensitivity.

Cod, whiting and sprat

206. As shown in Figure 11.14 to Figure 11.16 (Volume II), the offshore project area overlaps with low intensity cod and whiting spawning and nursery grounds and with sprat spawning and nursery grounds (intensity not defined).

207. These three species are pelagic spawners and are therefore not dependent on discrete spawning grounds with specific substrate characteristics for spawning. The degree of overlap between the spawning/nursery grounds of these species and the area impacted by TTS would however be very small relative to the total area used by these species for spawning/nursery. As these three species have a swim bladder which is involved in hearing, according to the Popper et al. (2014) criteria for behavioural impacts they would only be at high risk of behavioural impacts if located within tens and hundreds of metres from piling operations and at moderate risk when found within thousands of metres (Table 11.15).

208. Considering the areas where TTS and behavioural impacts could occur in the context of the wide distribution ranges of these species (including spawning/nursery grounds) they are considered receptors of low sensitivity.

Herring

209. As illustrated in Figure 11.17 (Volume II), the offshore project area is located immediately to the west of the spawning grounds that have been defined for the Downs herring. In addition, it overlaps with high intensity herring nursery grounds.

210. Inshore spawning grounds have also been identified in the study area for the spring spawning Blackwater herring, however these are at considerable distance from the array areas, and therefore from locations where piling may be undertaken (Figure 11.18, Volume II).

211. As shown in Figure 11.17 (Volume II), a relatively large section of the Downs herring grounds may be affected by noise levels where TTS could occur under the conservative assumption of a stationary receptor. The extent affected at TTS level would however be considerably reduced under a fleeing receptor scenario.

212. Herring have a swim bladder that is involved in hearing and according to Popper et al. (2014) criteria for behavioural impacts would be at high risk of behavioural impacts with tens and hundreds of metres from the piling operation and at moderate risk when located within thousands for metres.

213. In the context of this assessment it is important to note that evidence from existing research suggests that herring give precedence to spawning over avoidance reactions that are evident at other times of the year (Nøttestad et al., 1996; Skaret et al., 2003; Mohr, 1971). The lack of response to underwater noise during the spawning season observed in some studies (i.e. Peña et al., 2013) has been interpreted as a combination of a strong motivation to spawn and a progressively increased level of tolerance to noise over time.

214. For Downs herring, given the location of their spawning grounds and the potential level of overlap with areas affected by TTS and behavioural responses, and taking account of herring’s dependence on specific discrete grounds on which to lay their eggs, receptor sensitivity is considered to be high. In the case of the Blackwater herring, there would be no overlap with spawning grounds

therefore in light of the decreased magnitude the receptor sensitivity is considered to be medium.

Elasmobranchs

215. Elasmobranchs lack a swim bladder. and according to Popper et al. (2014) criteria for behavioural impacts, these species would be at high risk of behavioural impacts within tens of metres, moderate risk within hundreds of metres and low risk within thousands of metres from piling (Table 11.15).

216. Areas potentially affected by TTS (up to 39km for stationary receptors and up to 17km under a fleeing receptor scenario) and where behavioural impacts may occur would be small in the context of the wide distribution ranges of elasmobranch species, including those relating to spawning/nursery grounds for relevant species (i.e. thornback ray and tope; see Figure 11.19, Volume II).

217. Elasmobranchs are therefore considered to be receptors of low sensitivity.

Diadromous species

218. The diadromous species considered in the assessment include river lamprey, sea lamprey, salmon, sea trout, allis shad and twaite shad, European eel and smelt (Table 11.14). Potential ranges of behavioural impacts would depend on the hearing sensitivity of each species. As shown in Table 11.35, river and sea lamprey are species which lack a swim bladder; salmon, sea trout and smelt, species with a swim bladder that is not involved in hearing and European eel and allis and twaite shad species with a swim bladder that is involved in hearing. According to Popper et al. (2014) the risk of behavioural impacts on these species would be as follows:

- For species with no swim bladder and species with swim bladder which is not involved in hearing: high within tens of metres from the piling operation, moderate within hundreds of metres and low within thousands of metres; and
- For species with a swim bladder involved in hearing: high within tens and hundreds of metres from the piling operation and moderate within thousands of metres.

219. As described in Section 11.5.5.1 and in Appendix 11.1 (Volume III), diadromous species are only anticipated to be present in the offshore project area on an occasional basis and predominantly in inshore areas. The potential for these species to be subject to piling noise would be low and given the distance from the array areas to the coast and therefore to rivers, there is no potential for piling noise to affect these species during critical periods of their migration such as river entry and river exit. Diadromous fish species are therefore considered receptors of low sensitivity.

Significance of effect

220. Taking account of the identified magnitude of impact (low) and the receptor sensitivities identified above for each species, TTS and behavioural effects associated with piling noise are considered to result in the following impact significance:

- Dover sole (medium sensitivity): minor significance;

- Plaice, lemon sole and mackerel (low sensitivity): negligible significance;
- Sandeels (medium sensitivity): minor significance;
- Sea bass (low sensitivity): negligible significance;
- Cod, whiting and sprat (low sensitivity): negligible significance;
- Downs herring (high sensitivity): moderate significance;
- Blackwater herring (medium sensitivity): minor significance;
- Elasmobranchs (low sensitivity): negligible significance; and
- Diadromous species (low sensitivity): negligible significance.

11.6.1.5 Impact 5: Underwater noise and vibration from other construction activities

221. The following section provides an assessment of the potential impact of underwater noise during construction, other than piling noise, on fish and shellfish receptors.

222. Potential sources of underwater noise, aside from piling, that could be present during the construction phase of the Project are listed in Table 11.36.

Table 11.36 Summary of possible noise making activities during construction other than impact piling

Activity	Description
Cable laying	Noise from the cable laying vessel and any other associated noise during the offshore cable installation.
Dredging	Dredging may be required on site for seabed preparation work for certain foundation options, as well as for the export cable, array/interconnector cables and interconnector cable installation. Suction dredging has been assumed as a worst-case.
Trenching	Plough trenching may be required during offshore cable installation.
Rock placement	Potentially required on site for installation of offshore cables (cable crossings and cable protection) and scour protection around foundation structures.
Vessel noise	Jack-up barges for piling substructure and WTG installation. Other large and medium sized vessels to carry out other construction tasks and anchor handling.

223. In order to define the magnitude of the impact consideration has been given to Popper et al. (2014) criteria for continuous noise sources. These are described in Table 11.37.

224. As shown, for the most part, Popper et al. (2014) criteria are qualitative being provided in terms of relative risk (high, moderate, low) to the animal at various distances from the source of noise (near (N), intermediate (I) and far (F)). Exceptions to this are the recoverable injury and TTS criteria for fish with a swim bladder involved in hearing. As illustrated in Table 11.37, for these criteria quantitative thresholds have been defined. As such, impact ranges for these criteria have been modelled and are presented in Table 11.38.

Table 11.37 Popper et al (2014) criteria for fish in respect of shipping and continuous sounds

Category	Mortality/Mortal Injury	Recoverable Injury	Temporary Threshold Shift (TTS)	Behavioural
Fish with no swim bladder	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Fish with swim bladder not involved in hearing	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
Fish with swim bladder involved in hearing	(N) Low (I) Low (F) Low	170 dB rms for 48 h	158 dB rms for 12 h	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Moderate (F) Low
(N) Near: within few tens of metres; (I) Intermediate: within hundreds of metres; and (F) Far: within thousands of metres.				

Table 11.38 Summary of impact ranges for fish from Popper et al 2014 for shipping and continuous noise, covering the different construction noise sources

Unweighted SPL_{RMS}	Cable laying	Suction dredging	Trenching	Rock placement	Vessels (large)	Vessels (medium)
Recoverable injury 170 dB (48 hours)	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m
TTS 158 dB (12 hours)	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m	< 50 m

11.6.1.5.1 Magnitude of impact

225. From the information provided above, it is apparent that construction activities other than piling have only potential to result in localised disturbance to fish and shellfish receptors. As described in Table 11.37, however, the risk of mortality would be very low, even in close proximity to the source of noise. This would also be the case with regard to the risk of any injury or TTS with reference to the SPL_{RMS} guidance for continuous noise sources (see Table 11.38).

226. Noise associated with these activities may take place intermittently at discrete locations over the overall four-year construction period. The magnitude of the impact is therefore considered to be low.

11.6.1.5.2 Sensitivity of receptor

227. Fish and shellfish species present in the study area have very wide distribution ranges (including spawning and nursery grounds) in the context of the small areas potentially affected by construction noise from activities other than piling. Their sensitivity is therefore considered to be low.

11.6.1.5.3 Significance of effect

228. Taking account of the identified magnitude of impact (low) and receptor sensitivity (low), effects associated with construction noise are other than piling

are considered to result in an impact of negligible significance on fish and shellfish species.

11.6.1.6 Impact 6: Underwater noise and vibration from UXO clearance

229. A detailed underwater unexploded ordnance (UXO) survey will be carried out prior to construction. Whilst any UXO identified would be preferably avoided, there may be instances when it is considered unsafe to retrieve the UXO from the seabed and a controlled detonation may be required.

230. As described in Appendix 12.2 (Volume III), it is possible that UXO devices with a range of charge weights (or quantity of contained explosive) may be present within the offshore project area. In order to assess potential underwater noise levels associated with UXO clearance a selection of explosive sizes has been considered based on what may be present in the area.

231. In all cases the worst-case estimation has been used, assuming that the UXO to be detonated is not buried, degraded or subject to any other significant attenuation from its "as new" condition.

232. Taking account of Popper et al. (2014) explosion noise criteria for fish impact ranges associated with UXO detonation have been modelled (see Appendix 12.2) and are summarised in Table 11.39 for potential mortality/mortal injury.

233. For recoverable injury, TTS and behavioural impacts the qualitative criteria defined in Popper et al. (2014) have been used to inform the assessment. These are outlined in Table 11.40.

Table 11.39 Summary of the impact ranges of UXO detonation using the unweighted SPL_{peak} explosion noise criteria from Popper et al. (2014) for fish species

Unweighted SPL_{peak}		0.5 kg	25 kg +donor	55 kg +donor	120 kg +donor	240 kg +donor	525 kg +donor	698 kg +donor
Mortality & potential mortal injury	234 dB	< 50 m	170 m	230 m	300 m	370 m	490 m	530 m
	229 dB	80 m	290 m	380 m	490 m	620 m	810 m	890 m

Table 11.40 Popper et al. (2014) qualitative criteria for explosions for recoverable injury, TTS and behavioural impacts in fish species

Category	Recoverable injury	TTS	Behaviour
Fish with no swim bladder	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low
Fish with swim bladder not involved in hearing	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) High (F) Low
Fish with swim bladder involved in hearing	(N) High (I) High (F) Low	(N) High (I) High (F) Low	(N) High (I) High (F) Low

Category	Recoverable injury	TTS	Behaviour
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F). (N), (I) and (F) are equivalent to tens, hundreds and thousands of metres respectively			

11.6.1.6.1 Magnitude of impact

234. As illustrated in Table 11.39 and Table 11.40, the detonation of UXOs found in the offshore project area may result in injury and disturbance to fish species in the vicinity of the detonation. Physical injury/trauma would be expected in close proximity to the detonation (tens to hundreds of meters, depending on charge) with TTS and behavioural impacts potentially occurring at greater distances. In all cases, however, high risks are only anticipated at short distances. With this in mind and considering the short term and intermittent nature of this activity (limited to instances when detonation of UXO is required) the magnitude of the impact is considered to be low.

11.6.1.6.2 Sensitivity of receptor

235. The effect of UXO detonations may have severe consequences for fish and shellfish species at short range. However, given the small areas potentially affected impacts would occur at individual rather than at population level. Fish and shellfish species are therefore considered receptors of medium sensitivity.

11.6.1.6.3 Significance of effect

236. Taking account of the identified magnitude of impact (low) and receptor sensitivity (medium), effects associated with noise from UXO detonation are considered to result in an impact of minor significance on fish and shellfish species.

11.6.1.7 Impact 7: Changes in fishing activity

11.6.1.7.1 Magnitude of impact

237. The presence of safety zones associated with the Project during the construction phase could result in changes to fishing activity within the offshore project area but also in the wider area (i.e. due to displacement of fishing activity into other areas). Fishing activity may be reduced within the offshore project area as a result of 500m construction safety zones around offshore construction vessels, advisory safety zones and the physical presence of infrastructure within the array areas.

238. Receptors likely to be affected by an increase in fishing activity outside the offshore project area include those demersal fish and shellfish species targeted by commercial fisheries occurring within the offshore project area. It would not be expected that any changes in fishing activities in the offshore project area would lead to changes in populations of these species in the wider study area.

239. Given the short-term and temporary nature of the construction phase and considering the above the magnitude of the impact is assessed as low.

11.6.1.7.2 Sensitivity of receptor

240. The principal commercial fish and shellfish species targeted in the study area is presented in Appendix 11.1 (Volume III). The fish species of highest commercial importance include sole, bass, thornback ray, horse mackerel, herring, cod and plaice. These fish species are highly mobile, therefore any reduction in fishing

activity would be most beneficial to demersal fish species and shellfish, although non-target fish caught as by-catch are also likely to benefit due to a reduction in fishing mortality.

241. Shellfish species such as whelk, lobster and crab are also targeted in the study area, which would likely benefit most from a reduction in fishing effort. Roach et al. (2018) found that temporary restrictions of fishing areas led to an increase in lobster abundance and size. It is suggested that temporary restrictions of fishing activity can enable uninterrupted contribution to the spawning stocks through protection of habitats that became a refuge for young and spawning fish (Byrne Ó Cléirigh et al., 2000).

242. Fishing activity for these species is primarily regulated through the setting of annual total allowable catches (TACs) and limitation in fishing effort. It is therefore anticipated that the level of fishing for these species would be largely unaffected by changes in activity associated with the Project, as fishing will continue until TACs or set limitations in effort are reached (i.e. through vessel's fishing in the wider grounds available in the southern North Sea).

243. Furthermore, as described in Chapter 14 Commercial Fisheries (Volume I), significant impacts (i.e. exceeding minor significance) in respect of loss of fishing grounds and associated potential for displacement have not been identified for any of the fleets active in areas relevant to the Project. Therefore, the sensitivity of commercially targeted fish stocks in respect of potential changes in fishing activity as a result of the Project is considered to be low.

11.6.1.7.3 Significance of effect

244. Fish and shellfish receptors in general are considered to have low sensitivity to changes in fishing activity. This, in combination with the low magnitude of the impact associated with the Project, would result in an impact of negligible significance.

11.6.2 Potential impacts during operation

245. The potential impacts of the Project on fish and shellfish receptors during O&M are assessed below. As outlined in Table 11.2, these include the following:

- Impact 8: Temporary habitat loss/ physical disturbance;
- Impact 9: Long term habitat loss;
- Impact 10: Increased suspended sediment concentrations and re-deposition;
- Impact 11: Re-mobilisation of contaminated sediments;
- Impact 12: Underwater noise and vibration;
- Impact 13: Electromagnetic Fields (EMFs);
- Impact 14: Introduction of hard substrate; and
- Impact 15: Changes in fishing activity.

11.6.2.1 Impact 8: Temporary habitat loss/ physical disturbance

11.6.2.1.1 Magnitude of impact

246. During the operational phase of the Project, activities such as export/interconnector cable repairs and reburial and turbine repairs have the potential to result in temporary habitat loss /physical disturbance to fish and shellfish receptors. Similarly, the presence of machinery on the seabed (i.e. jack up vessel legs, vessel anchors) could also result in physical disturbance or temporary habitat loss. The area disturbed would be comparatively much smaller than during construction (see Table 11.2).

247. The following planned and unplanned maintenance activities are assumed as worst-case scenarios:

- Reburial of 25% of the array and interconnector cables is estimated once every 5 years x 12m disturbance width (approximately 0.68km^2 disturbance);
- Reburial of 25% of the export cables is estimated once every 5 years x 12m disturbance width (approximately 0.75km^2 disturbance);
- Repairs from cable breakage are estimated for two array/interconnector cable and two export cable repairs every 5 years. Approximately 12km^2 disturbance at each repair location based on 1,000m section removed x 12m disturbance width (approximately 0.05km^2 disturbance);
- Maintenance of offshore infrastructure would be required during O&M. An estimated 180 major component replacement activities may be required per year, using jack up vessels and/or anchoring (approximately 0.3km^2 disturbance); and
- Anchored vessels placed during the number of cable repairs described above, with each having a 546m^2 footprint.

248. The impacts from planned maintenance and repair works during the operational phase would be temporary, localised and small scale and overall there would be less impact on fish and shellfish receptors than during construction (see Section 11.6.1.1).

249. Given the small area of disturbance, the generally wide distribution ranges (or no direct overlap of habitats with the offshore project area) of fish and shellfish species, and that the seabed is anticipated to quickly recover to its original condition the magnitude of the impact of physical disturbance/temporary habitat loss to fish and shellfish receptors during the operational phase is considered to be negligible.

11.6.2.1.2 Sensitivity of receptor

250. The fish and shellfish species likely present in the offshore project area use comparatively large areas for spawning, as nursery grounds and for foraging, and for the most part have wide distribution ranges; all of which may be spatially and temporally variable. The sensitivity of fish and shellfish receptors identified in the offshore project area have been assessed in relation to physical disturbance and temporary habitat loss in the construction (Impact 1), as set out in Section 11.6.1.1.2.

251. Given the small temporary areas where physical disturbance and temporary habitat loss may occur, and that the benthic communities are characteristic of highly disturbed environments, fish and shellfish species in general are considered receptors of low sensitivity.

11.6.2.1.3 Significance of effect

252. Based on the worst-case medium sensitivity of habitats and biotopes and the negligible magnitude of temporary physical disturbance during the operational phase, the effect is assessed as minor significance for the offshore project area. This has been reached on the basis that each disturbance activity would occur relatively infrequently, would be localised and temporary and that benthic ecology receptors would recover rapidly.

253. Taking account of the identified magnitude of impact (negligible) and receptor sensitivity (low), effects associated with temporary physical disturbance and habitat loss during operation are considered to result in an impact of negligible significance for all fish and shellfish species other than those considered separately.

254. Of the receptors that were assessed separately, Blackwater herring was assessed as low sensitivity given the lack of overlap of spawning grounds, resulting in negligible significance whereas Downs herring, sandeels and, oysters/ cockles were considered to be receptors of medium sensitivity which results in an impact of minor significance.

11.6.2.2 Impact 9: Long term habitat loss

11.6.2.2.1 Magnitude of impact

255. The worst-case scenario in terms of permanent loss of habitat during the operational phase is presented in Table 11.2. This would be primarily a result of the introduction of foundations associated with turbines, and any required scour around these structures, as well as protection measures introduced for the array/ interconnector and export cables.

256. Within the array areas it is estimated that a worst-case permanent loss of habitat would represent an area of approximately 6.69km^2 which is 4.46% of the array areas. Within the offshore cable corridor, the estimated worst-case loss of habitat is approximately 0.15km^2.

257. Loss of habitat would be permanent throughout the expected design life of the Project. However, given the relatively small area of seabed potentially lost in the array areas and that these areas would be localised to areas where project infrastructure is located, the effect is considered to be of low magnitude. In relation to the offshore cable corridor area, given the comparatively smaller footprint of the habitat loss the magnitude of the impact is considered to be negligible. In view of the offshore project area as a whole, the magnitude of the impact would be low.

11.6.2.2.2 Sensitivity of receptor

258. The fish and shellfish species likely present in the offshore project area use comparatively large areas for spawning, as nursery grounds and for foraging, and for the most part have wide distribution ranges; all of which may be spatially and temporally variable. Further, as indicated in Chapter 10 Benthic and Intertidal Ecology (Volume I), significant impacts on the benthos associated with permanent loss of habitat are not expected (impacts assessed as of minor

adverse significance in Chapter 10 Benthic and Intertidal Ecology, Volume I). Therefore, in general terms, impacts as a result of habitat loss are expected to be minimal and fish and shellfish species in general are considered receptors of low sensitivity.

259. Species that depend on specific substrates for spawning may however be more susceptible to the impact of habitat loss. In the study area, these include the following:

- Herring (demersal spawners)
- Sandeels (demersal spawners);

260. A separate assessment of sensitivity is provided for herring and sandeel below. Additional species-specific information on magnitude is also included, where relevant, to provide context to the assessment of sensitivity.

Herring

261. Herring are demersal spawners and require the presence of suitable coarse substrate on which to lay their eggs. Therefore, there could be potential for the loss of seabed habitat associated with the Project to result in a loss of spawning grounds to this species. As discussed in Appendix 11.1 (Volume III), there are two distinct herring populations of relevance in the study area. These are the Downs herring and the Blackwater herring.

262. Defined spawning grounds for the Downs herring are located immediately to the east of the southern array area with limited overlap with the offshore project area (Figure 11.2, Volume II). Sediment samples, however, indicate that for the most part the offshore project area is unsuitable as herring spawning habitat. Whilst limited, as there may be some overlap between spawning grounds and the offshore project area, the Downs herring is considered a receptor of medium sensitivity.

263. In the case of the Blackwater herring, spawning grounds are located in inshore areas around the Blackwater Estuary and Herne Bay at considerable distance from the offshore project area (Figure 11.2, Volume II). As such, it is considered a receptor of low sensitivity.

Sandeels

264. Sandeels depend on the presence of an appropriate sandy substrate in which to burrow and lay their eggs on the seabed (demersal spawners). Therefore, there could be potential for the permanent loss of seabed habitat associated with the Project to result in a loss of habitat to sandeels, including a loss of spawning habitat.

265. It should be noted, however, that studies of fish populations in operational wind farms (i.e. Stenberg et al., 2011; Stenberg et al., 2015) have not detected significant changes to sandeel populations. It has been suggested (Stenberg et al., 2015) that the direct loss of habitat associated with offshore wind farm infrastructure and indirect effects (i.e. changes to sediment) are too low to influence the abundance of sand-dwelling species such as sandeels.

266. Furthermore, as described previously for assessment of impacts in respect of temporary disturbance/loss of habitat during construction (paragraph 86 to 91),

whilst sandeels are expected to be found in some numbers in the study area, available information from the IBTS (Figure 11.5, Volume II), the distribution of defined spawning and nursery grounds (Figure 11.4, Volume II), known sandeel grounds and fishing areas (Figure 11.6, Volume II) and sediment data from the offshore project area, all suggest that the offshore project area is not a key sandeel area. It is therefore expected that the extent of sandeel habitat affected by physical habitat loss will be small.

267. Given the above but recognising sandeels' dependence on the presence of suitable habitat for burrowing and spawning, they are considered receptors of medium sensitivity.

11.6.2.2.3 Significance of effect

268. In general terms, impacts as a result of habitat loss are expected to be minimal and fish and shellfish species are considered receptors of low sensitivity. In combination with the low magnitude of impact assessed for the Project, the impact of permanent loss of habitat is considered to be of negligible significance.

269. Of the receptors that were assessed separately, Downs herring and sandeels were considered to be receptors of medium sensitivity which results in an impact of minor significance.

11.6.2.3 Impact 10: Increased suspended sediment concentrations and re-deposition

11.6.2.3.1 Magnitude of impact

270. During the operational phase of the Project, activities such as export/interconnector cable repairs and reburial and turbine repairs have the potential to result in increases in SSC within the water column and subsequent deposition onto the seabed. The effects of increased SSCs have been assessed in Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I), which found that the worst-case volumes of sediment released following O&M activities are considerably less than in the construction phase.

271. During construction it was considered that overall changes from SSC and deposition of fine sands and mud-sized sediment will not be measurable due to prevailing hydrodynamic conditions and that the magnitude was assessed as negligible (Section 11.6.1.2.1). As operational activities are temporary, localised and small scale, the magnitude is considered to be negligible.

11.6.2.3.2 Sensitivity of receptor

272. The sensitivity of fish and shellfish receptors will be as assessed for construction (Section 11.6.1.2.2). In general terms, adult and juvenile fish, being mobile, would be expected to rapidly redistribute to undisturbed areas within their habitat range. Similarly, it is understood that motile shellfish species will be relatively tolerant of the small increases in SSCs and low levels of re-deposition given the anticipated levels of SSCs are considered to be within the range of natural variability for the area. As such, fish and shellfish in general are considered receptors of low sensitivity.

273. Where separate assessments of sensitivity are provided for species/species groups that are highly dependent on substrate-specific seabed, additional species-specific information on magnitude is also included, where relevant, to provide context to the assessment of sensitivity.

274. The offshore project area is considered to be of comparatively low importance to the demersal spawning sandeels, however, recognising their limited mobility and substrate dependence, they are considered receptors of medium sensitivity.

275. The Downs herring is considered a receptor of medium sensitivity in light of the relative tolerance of herring eggs to increases in SSCs (such as those associated with the maintenance and repairs) and the potential albeit limited overlap between spawning grounds and the offshore project area.

276. Sedentary/sessile filter feeders such as cockles and oysters are amongst the most vulnerable to increased SSCs and smothering effects from sediment re-deposition given their lack of motility. However, the prevailing hydrodynamic conditions indicate a tolerance to the small increases in SSCs and low level of re-deposition expected during maintenance and repair works in the operational phase. As such, oysters and cockles are considered to have a medium sensitivity.

11.6.2.3.3 Significance of effect

277. In general terms, given the sensitivity of fish and shellfish receptors is low, in combination with the negligible magnitude of the impact associated with the Project, this would result in an impact of negligible significance.

278. Of the receptors that were assessed separately, Downs herring, sandeels, and oysters and cockles are considered to be receptors of medium sensitivity which results in an impact of minor significance.

11.6.2.4 Impact 11: Re-mobilisation of contaminated sediments

11.6.2.4.1 Magnitude of impact

279. During the operational phase of the Project, activities such as export/interconnector cable repairs and reburial and turbine repairs have the potential to disturb contaminated sediment and re-mobilise it back into the water column. However, Chapter 9 Marine Water and Sediment Quality (Volume I) assessed the impact in more detail and concluded that even though there are some elevated levels of contaminants within the sediments, they align with typical levels for the region and do not pose a high risk. The magnitude of impact is considered negligible.

11.6.2.4.2 Sensitivity of receptor

280. As noted in Section 11.6.1.3.2, the levels of contaminants found are within environmental protection standards, therefore, all fish and shellfish receptors are assessed as not sensitive (negligible sensitivity) to changes that remain within these standards.

11.6.2.4.3 Significance of effect

281. The overall worst-case effect is considered to be of negligible significance from the remobilisation of contaminated sediments given the negligible magnitude and negligible sensitivity to the existing contaminant levels found in the area.

11.6.2.5 Impact 12: Underwater noise and vibration

11.6.2.5.1 Magnitude of impact

282. During operations underwater noise and vibration will occur as a result of vessel activity for maintenance activities, as well as from operational turbines, where mechanically generated vibration from the turbines, is transmitted into the sea

through the structure of the support pile and foundations (Appendix 12.2, Volume III).

283. Noise from the operation of wind turbines would be present for the design life of the Project and would contribute to the ambient noise in the region. As described in Appendix 12.2 (Volume III), in line with the modelling carried out in respect of operational wind turbines, impact ranges associated with operational noise from wind turbines would be very small (i.e. <50m in respect of fish for recoverable injury/PTS) (Table 11.41).

284. In respect of noise associated with O&M vessels servicing the Project, it should be noted that a maximum of 1,587 vessel round trips are expected to occur each year (average of 4/day) during the operational phase. This would be very small in the context of the current levels of vessel traffic in the area (Chapter 15 Shipping and Navigation, Volume I) and less than that modelled during construction (Table 11.38).

Table 11.41 Summary of the operational WTG noise impact ranges using the continuous noise criteria from Popper et al. (2014) for fish (swim bladder involved in hearing)

Popper et al. (2014) Unweighted SPL_{RMS}	Operational WTG (14 MW)	Operational WTG (25 MW)
Recoverable injury 170 dB (48 hours) Unweighted SPL_{RMS}	< 50 m	< 50 m
TTS 158 dB (12 hours) Unweighted SPL_{RMS}	< 50 m	< 50 m

285. From the information provided above, it is understood that only O&M activities have potential to result in localised disturbance to fish and shellfish receptors. As described in Table 11.37, however, the risk of mortality would be very low, even in close proximity to the source of noise. This would also be the case with regard to the risk of any injury or TTS with reference to the SPL_{RMS} guidance for continuous noise sources (see Table 11.38).

286. Taking the small increase above background noise levels expected during operation and the localised nature of the potential impact, the magnitude of the impact is considered to be low.

11.6.2.5.2 Sensitivity of receptor

287. The results from monitoring programmes indicate that the presence of operational wind farms has not identified significant impacts on fish and shellfish communities. Further information is provided on the studies of fish populations and assemblages within operational offshore wind farms in Section 11.6.2.7. Considering this and the small areas potentially affected by operational noise in the context of the distribution ranges of fish and shellfish species, their sensitivity to operational noise is assessed as low.

11.6.2.5.3 Significance of effect

288. Taking account of the identified magnitude of impact (low) and receptor sensitivity (low), effects associated with operational noise and maintenance activities are considered to result in an impact of negligible significance on fish and shellfish species.

11.6.2.6 Impact 13: Electromagnetic Fields (EMFs)

11.6.2.6.1 Magnitude of impact

289. The transport of electricity through cables generates a localised EMF which could potentially affect the sensory mechanisms of some species of fish and shellfish. EMF will result from the operation of up to 228km of High Voltage Alternating Current (HVAC) inter-array and interconnector cables (maximum operating voltage of 132 kilovolts (kV), and 250.8km of HVAC export cable (comprising of up to four cables operating at a capacity up to 400kV).

290. EMF comprise both the electric (E) fields, and the magnetic (B) fields. In nature, E-fields are induced in the sea when saltwater, a conductor, moves in the natural B-field, and will vary with the B-field strength and current speeds. Background measurements of B-fields are approximately 50μT (micro tesla) in the North Sea and the naturally occurring E-field in the North Sea is approximately 25μVm-1 (Tasker et al 2010). The B- and induced electric (iE) fields produced by Alternating Current (AC) change in direction and magnitude over time as the current flow alternates between positive and negative polarity. Therefore, the B-fields that HVAC cables generate are constantly changing. As a result, the motion of these B-fields through the surrounding seawater continuously induces varying iE-fields.

291. It has been shown that industry-standard AC cables can be effectively insulated to prevent E-field emissions but not B-field emissions (Scott et al 2018). B-fields are expected to attenuate rapidly with distance from cables and given their dependence on B-fields, iE-fields are also expected to attenuate rapidly both horizontally and vertically with distance from the cables (CMACS, 2012). Normandeau et al. (2011) modelled expected B-fields using design characteristics taken from a range of undersea cable projects. For eight of the ten AC cables modelled it was found that the intensity of the B-fields was a function of voltage (ranging from 33kV to 345kV) although separation between the cables and burial depth also influenced field strengths. The predicted B-fields were strongest directly over the cables and decreased rapidly with vertical and horizontal distance from the cables (Table 11.42).

Table 11.42 Averaged magnetic (B-field) strength values from AC cables buried 1m (Normandeau et al., 2011)

Distance above seabed (m)	Magnetic Fields Strength (μT) Horizontal distance (m) from cable		
	0	4	10
0	7.85	1.47	0.22
5	0.35	0.29	0.14
10	0.13	0.12	0.08

292. As part of the embedded mitigation measures stated in Section 11.3.3 (Table 11.3), offshore cables would be buried to a minimum burial depth of 0.5m (average burial depth of 1.2m), where practicable. Where substrate conditions prevent burial, and at cable or pipeline crossings, cable protection would be deployed.

293. The areas affected by EMFs generated by the worst-case scenario (minimum indicative target depth cable burial (0.5m) and highest power-rating) associated with the Project are expected to be small, being limited to the offshore project area, and restricted to the immediate vicinity of the cables (i.e. within metres). In addition, EMFs are expected to attenuate rapidly in both horizontal and vertical plains with distance from the source. The magnitude of the impact is therefore considered to be low.

11.6.2.6.2 Sensitivity of receptor

294. Marine fish and shellfish species are known either to be sensitive to natural magnetic, electric, and electromagnetic fields or have the potential to detect them (Gill and Taylor, 2001; Gill et al., 2005; Hutchison et al., 2020). These species can be categorised into two groups based on their mode of magnetic field detection, which may be iE-field detection (electro-receptive) or direct B-field detection (magneto-receptive), noting that some species may use both (Anderson et al., 2017).

295. Electro-receptive species include elasmobranchs (sharks, skates and rays), holocephalans (e.g. ratfish) and agnathans (i.e. lampreys). These can detect the presence of a B-field either indirectly by detection of the iE-field induced by the movement of water through a B-field or directly by their own movement through that field. In natural scenarios, iE-fields usually result from organisms positioning themselves in tidal currents and animals may time activities such as foraging or migration by detecting diurnal cues resulting from varying tidal flows.

296. The detection mechanisms of magneto-receptive species are less well understood but are believed to use magnetite-based and photochemical systems (Nordmann et al., 2017). It is generally believed that they are able to detect magnetic cues such as the Earth's geomagnetic field to orientate during migration.

297. The sensitivity of the main receptors found in the study area for which there is evidence of a response to E or B-fields, together with an assessment of the potential impacts arising from the proposed worst-case cabling, is given separately for elasmobranchs, diadromous migratory species, other fish species and shellfish. Additional information on species-specific magnitude is also provided for context, where relevant. It is understood that the sensitivity and biological relevance of EMFs may vary throughout species' life history and electro-sensitivity may include detection of prey, predator avoidance, communication and reproductive behaviours (Hutchison et al., 2020). Magneto-sensitivity may support long or short-range migrations or movements including orientation, homing, and navigation (Gill et al., 2005; Normandeau et al., 2011).

Elasmobranchs

298. Elasmobranchs are the species group considered to be the most electro-sensitive. These species naturally detect bioelectric emissions from prey, conspecifics and potential predators and competitors through sensitivity to very weak voltage gradients (Gill et al., 2005). They are also known to detect magnetic fields. A number of laboratory and field experiments have been carried out with elasmobranchs using cables of the type used by the offshore renewable energy industry that indicated that EMF can be detected by electro-sensitive species such as rays and dogfish (Gill and Taylor., 2001; Gill et al., 2005; Gill et al., 2009; CMACS, 2003; COWRIE, 2009).

299. Both attraction and repulsion reactions to E-fields have been observed in elasmobranch species however, the responses were variable between both species and individuals and were not predictable and did not always occur. A study by Love et al., (2016) found no evidence to suggest that electro-sensitive species such as elasmobranchs were either attracted or repelled by the EMFs emitted from the energised power cables. An increase in distance travelled was observed in studies of thornback ray in response to an AC cable emitting EMF within the range of detectability of the skate, whereas lesser spotted dogfish were more likely to be found within the zone of EMF emissions (Gill et al., 2009). Research carried out by Hutchison et al. (2018) on the impact of HVDC cables on the little skate *Leucoraja erinacea* found evidence of behavioural responses in elasmobranchs in the proximity of the cables such as changes to their movement and distribution. These were interpreted as attraction responses, consistent with benthic elasmobranchs foraging behaviour. It was noted that the larger distances travelled and increased number of large turns observed, could represent an increased energetic expense.

300. Information gathered as part of the monitoring programmes at Burbo Bank offshore wind farm suggested that certain elasmobranch species feed inside the wind farm and demonstrated that they are not excluded during periods of low power generation (Cefas, 2009). Monitoring at Kentish Flats found an increase in thornback rays, smoothhounds and other elasmobranchs during post-construction surveys in comparison to pre-construction surveys. There appeared to be no discernible difference however, between the data for the wind farm and reference areas in terms of changes to population structure and it was concluded that the population increase observed was unlikely to be related to the operation of the wind farm (Cefas, 2009).

301. A study commissioned by the MMO (2014) evaluated the results of post environmental data associated with post-consent monitoring of licence conditions of offshore wind farms. The report concluded the following:

"*From the results of post-consent monitoring conducted to date, there is no evidence to suggest that EMFs pose a significant threat to elasmobranchs at the site or population level, and little uncertainty remains. Targeted research using high tech equipment and experimental precision has been unable to ascertain information beyond that of fish being able to detect EMFs and at what levels they become attracted or abhorrent to them. EMFs emitted from standard industry cables for offshore wind farms are unlikely to be repellent to elasmobranchs beyond a few metres from the cable if buried to sufficient depth. It is likely that the subtler effects of EMF, including attraction of elasmobranchs, inquisitiveness and feeding response to low level EMFs, may occur. The Burbo Bank offshore wind farm post-consent monitoring undertook EMF specific surveys including stomach analysis of common elasmobranch species. Fish caught at the cable site (and hence subject to EMFs) were well fed. No deleterious effects were recorded to fish populations, at least when this effect occurs in association with the probable increased feeding opportunities reported as a result of increased habitat heterogeneity*".

302. In light of the above it is considered that at worst, any EMF related effects are expected to result in temporary behavioural reactions rather than cause a barrier to migration or result in long term impacts upon feeding in elasmobranch

species. Taking the above into account and the likely presence of elasmobranch species both in the North Falls array areas and along the offshore cable corridor, this species group are considered to be receptors of medium sensitivity.

Lamprey

303. Lampreys, like elasmobranchs, possess electroreceptors that are sensitive to weak, low-frequency E-fields (Bodznick and Northcutt, 1981; Bodznick and Preston, 1983). Whilst responses to E-fields have been reported in these species, information on the use that they make of the electro-sensitivity is limited. It is likely however, that they use it in a similar way as elasmobranchs to detect prey, predators or conspecifics and potentially for orientation or navigation (Normadeau et al., 2011). There is also a concern that EMF has the potential to interfere with navigation during migration. Spawning of lampreys occurs in rivers, therefore, lampreys are only expected to be sporadically present in the vicinity of the Project during the marine migration phase, primarily in areas relevant to the offshore cable corridor, and their sensitivity to EMFs is considered to be low.

Salmon and sea trout

304. As magneto-sensitive species, there is a concern that EMF has the potential to interfere with the navigation of migrating salmon and sea trout however, any potential impacts on movement and behaviour in salmonids would be closely linked to the proximity of the fish to the EMF source. Gill and Bartlett (2010) suggest that any impact associated with EMFs on the migration of salmon and sea trout would be dependent on the depth of water and the proximity of home rivers to development sites. During the later stages of marine migration, salmon and sea trout rely on their olfactory system to find and identify their natal river. During these stages, they are likely to be migrating in the mid to upper layers of the water column, increasing their physical distance from the offshore cables.

305. The potential interaction of salmon and sea trout with the offshore project area would only be expected to occur on an occasional basis during marine migration/feeding in coastal areas (i.e. in inshore areas possibly in the proximity of the offshore cable corridor), as indicated in Section 11.5.5.1. Swedpower (2003) found no measurable impact when subjecting salmon and sea trout to B-fields twice the magnitude of the geomagnetic field. Similarly, in a study conducted by Marine Scotland Science (MSS; Armstrong et al., 2016) on the behaviour of captive Atlantic salmon, no evidence of unusual behaviour was found associated with B-fields up to 95µT. Furthermore, Atlantic salmon migration in and out of the Baltic Sea over a number of operational subsea HVDC cables has been observed to continue apparently unaffected by the EMFs produced by the cables (Walker, 2001). Research carried out in San Francisco Bay in respect of the impact of a HVDC cable on the migration of Chinook salmon *Oncorhynchus tshawytscha*, found the HVDC cable had a mixed but limited effect on the movements and migration success of smolts (Wyman et al., 2018). Similarly, a study by Bureau of Ocean Energy Management (BOEM) (2016) reported that energised cables do not appear to present a strong barrier to the natural seasonal movement patterns of migratory fish and while they may be attracted to the cable after activation, they do not appear to be impeded from successfully migrating through the Bay (BOEM, 2016).

306. Taking the above into account, Atlantic salmon and sea trout are considered receptors of low sensitivity.

European eel

307. European eel, similar to Atlantic salmon, can use magneto-sensitivity for orientation and direction-finding during migration (Gill and Bartlett, 2010). Experiments undertaken at the operational wind farm of Nysted detected potential barrier effects, however correlation analysis between catch data and data on power production showed no indication that the observed effects were attributable to EMFs. Furthermore, mark and recapture experiments showed that eels did cross the offshore export cable (Hvidt et al., 2005). Similarly, a study carried out by Marine Scotland Science (Orpwood et al., 2015) where European eels were exposed to an AC magnetic field of 9.6µT found no evidence of a difference in movement, nor observations of startle or other obvious behavioural changes.

308. As indicated in Section 11.5.5.1 the potential interaction of European eel with the offshore project area would only be expected to occur on an occasional basis during marine migration/feeding in coastal areas (i.e. in inshore areas possibly in the proximity of the offshore cable corridor). Any potential impacts on movement and behaviour would be closely linked to the proximity of the fish to the EMF source. While eels are likely to be distributed through the water column they are highly mobile (Righton et al., 2016), Taking the above into account, European eel is therefore considered a receptor of low sensitivity.

Other fish species in general

309. In addition to the fish species mentioned above, studies have also indicated responses to EMF in other fish species such as cod and plaice (Gill et al., 2005). Responses have been suggested to be behavioural, potentially in relation to feeding, predator or conspecific detection or navigation, however limited data are available to support this (Normandeu et al., 2011). A recent study on haddock larvae has identified that haddock larvae orientation at sea is guided by a magnetic compass mechanism (Cresci et al., 2019). A similar study on herring larvae found no evidence of magnetic compass orientation at that life stage (Cresci et al., 2020).

310. As suggested in the assessments of operational noise and introduction of hard substrate sections (Section 11.6.2.5 and 11.6.2.7), the results of monitoring programmes carried out in operational wind farms to date do not suggest that significant changes in the fish assemblage have occurred during the operational phase of offshore wind farms. It has been suggested that the localised reef/refuge attraction effect of fish to offshore wind farm foundations and scour protection indicates that EMFs from cabling do not seem to have an observable impact on the fish and shellfish (Leonhard and Pedersen, 2006; Lindeboom et al., 2011).

311. In line with this, research carried out at the Nysted offshore wind farm in Denmark that focused on detecting and assessing possible impacts of EMFs on fish during power transmission (Hvidt et al., 2005) found no differences in the fish community composition after the wind farm became operational. A study of the effect of EMFs from subsea cables on marine organisms found no evidence that there were significant differences in fish communities between energised

and unenergised cables (Love et al., 2016). In light of the above the sensitivity of other fish species in general to EMF is assessed as low.

Shellfish

312. While research on the ability of marine invertebrates to detect EMF has been limited, in recent years, research effort has been focused on reducing the knowledge gaps on the impact of EMF on invertebrates. Although there is no direct evidence of effects to invertebrates from undersea cable EMFs (Normandeau et al., 2011), the ability to detect magnetic fields has been studied for some species and there is evidence in some of a response to B-fields, including molluscs and crustaceans. Crustacea, including lobster and crabs, have been shown to demonstrate a response to B-fields. The Caribbean spiny lobster *Palinurus argus* and the American lobster *Homarus americanus* both use magneto-sensitivity in navigation (Boles and Lohmann, 2003; Hutchison et al., 2020). It is uncertain, however, if other crustaceans including commercially important brown crab and European lobster are able to respond to B-fields in this way. Limited research undertaken with the European lobster found no neurological response to B-field strengths considerably higher than those expected directly over an average buried power cable (Normandeau et al, 2011; Ueno et al., 1986).

313. Hutchison et al. (2018; 2020) studied the potential impact of a HVDC cable on American lobster *Homarus americanus* and reported subtle changes in behavioural activity when they were exposed to the cable's EMFs. The results however indicate that the cable did not represent a barrier to migration. Taormina et al. (2020) found no statistically significant effect on the exploratory and sheltering behaviours of juvenile lobsters when exposed to B-fields of up to 200µT.

314. In a laboratory study using comparatively high B-fields (2.8mT and 40mT, compared to nT- or µT-level EMFs measured in the field) Scott et al. (2018) identified a clear attraction to EMF exposed shelters (B-fields of 2.8mT) and a decrease in roaming behaviour. In addition, the daily behavioural and physiological rhythmic processes of the haemolymph L-Lactate and D-Glucose levels were disrupted. The EMF did not however appear to affect stress related parameters (i.e. hemocyanin concentrations, respiration rate, activity level or the antennular flicking rate). In a subsequent study, Scott et al. (2021) investigated the effects of exposure to different EMF strengths (250µT, 500µT, 1000µT) on edible crabs and found limited impacts at exposure to 250µT. Exposure to 500 and 1000µT was found to disrupt the L-Lactate and D-Glucose circadian rhythm and alter total haemocyte count, with crabs showing clear attraction to EMF exposed shelters and a significant reduction in time spent roaming.

315. A study undertaken by Love et al. (2017) on the potential for energised cables off southern California to impact commercially important crab species in the area found no evidence that the EMF influenced the catchability of these two species.

316. From a benthic community perspective, Love et al. (2016) found no evidence that there were significant differences in invertebrate assemblages between energised and unenergised cables in the Pacific region. Indirect evidence from post construction monitoring programmes undertaken in operational wind farms

also does not suggest that shellfish species have been affected by the presence of submarine power cables.

317. In light of the above, and noting that the updated State of the Science report summarised that research concerning invertebrates since 2016 generally supports previous studies that demonstrated no or minor effects of encounters with EMFs (Gill and Desender, 2020), the sensitivity of shellfish species to EMFs is considered to be low.

11.6.2.6.3 Significance of effect

318. EMF from inter-array, interconnector and export cables will represent a long term and continuous impact throughout the lifetime of the Project. However, any effects will be highly localised i.e. within metres of the cables, therefore will only affect a relatively small proportion of the fish and shellfish habitats in the study area and the wider southern North Sea.

319. Overall, the sensitivity of fish and shellfish receptors (excluding elasmobranchs) is low and the magnitude of the impact is deemed to be low. The effect will, therefore, be of negligible significance.

320. Taking the low magnitude of the impact assessed for the Project and the sensitivity of elasmobranchs as medium, the impact is considered to be of minor significance.

11.6.2.7 Impact 14: Introduction of hard substrate

11.6.2.7.1 Magnitude of impact

321. The introduction of subsurface infrastructure associated with the Project has the potential to alter the structure of benthic habitats and associated faunal assemblages. All Project infrastructure that has a subsea surface element would represent a potential substrate for colonisation by marine fauna and flora, including non-native species (see Chapter 10 Benthic and Intertidal Ecology, Volume I). Hard substrates introduced would include turbines, foundations and associated scour protection as well as any cable protection. The area of introduced substrate would be proportional to the permanent loss of area estimated for the Project (see Section 11.6.2.2).

322. The southern North Sea is considered an open, sandy marine environment and the seabed across the offshore project area is characterised predominantly by coarse sand in the north array site and medium sand in the south array and offshore export cable corridor (Chapter 8 Marine Geology, Oceanography and Physical Processes, Volume I). The introduction of hard substrate would increase habitat heterogeneity through the installation of hard structures in an area predominantly characterised by soft substrate habitat. As described in Section 10.6.2.7 of Chapter 10 Benthic Ecology (Volume I), as this represents a potential change from the existing environmental baseline it is not considered to be beneficial.

323. The hard substrate associated with the installation of the Project would occupy discrete areas only (i.e. around foundations) and would not be continuous along large lengths of offshore cables. Taking this into account and the relatively small overall area occupied by the infrastructure, the magnitude of the impact is considered to be low in respect of the array areas (where the majority of hard substrate will be introduced). In the case of the offshore cable corridor, given the small areas where cable protection is anticipated to be used the magnitude

of the impact is considered negligible, with the magnitude within the offshore project area as a whole assessed as low.

11.6.2.7.2 Sensitivity of receptor

324. The potential for marine subsea structures to attract and concentrate fish is well documented (Bohnsack, 1989; Bohnsack and Sutherland, 1985; Jørgensen et al., 2002; Sayer et al., 2005). Through the colonisation of marine fauna on introduced hard substrate, the expected increase in diversity and productivity of seabed communities may have an impact on fish assemblages, resulting in either attraction, increased productivity or changes in species composition (Hoffman et al., 2000).

325. A study by Stenberg et al. (2015) on the effects of the Horns Rev 1 offshore wind farm on fish abundance, diversity and spatial distribution seven years post-construction found overall fish abundance increased slightly inside the offshore wind farm and declined in the control area. However, none of the key fish species or functional fish groups showed signs of negative long-term effects due to the presence of the wind farm. Overall, results indicated that some fish species benefited from the more diverse and complex habitat. It was also found, however, that the impacted area was not large enough to have adverse negative effects on species inhabiting the original sand bottom between turbines (i.e. dab and sandeels). A study by van Hal et al. (2017) on a Dutch offshore wind farm five years post-construction suggested that weather conditions and seasonality had more effect on fish aggregation levels than the wind farm structures and that abundance of pelagic fish species such as horse mackerel, herring and sprat were unaffected by the presence of scour protection.

326. Similarly, a review of the short-term ecological effects of the offshore wind farm Egmond aan Zee in the Netherlands, based on post-construction monitoring after two years (Lindeboom et al., 2011) found minor effects upon fish assemblages, especially near the monopiles, where there was evidence of increased abundances of small demersal fish species (e.g. gobies and goldsinny wrasse). A similar study conducted at Bligh Bank wind farm found that there was a decrease in overall demersal fish densities within the wind farm compared to control sites, however, for a number of commercially important species (turbot, sole and plaice), higher densities/increases in length distribution were observed (Vandendriessche et al., 2012). It was not possible to determine whether this was attributable to a refuge effect (commercial fishing is excluded from Belgian wind farms), changes in epibenthic fauna (e.g. prey), substrate composition, or any combination of these variables.

327. Monitoring studies carried out at the Lillgrund wind farm in Sweden on the abundance and distribution patterns of benthic fish communities found no large-scale effects on fish diversity and abundance post-construction (Bergström et al., 2013). Changes at smaller spatial scales were noted, particularly an increase in piscivores (cod, eel, shorthorn sculpin), as well as the reef-associated goldsinny wrasse, which were all observed close to the foundations in the first year of operation. Any changes in populations observed over time, however, were considered to be driven by wider environmental factors. Similarly, the results of pre-construction and post-construction monitoring surveys in North Hoyle and Barrow offshore wind farms in the UK suggest the abundance of commercial fish species has remained broadly comparable and

in line with long term trends in the regional area (Walker et al., 2009). A review by Glarou et al. (2020) found that that artificial structures often increase the abundance of hard-bottom species as well as fish diversity in the local area. It was suggested that while the loss of soft-bottom substrate may result in negative effects on soft-bottom species at the local scale, any effects should be evaluated at larger spatial scales and related to the fish species populations and life history.

328. Crustaceans would be expected to exhibit the greatest affinity to hard substrate installed for scour protection material, foundation bases and cable protection through the expansion of their natural habitats (Linley et al., 2007). There may be therefore potential for increases of benthic species including crabs and lobsters as a result of colonisation of subsurface structures by subtidal sessile species on which they feed (Linley et al., 2007). Post construction monitoring surveys at the Horns Rev 1 offshore wind farm noted that the hard substrates were used as a hatchery or nursery ground for several species, and was particularly successful for edible crab. They concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult, 2006).

329. In the context of the wider community where the same habitats and species are known to be present, the sensitivity of fish and shellfish in general receptors is therefore considered to be low.

11.6.2.7.3 Significance of effect

330. As suggested by the results of the post-construction monitoring surveys cited above, any changes in the community structure and abundance of fish and shellfish species within the offshore project area would be expected to be small and for the most limited to the immediate vicinity of the hard substrate introduced. Fish populations are unlikely to show noticeable benefits as a result of this impact, though there is evidence that shellfish populations (particularly brown crab and lobster) would benefit from the introduction of hard substrates. Taking the low magnitude of the impact assessed for the Project and the low sensitivity of the receptors, the impact is considered to be of negligible significance.

11.6.2.8 Impact 15: Changes in fishing activity

11.6.2.8.1 Magnitude of impact

331. The presence of infrastructure associated with the Project during the operation phase could result in changes to fishing activity within the offshore project area but also in the wider area (i.e. due to displacement of fishing activity into other areas). The intensity of fishing activities (including trawling and potting) may be reduced as a result of the physical presence of the infrastructure. This has the potential to enhance fish and shellfish populations by providing refuge from commercial fishing activities (Byrne Ó Cléirigh, 2000; Roach et al., 2018).

332. The maximum design scenario for reduced fishing activity in the offshore project area assumes no restrictions to fishing within the array areas (except for advisory safety zones around the turbines) or the offshore cable corridor during the design life (see Table 11.2). It is assumed, however, that trawling activity may potentially be reduced within the array areas for logistical and safety reasons. Given the multiple factors that can influence the spatial and temporal intensity of commercial fishing (e.g. legislation, quota, weather, natural variation

of target species, climate change, individual fishers choice) the extent to which this additional reduction will take place is not possible to quantify.

333. As described in Section 11.5.2, the species of commercial importance in the study area include sole, whelk, bass, thornback ray, horse mackerel, herring, cod, plaice, lobster and crab. These species are targeted across the southern North Sea, with the offshore project area accounting for a small area in the context of the overall fishing grounds for these species (see Chapter 14 Commercial Fisheries, Volume I), therefore it would not be expected that any changes in fishing activities in this area would lead to changes in populations of these species in the fish and shellfish study area. Whilst the long-term nature of the operational phase is recognised, considering the above the magnitude of the impact is assessed as low.

11.6.2.8.2 Sensitivity of receptor

334. As outlined in Section 11.6.1.7, fishing activity for commercially targeted species is primarily regulated through the setting of annual TACs and limitation in fishing effort, therefore it is anticipated that the level of fishing mortality for these species would be largely unaffected by changes in activity associated with the Project. The fish species of commercial importance include sole, bass, thornback ray, horse mackerel, herring, cod and plaice. Given that these are typically highly mobile any reduction in fishing activity would be most beneficial to demersal fish species and shellfish, although non-target fish caught as by-catch are also likely to benefit due to a reduction in fishing mortality.

335. Shellfish species such as whelk, lobster and crab are also targeted in the study area, which would likely benefit most from a reduction in fishing effort. Roach et al. (2018) found that temporary restrictions of fishing areas led to an increase in lobster abundance and size. It is suggested that temporary restrictions of fishing activity can enable uninterrupted contribution to the spawning stocks through protection of habitats that became a refuge for young and spawning fish (Byrne Ó Cléirigh et al., 2000). A potential reduction in demersal trawling within the array areas may also benefit shellfish communities whose benthic habitats have been subjected to ongoing physical disturbance from fishing gear (Byrne Ó Cléirigh et al., 2000; Hiddink et al., 2019).

336. Furthermore, as described in Chapter 14 Commercial Fisheries (Volume I), significant impacts (i.e. exceeding minor significance) in respect of loss of fishing grounds and associated potential for displacement have not been identified for any of the fleets active in the offshore project area. Therefore, the sensitivity of fish and shellfish receptors in respect of potential changes in fishing activity as a result of the Project is considered to be low.

11.6.2.8.3 Significance of effect

337. Taking the low receptor sensitivity and low magnitude of the impact the resulting impact arising from changes in fishing activity is considered of negligible significance.

11.6.3 Potential impacts during decommissioning

338. The final decommissioning policy is yet to be decided as it is recognised that rules and legislation change over time in line with best industry practice. The decommissioning methodology and programme would need to be finalised

nearer to the end of the lifetime of the Project to ensure it is in line with the most recent guidance, policy and legislation.

339. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in Chapter 5 Project Description (Volume I) and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all of the wind turbine components and part of the foundations (those above seabed level), and removal of some or all of the array and export cables. Scour and cable protection would likely be left in situ.

340. During the decommissioning phase, there is potential for wind turbine foundation and cable removal activities to cause effects that would be comparable to those identified for the construction phase and the operational phase, specifically:

- Impact 16: Temporary habitat loss / physical disturbance;
- Impact 17: Re-mobilisation of contaminated sediments;
- Impact 18: Underwater noise and vibration; and
- Impact 19: Changes in fishing activity.

341. Permanent habitat loss as a result of infrastructure decommissioned in situ is assessed as for the operational impact because the impact begins when the operation phase starts when the wind farm infrastructure is in place.

342. The magnitude of decommissioning effects will be comparable to or less than the construction phase. Accordingly, given that comparable impacts were assessed to be of negligible or minor significance for the identified fish and shellfish ecology receptors during the construction phase, it is anticipated that the same would be true for the decommissioning phase.

11.7 Cumulative effects

11.7.1 Identification of potential cumulative effects

343. The first step in CEA process is the identification of which residual effects assessed for the Project on their own have the potential for a cumulative effect with other plans, projects and activities. This information is set out in Table 11.43 below. The development activities taken forward for cumulative assessment have been selected on the basis of availability and quality of information and the probability of a cumulative effect occurring, including, where relevant, spatial overlap.

Table 11.43 Potential cumulative impacts

Impact	Potential for cumulative effect	Rationale
Construction		
Impact 1: Physical disturbance and temporary habitat loss;	Yes	Effects will occur at isolated locations for a time-limited duration and are local in nature. Given the presence of nearby offshore wind farms, however, cumulative effects must be assessed.

Impact	Potential for cumulative effect	Rationale
Impact 2: Increased SSCs and sediment re-deposition;	Yes	Increases in SSC are expected to be localised at the point of discharge and short-term. The small quantities of fine sediment may be transported further; however, it will be widely and rapidly dispersed and not increase the volume of sediment already present in the benthos. The elevation of SSC is expected to be lower than concentrations that would develop in the water column during storm conditions. However, due to nearby offshore wind farms, cumulative effects must be assessed.
Impact 3: Re-mobilisation of contaminated sediments	No	The level of contaminated sediment found in the offshore site investigation are not of significant concern and present a negligible magnitude for effect on the fish and shellfish receptors.
Impact 4: Underwater noise from piling for foundation installation	Yes	There is potential for interactive effects from underwater noise associated with offshore wind farm activities.
Impact 5: Underwater noise from other construction activities	Yes	
Impact 6: Underwater noise from UXO clearance	Yes	
Impact 7: Changes in fishing activity	No	The sensitivity of fish and shellfish receptors to changes in fishing activity is considered to be negligible. It is anticipated that the level of commercial fishing would be largely unaffected by changes in activity associated with the Project, as fishing will continue until TACs or set limitations in effort are reached.
Operation & Maintenance		
Impact 8: Temporary habitat loss/ physical disturbance	Yes	Effects will occur at isolated locations for a time-limited duration and are local in nature with a negligible impact magnitude. Given the presence of nearby offshore wind farms, however, cumulative effects must be assessed.
Impact 9: Long term habitat loss	Yes	Additive habitat loss across the region. Other developments in the region have the potential to have cumulative habitat loss impacts.
Impact 10: Increased suspended sediment concentrations and re-deposition	Yes	Effects will occur at isolated locations for a time-limited duration and are local in nature with a negligible impact magnitude. However, due to nearby offshore wind farms, cumulative effects must be assessed.
Impact 11: Re-mobilisation of contaminated sediments	No	The level of contaminated sediment found in the offshore site investigation are not of significant concern and present a negligible magnitude for effect on the benthic environment.
Impact 12: Underwater noise and vibration	Yes	There is potential for interactive effects from underwater noise associated with offshore wind farm activities.
Impact 13: Electromagnetic Fields (EMFs)	Yes	EMF will be highly localised around the offshore cable corridor and interconnector cables. However, due to nearby offshore wind farms, cumulative effects must be assessed.
Impact 14: Introduction of hard substrate	Yes	The introduction of subsurface infrastructure associated with the Project has the potential to alter the structure of benthic habitats and associated faunal assemblages. It is anticipated that any changes in the community structure and abundance of fish and

Impact	Potential for cumulative effect	Rationale
		shellfish species within the Project would be expected to be limited to the immediate vicinity of the hard substrate introduced.
Impact 15: Changes in fishing activity	No	The sensitivity of fish and shellfish receptors to changes in fishing activity is considered to be negligible. It is anticipated that the level of commercial fishing would be largely unaffected by changes in activity associated with the Project, as fishing will continue until TACs or set limitations in effort are reached.
Decommissioning		
Impact 16: Temporary habitat loss / physical disturbance	Yes	Effects will occur at isolated locations for a time-limited duration. Given the presence of nearby offshore wind farms, however, cumulative effects must be assessed.
Impact 17: Re-mobilisation of contaminated sediments	No	The level of contaminated sediment found in the offshore site investigation are not of significant concern and present a negligible magnitude for effect on the benthic environment.
Impact 18: Underwater noise and vibration	Yes	There is potential for interactive effects from underwater noise associated with offshore wind farm decommissioning activities and projects within a representative 100km buffer of the North Falls array areas are considered.
Impact 19: Changes in fishing activity	No	The sensitivity of fish and shellfish receptors to changes in fishing activity is considered to be negligible. It is anticipated that the level of commercial fishing would be largely unaffected by changes in activity associated with the Project, as fishing will continue until TACs or set limitations in effort are reached.

11.7.2 Other plans, projects and activities

344. The second step in the cumulative assessment is the identification of the other plans, projects and activities that may result in cumulative effects for inclusion in the CEA (described as 'project screening'). This information is set out in Table 11.44 below, together with a consideration of the relevant details of each, including current status (e.g. under construction), planned construction period, closest distance to the offshore project area, status of available data and rationale for including or excluding from the assessment.

345. The Project screening has been informed by the development of a CEA Project List which forms an exhaustive list of plans, projects and activities in a very large study area relevant to North Falls. The list has been appraised, based on the confidence in being able to undertake an assessment from the information and data available, enabling individual plans, projects and activities to be screened in or out.

346. Other projects/activities have been considered within a 50km buffer area from the Project to enable the assessment of activities within relevant fish and shellfish habitats (including spawning and nursery grounds) that are representative of those relevant to North Falls. Given that the habitats recorded in the offshore project area are characteristic of the wider southern North Sea region the impacts and receptors affected by projects within this buffer are likely to be similar to those for North Falls. For the impact of underwater noise, a larger area of search was used (100km), given the predicted greater area of effect

noise is predicted to have. The distances from the offshore project area to other projects and activities are summarised in Table 11.44.

Table 11.44 Summary of projects considered for the CEA in relation to fish and shellfish receptors (project screening)

Project	Status	Construction period	Closest distance from the array areas (km)	Distance from the offshore cable corridor (km)	Confidence in data	Included in the CEA (Y/N)	Rationale
Offshore wind farms							
Greater Gabbard offshore wind farm	Operational since 2012	N/A	0 km	5.6 km	High	Yes	Both GGOW and GWF are operational therefore there is potential cumulative effect on fish and shellfish receptors from ongoing maintenance activities.
Galloper OWF offshore wind farm	Operational since 2018	N/A	0 km	8.5 km	High	Yes	
Five Estuaries offshore wind farm	In Planning	Unknown	0 km (0.04m)	14.8 km	High	Yes	Potential for cumulative effect during construction and operational phases. Fish and shellfish receptors could be affected if construction of North Falls occurs at a similar time to Five Estuaries OWF due to the close proximity of the Project.
East Anglia TWO offshore wind farm	Consent granted	Construction planned mid 2020s	14.8 km	37.2 km	High	Yes	Potential for cumulative effect during operational phase.
Thanet offshore wind farm	Operational since 2010	N/A	24.4 km	36.2 km	High	No	Any ongoing effects of maintenance activity from these offshore wind farms will be highly localised and therefore, given the distance from the North Falls offshore project area, there is no pathway for significant cumulative effects. This approach is in keeping with the GWF EIA, where it was agreed with Cefas and Defra that no assessment of cumulative effects was required with other Round 2 sites in the Thames strategic area (except GGOW). Given the proximity and similarity between GWF and North Falls, they have not been considered in this assessment (ABPmer, 2010).
London Array offshore wind farm	Operational since 2013	N/A	19.4 km	15.5 km	High	No	
Gunfleet Sands offshore wind farm	Operational since 2010	N/A	43.3 km	10.3 km	High	No	

Project	Status	Construction period	Closest distance from the array areas (km)	Distance from the offshore cable corridor (km)	Confidence in data	Included in the CEA (Y/N)	Rationale
East Anglia ONE	Operational since 2020	N/A	38.29 km	59.61 km	High	No	Sited in 15km- 50km radius
East Anglia ONE North	Consent Authorised	2023-2026	46.96 km	69.73 km	High	Yes	Sited in 15km- 50km radius Potential for cumulative effect during operational phase.
Princess Elisabeth - Noordhinder Noord (Belgian)	In Planning	Unknown	34 km	48.7 km	Medium	No	Sited in 15km- 50km radius
Princess Elisabeth - Nordhinder Zuid (Belgian)	In Planning	Unknown	33.8 km	48 km	Medium	No	Sited in 15km- 50km radius
Seamade (Mermaid)	Operational since 2020	N/A	46.1 km	60.8 km	High	No	Sited in 15km- 50km radius
Northwester 2	Operational since 2020	N/A	47.4 km	62.2 km	High	No	Sited in 15km- 50km radius
Kentish Flats + extension	Operational since 2005	N/A	54.01 km	37.66 km	High	No	Sited in 50km- 100km radius
Norfolk Vanguard	Consent authorised	2025-2027	95.76 km	117.16 km	High	No	Sited in 50km- 100km radius and no overlap with piling activities.
East Anglia THREE	Consent authorised	2023-2026	81.75 km	104.67 km	High	No	Sited in 50km- 100km radius and no overlap with piling activities.
BELWIND	Operational since 2010	N/A	51.8 km	66.7 km	High	No	Sited in 50km- 100km radius

Project	Status	Construction period	Closest distance from the array areas (km)	Distance from the offshore cable corridor (km)	Confidence in data	Included in the CEA (Y/N)	Rationale
Nobelwind	Operational since 2017	N/A	53.4 km	68.3 km	High	No	Sited in 50km- 100km radius
Seamade (Seastar)	Operational since 2020	N/A	55.2 km	70.1 km	High	No	Sited in 50km- 100km radius
North Wind	Operational since 2014	N/A	58.4 km	73.4 km	High	No	Sited in 50km- 100km radius
Rentel	Operational since 2018	N/A	60.9 km	75.9 km	High	No	Sited in 50km- 100km radius
Thornton Bank 1-3	Operational since 2009-2013	N/A	62.1 km	77 km	High	No	Sited in 50km- 100km radius
Norther	Operational since 2019	N/A	66.9 km	81.8 km	High	No	Sited in 50km- 100km radius
Borselle 1-5	Operational since 2020-2021	N/A	50.4 km	65 km	High	No	Sited in 50km- 100km radius
Subsea cables and pipelines							
NeuConnect Interconnector	Pre-construction	2022-2028	0 km	0 km	High	Yes, subject to available information	The NeuConnect Interconnector bisects the North Falls export cable corridor and interconnector cable corridor and there is potential for temporal overlap of cable installation activities.
BritNed Interconnector	Operational since 2009	N/A	0 km	10.86 km	High	No	The BritNed Interconnector passes through the south of the south array but has been operational since 2009. There is therefore no potential for cumulative impact on the identified receptors.

Project	Status	Construction period	Closest distance from the array areas (km)	Distance from the offshore cable corridor (km)	Confidence in data	Included in the CEA (Y/N)	Rationale
Nautilus Interconnector	Pre-application	2025-2028	Cable route unknown	Cable route unknown	Low	Yes (Subject to available information)	The offshore study area for Nautilus intersects with the North Falls offshore project area, Therefore, there is potential for cumulative effects, subject to the final location and programme for the interconnector.
Sea Link	Pre-application	2026-2030	Cable route unknown	Cable route unknown	Low	Yes (Subject to available information)	The emerging preferred and alternative routes for Sea Link intersect with the North Falls offshore cable corridor. Therefore, there is potential for cumulative effects, subject to the final location and programme for the interconnector.
Tarchon Energy Interconnector	Pre-application	N/A	Cable route unknown	Cable route unknown	Low	Yes (Subject to available information)	Interconnector between UK and Germany
Aggregate areas							
Outer OTE aggregate exploration and option area 528/2	Unknown	N/A	8.4 km	14 km	Low	Yes, subject to available information	There is potential for some interaction between dredging and aggregate exploration on fish and shellfish ecology. Removal of sediment and sediment plumes have the potential to have a cumulative effect. The annual report produced by the Crown Estate for aggregate dredging within the Thames estuary region states that only approximately 6% of the total licensed aggregate extraction areas was dredged at any one time. Furthermore, the area dredged with high intensity was 0.62km^2 however, 90% of regional dredging effort took place within 1.77km^2. (Crown Estate 2021). Sited within 15km radius
East Orford Ness aggregate exploration and option area 1809	Unknown	N/A	2 km	24.8 km	Low	Yes, subject to available information	
Thames D aggregates production agreement area 524	Production agreement secured 2022	2022-2036	0	12.5	Low	Yes, subject to available information	

Project	Status	Construction period	Closest distance from the array areas (km)	Distance from the offshore cable corridor (km)	Confidence in data	Included in the CEA (Y/N)	Rationale
Thames D aggregates production agreement area 524	Production agreement secured 2022	2022-2036	0 km	12.5 km	Medium	No	Sites which were operational at the time of the North Falls characterisation surveys are a component of the baseline environment.
Southwold East aggregates production agreement area 430	Operational since 2012	N/A	27.3 km	48.4 km	Medium	No	
North Inner Gabbard aggregate production area 498	Operational since 2015	N/A	1.7 km	24 km	Medium	No	
Shipwash aggregate exploration and option area 507	Operational since 2016	N/A	0.2 km	9.8 km	Medium	No	
Longsand aggregate exploration and option area 508	Operational since 2014	N/A	11.7 km	5.8 km	Medium	No	
Longsand aggregate exploration and option area 509	Operational since 2015	N/A	11.7 km	2.1 km	Medium	No	

Project	Status	Construction period	Closest distance from the array areas (km)	Distance from the offshore cable corridor (km)	Confidence in data	Included in the CEA (Y/N)	Rationale
Longsand aggregate exploration and option area 510	Operational since 2015	N/A	7.3 km	3.5 km	Medium	No	
North Falls East aggregate exploration and option area 501	Operational since 2017	N/A	13.2 km	27.5 km	Medium	No	

11.7.3 Assessment of cumulative impacts

11.7.3.1 Cumulative impact 1: Physical disturbance and temporary habitat loss during construction

347. There is the potential for cumulative physical disturbance and temporary habitat loss as a result of construction activities associated with North Falls and activities at other offshore wind farm projects, aggregate extraction sites and interconnector cables. Temporary physical disturbance to the seabed will result in an increase in suspended sediments and temporary habitat loss.

348. North Falls is being built as an extension of GGOW and, therefore there is potential for construction works to be conducted at the same time, or similar time, to maintenance works at GGOW and/or the neighbouring GWF. The construction programmes of East Anglia TWO OWF and East Anglia ONE North OWF also indicate that they will also be operational when North Falls is being constructed.

349. The construction programme of North Falls (2028-2030) may overlap with the construction programme of Five Estuaries OWF (2028-2030).

350. The NeuConnect Interconnector cable bisects the North Falls offshore cable corridor and there is potential for temporal overlap of cable installation activities. It is unlikely however, for health and safety and navigational safety reasons, that cable installation works for North Falls and the NeuConnect interconnector would occur in the same place at the same time.

351. There may also be temporal overlap from marine aggregate extraction sites in adjacent areas. It is noted however that only approximately 6% of the total licensed aggregate extraction areas in the Thames estuary region were dredged at any one time in 2021 (Crown Estate, 2021).

352. As assessed for North Falls, activities from other OWFs, interconnector cable installation and aggregate extraction sites would occur at localised, discrete locations (i.e. limited to the immediate vicinity of works) and would be temporary and short term. As such, the magnitude of the impact of cumulative physical disturbance/temporary habitat loss is considered to be low.

353. The sensitivity of the fish and shellfish receptors is detailed in Section 11.6.1.1. Most of the fish species included for assessment are highly mobile with wide distribution ranges. The sediment and associated benthic community around the North Falls offshore project area is also characteristic of highly disturbed environments that are expected to quickly recover from disturbance. The sensitivity of fish and shellfish species in general is therefore considered to be low. In the case of species which depend on specific substrates and species or life stages of reduced mobility, considering the potential increased area of their habitat affected and their reduced ability to relocate to other areas, the sensitivity is considered to be medium.

354. Potential cumulative effects from physical disturbance and temporary habitat loss is therefore assessed to be of minor significance.

11.7.3.2 Cumulative impact 2: Increased SSCs and sediment re-deposition during construction

355. There may be potential for increased SSCs and sediment re-deposition associated with other projects to cumulatively add to the impact identified for North Falls, provided construction/works schedules coincide. The North Falls construction programme may overlap with maintenance works at the operational GGOW and GWF, the construction programmes of the NeuConnect Interconnector and Five Estuaries OWF, and aggregate extraction activities (Table 11.44).

356. As detailed for cumulative effect 1 (paragraph 350), while there is potential for temporal overlap it is unlikely that offshore export cable installation works for North Falls and the NeuConnect interconnector would occur in the same place at the same time. It is also considered that plumes from adjacent wind farms (e.g. Five Estuaries OWF) would be unlikely to overlap due to the short-term and highly localised nature of plumes arising from construction works. As discussed in Chapter 8 Marine Geology, Oceanography and Physical Processes (Volume I), overall changes from increased suspended sediments and deposition of fine sands and mud-sized sediment will not be measurable due to prevailing hydrodynamic conditions with high wave activity agitating the seabed regularly.

357. To assess the potential for cumulative effects from North Falls and marine aggregate extraction activities in adjacent areas, Chapter 9 Marine Water and Sediment Quality (Volume I) references the GWF EIA and supporting technical appendix by ABPmer (2011). The CEA for GWF determined that based on previous modelling investigations undertaken for dredging areas, no cumulative impact was predicted.

358. Taking the above into consideration the cumulative impact is assessed to be of negligible magnitude.

359. Adult and juvenile fish in general, being mobile, would be expected to redistribute to undisturbed areas within their range and are therefore considered receptors of low sensitivity. In the case of species and life stages of relatively low mobility and those highly dependent on the presence of specific substrates, considering the potential increased area of their habitat affected and their more reduced ability to relocate to other areas, their sensitivity is considered to be medium. The cumulative impact of increased SSCs and sediment re-deposition is therefore predicted to be of minor significance during construction.

11.7.3.3 Cumulative impact 3: Underwater noise from piling for foundation installation during construction

360. There is potential for noise generated during piling activity in the North Falls array areas and other wind farm projects to result in cumulative impacts on fish species. This would be a result of either increased spatial or temporal effects resulting from concurrent or sequential piling at different OWFs, or a combination of both. The construction programme of North Falls (2028-2030) may overlap with the construction programme of Five Estuaries OWF (2028-2030).

361. Active piling will only occur over a small percentage of the overall construction period of OWF projects and it is unlikely that piling will occur concurrently at

multiple OWF projects, therefore the potential for the Project to significantly contribute to a cumulative impact would be limited. Taking account of the increased spatial (if construction occurs concurrently) or temporal (if construction occurs sequentially) effects associated with piling at Five Estuaries OWF in addition to North Falls, but recognising the intermittent and short term nature of piling, the magnitude of the potential impact is considered to be low.

362. Of particular concern in this regard is the potential for behavioural impacts to occur on species which use the area for spawning, however consideration has also been given to other fish species. Species with spawning grounds in the study area include:

- Dover sole;
- Plaice;
- Lemon sole;
- Mackerel;
- Sandeels;
- Seabass;
- Cod;
- Whiting;
- Sprat; and
- Herring.

363. The sensitivity of the relevant fish species has been assessed in Section 11.6.1.4.5. In general, fish and shellfish species present in the study area have very wide distribution ranges (including spawning and nursery grounds) in the context of the small areas potentially affected by construction noise and are considered receptors of low sensitivity.

364. Dover sole, taking account of its more restricted overall distribution range and the smaller extent of their spawning and nursery grounds in a North Sea context, are considered receptors of medium sensitivity.

365. Whilst the level of overlap between sandeel habitat and areas potentially affected by underwater noise would be expected to be small, considering the seabed habitat specificity and burial behaviour of sandeels they are considered receptors of medium sensitivity.

366. For Downs herring the receptor sensitivity is considered to be high, given the potential level of overlap of their spawning grounds with areas affected by TTS and behavioural responses, and taking account of herring's dependence on specific substrates for spawning. In the case of the Blackwater herring, however, there would be no overlap with spawning grounds therefore in light of the decreased magnitude the receptor sensitivity is assessed as medium.

367. In view of the above, the cumulative impact of construction noise from piling on fish species is considered to be of minor to moderate significance

11.7.3.4 Cumulative impact 4: Underwater noise from other construction activities during construction

368. In addition to piling noise, there may be other activities associated with construction works at other projects that could result in potential disturbance to fish and shellfish receptors (i.e. vessel transit, cable installation, rock placement, dredging). The indicative construction programme of North Falls (2028-2030) may overlap with the construction programme of Five Estuaries OWF (2028-2030) and the NeuConnect Interconnector bisects the North Falls offshore cable corridor and there is potential for temporal overlap of cable installation activities for the NeuConnect Interconnector.

369. As described in Section 11.6.1.5 for the Project alone, potential impacts on fish and shellfish associated with this would occur over very small areas (i.e. in the immediate proximity of construction works/ construction vessels).

370. Whilst the potential for additive disturbance to occur as a result of construction activities in other OWFs, either temporally (where construction is sequential) or spatially (where construction occurs concurrently) is recognised, given the small and localised areas affected, the magnitude of the cumulative impact is considered to be low.

371. Taking account of the comparatively wide distribution ranges of fish and shellfish species in the context of the small areas potentially affected (including the extent of the spawning and nursery grounds of relevant species), the sensitivity of fish and shellfish receptors is considered to be low. This results in an impact of minor significance.

11.7.3.5 Cumulative impact 5: Underwater noise from UXO clearance during construction

372. As described for assessment of noise from UXO removal for the Project alone (Section 11.6.1.6), the detonation of UXO associated with other offshore wind farm developments, would also result in injury and disturbance to fish species in the vicinity of the detonation. Physical injury / trauma would occur in close proximity to the detonation with TTS and behavioural effects occurring at greater distances.

373. Whilst it is recognised that the number of UXO detonations required will increase considering the other projects included for cumulative assessment, UXO clearance will still be an activity that is localised, short term and intermittent in nature (only occurring where UXO cannot be removed by other means). It is therefore considered that for the most part any effects on fish and shellfish receptors would be limited to the vicinity of the area where the detonation takes place and the magnitude of the impact is considered to be low.

374. Taking account of the severity of the impact particularly at close range, but acknowledging that impacts would occur at individual rather than at population level, fish species are considered receptors of medium sensitivity. This, in combination with the low magnitude of the impact results in an impact of minor significance.

11.7.3.6 Cumulative impact 6: Temporary habitat loss/ physical disturbance during operation

375. There is the potential for cumulative physical disturbance and temporary habitat loss as a result of maintenance activities associated with North Falls and

activities at other offshore wind farm projects, aggregate extraction sites and interconnector cables. Temporary physical disturbance to the seabed will result in an increase in suspended sediments and temporary habitat loss.

376. There is potential for maintenance works to be conducted at the same time, or similar time, to maintenance works at the adjacent operational wind farms (GGOW, GWF) and potentially East Anglia TWO OWF, East Anglia ONE North OWF and Five Estuaries OWF based on their construction programmes.

377. The NeuConnect Interconnector bisects the North Falls offshore export cable corridor and there is potential for temporal overlap of cable maintenance activities. It is unlikely however, for health and safety and navigational safety reasons, that maintenance works for North Falls and the NeuConnect interconnector would occur simultaneously.

378. There may be temporal overlap from marine aggregate extraction sites in adjacent areas. It is noted however that only approximately 6% of the total licensed aggregate extraction areas in the Thames estuary region were dredged at any one time in 2021 (Crown Estate 2021).

379. As assessed for North Falls, activities from other OWFs, interconnector cable installation and aggregate extraction sites would occur at localised, discrete locations (i.e. limited to the immediate vicinity of works) and would be temporary and short term. Given that the cumulative impact during operation would be less than that for construction the magnitude of the impact of physical disturbance/temporary habitat loss to fish and shellfish receptors in general is assessed as low.

380. Most of the fish species included for assessment are highly mobile with wide distribution ranges (including the extent of spawning and nursery grounds for relevant species) and would be able to make use of suitable undisturbed areas in the vicinity of works. The sediment and benthic community around the offshore project area is also characteristic of highly disturbed environments that are expected to quickly recover from disturbance. The sensitivity of fish and shellfish species in general is therefore considered to be low.

381. In the case of species which depend on specific substrates and species or life stages of reduced mobility, considering the potential increased area of their habitat affected and their reduced ability to relocate to other areas, the sensitivity is considered to be medium.

382. Potential cumulative effects from physical disturbance and temporary habitat loss during operation is therefore assessed to be of minor significance.

11.7.3.7 Cumulative impact 7: Long term habitat loss during operation

383. The associated loss of habitat through the introduction of infrastructure associated with North Falls together with that associated with other projects could result in cumulative impacts on fish and shellfish species in terms of loss of seabed habitat.

384. It should be noted, however, that the loss of seabed habitat would be widely dispersed between projects, and localised to discrete areas within projects (e.g. where cables need protection and around foundations). The cumulative assessment in Chapter 10 Benthic and Intertidal Ecology (Volume I) determined

that the cumulative habitat loss was of low magnitude in the context of the wider North Sea region.

385. Species that depend on specific substrates for spawning, such as herring and sandeel may however be more susceptible to the impact of cumulative habitat loss, however, the available information indicates that the offshore project area is not a key sandeel or herring spawning area (see Section 11.6.2.2 for further details).The magnitude of the cumulative impact for fish and shellfish receptors is therefore assessed as low.

386. The sensitivity of fish and shellfish species to long term habitat loss during operation is detailed in Section 11.6.2.2 for North Falls. The fish and shellfish species in the region use comparatively large areas for spawning, as nursery grounds and for foraging, and typically have wide distribution ranges. Therefore, in general terms, impacts as a result of habitat loss are expected to be minimal and fish and shellfish species are considered receptors of low sensitivity. Given the dependence of sandeels and herring on specific substrates and therefore their more limited habitat availability these species are considered to be of medium sensitivity.

387. The cumulative impact of long term habitat loss is therefore considered to be of minor significance.

11.7.3.8 Cumulative impact 8: Increased SSCs and re-deposition during operation

388. There may be potential for increased SSCs and sediment re-deposition associated with other projects to cumulatively add to the impact identified for North Falls once operational. The North Falls maintenance works may overlap with maintenance works at the operational GGOW and GWF, the NeuConnect Interconnector, Five Estuaries OWF, and aggregate extraction activities.

389. The worst-case volumes of sediment released following operational activities are considerably less than in the construction phase (Section 11.7.3.2). Should maintenance activities occur simultaneously at adjacent OWFs, the short-term and highly localised nature of plumes mean that they are unlikely to overlap and contribute to a cumulative effect. Similarly for marine aggregate extraction activities no cumulative impact is predicted (Chapter 9 Marine Water and Sediment Quality, Volume I).

390. Taking the above into consideration, and that overall changes from increased suspended sediments and deposition of fine sands and mud-sized sediment will not be measurable as a result of the prevailing hydrodynamic conditions of the area the magnitude is assessed as negligible.

391. The sensitivity of fish and shellfish receptors is detailed in Section 11.6.1.2.2. Adult and juvenile fish in general, being mobile, would be expected to redistribute to undisturbed areas within their range and are therefore considered receptors of low sensitivity. In the case of species and life stages of relatively low mobility and those highly dependent on the presence of specific substrates, considering the potential increased area of their habitat affected and their more reduced ability to relocate to other areas, their sensitivity is considered to be medium.

392. The cumulative impact of increased SSCs and sediment re-deposition is therefore predicted to be of minor significance during operation.

11.7.3.9 Cumulative impact 9: Electromagnetic Fields (EMFs) during operation

393. EMFs associated with cables within the offshore project area, other OWF projects and the NeuConnect Interconnector cable could result in a cumulative impact on sensitive fish and shellfish species (particularly elasmobranchs).

394. As described in the assessment of EMFs for the Project alone, the areas affected by EMFs would be expected to be very small, being limited to the immediate vicinity of the offshore cables (i.e. within metres). It is anticipated therefore that only a relatively small proportion of the fish and shellfish habitats would be affected cumulatively in the context of the wider southern North Sea. The magnitude of the impact is therefore considered to be low.

395. The sensitivity of the fish and shellfish receptors are as described in Section 11.6.2.6. In general, the sensitivity of fish and shellfish receptors (excluding elasmobranchs) is low. Elasmobranchs are assessed as having medium sensitivity given their increased ability to detect EMFs compared to other species groups. The cumulative impact is therefore assessed to be of minor significance.

11.7.3.10 Cumulative impact during decommissioning

396. As outlined for the Project alone (Section 11.7.6), it is anticipated that the types of effect on fish and shellfish receptors during the decommissioning phase in a cumulative context would be comparable to those identified for the construction phase. The potential cumulative impacts identified for decommissioning include:

- Impact 10: Temporary habitat loss / physical disturbance;
- Impact 11: Underwater noise and vibration

397. The sensitivity of receptors during the decommissioning is therefore assumed to be the same as given for the construction phase. The magnitude of impact is considered to be no greater and in all probability less than considered for the construction. Therefore, it is anticipated that any cumulative decommissioning impacts would not be greater, and probably less than those assessed for the construction phase.

11.8 Inter-relationships

398. The assessment of the impacts arising from construction, operation and decommissioning of the Project indicates that impacts on receptors addressed in other chapters may potentially further contribute to the impacts assessed on fish and shellfish species and vice versa. A summary of the principal linkages, related chapters and signposts within the chapter is given in Table 11.45.

Table 11.45 Fish and shellfish ecology inter-relationships

Topic and description	Related chapter (Volume I)	Where addressed in this chapter	Rationale
Benthic and Intertidal Ecology	10	Sections 11.5.5, 11.5.8 and 11.6	The benthic environment provides habitat and prey species for fish and shellfish receptors. Impacts on benthic ecology can have subsequent impacts on fish and shellfish

Topic and description	Related chapter (Volume I)	Where addressed in this chapter	Rationale
Commercial Fisheries	14	Sections 11.5.2, 11.5.7, 11.5.8 and 11.6	Changes in commercial fishing activity associated with the Project can have effects on fish and shellfish stocks.
Marine Mammals	12	Sections 11.5.5, 11.5.6 and 11.5.7	Impacts on fish and shellfish ecology can have an impact on the prey resource for marine mammals.
Offshore Ornithology	13	Sections 11.5.5, 11.5.6 and 11.5.7	Impacts on fish and shellfish ecology can have an impact on the prey resource for bird species.

11.9 Interactions

399. The impacts identified and assessed in this chapter have the potential to interact with each other. The areas of potential interaction between impacts are presented in Table 11.46. This provides a screening tool for which impacts have the potential to interact. Table 11.47 provides an assessment for each receptor (or receptor group) as related to these impacts.

400. Within Table 11.47 the impacts are assessed relative to each development phase (Phase assessment, i.e. construction, operation or decommissioning) to see if (for example) multiple construction impacts affecting the same receptor could increase the level of impact upon that receptor. Following this, a lifetime assessment is undertaken which considers the potential for impacts to affect receptors across all development phases.

Table 11.46 Interaction between impacts - screening [does impact 1 affect the same receptor as impact 2, impact 3 etc y/n]

Potential interaction between impacts							
Construction							
	Impact 1: Physical disturbance and temporary habitat loss	Impact 2: Increased SSCs and sediment re-deposition	Impact 3: Remobilisation of contaminated sediments	Impact 4: Underwater noise from piling for foundation installation	Impact 5: Underwater noise from other construction activities	Impact 6: Underwater noise from UXO clearance	Impact 7: Changes in fishing activity
Impact 1: Physical disturbance and temporary habitat loss	-	Yes	Yes	No	No	No	No
Impact 2: Increased SSCs and sediment re-deposition	Yes	-	Yes	No	No	No	No
Impact 3: Remobilisation of contaminated sediments	Yes	Yes	-	No	No	No	No
Impact 4: Underwater noise from piling for foundation installation	No	No	No	-	Yes	Yes	No
Impact 5: Underwater noise from other construction activities	No	No	No	Yes	-	Yes	No
Impact 6: Underwater noise from UXO clearance	No	No	No	Yes	Yes	-	No
Impact 7: Changes in fishing activity	No	No	No	No	No	No	-

Potential interaction between impacts								
Operation								
	Impact 8: Temporary habitat loss/ physical disturbance	Impact 9: Long term habitat loss	Impact 10: Increased SSCs and re-deposition	Impact 11: Remobilisation of contamination sediments	Impact 12: Underwater noise and vibration	Impact 13: EMFs	Impact 14: Introduction of hard substrate	Impact 15: Changes in fishing activity
Impact 8: Temporary habitat loss/ physical disturbance	-	Yes	Yes	Yes	No	No	No	No
Impact 9: Long term habitat loss	Yes	-	No	No	No	No	Yes	No
Impact 10: Increased SSCs and re-deposition	Yes	No	-	Yes	No	No	No	No
Impact 11: Remobilisation of contamination sediments	Yes	No	Yes	-	No	No	No	No
Impact 12: Underwater noise and vibration	No	No	No	No	-	No	No	No
Impact 13: EMFs	No	No	No	No	No	-	No	No
Impact 14: Introduction of hard substrate	No	No	No	No	No	No	-	No
Impact 15: Changes in fishing activity	No	No	No	No	No	No	No	-
Decommissioning								
It is anticipated that the decommissioning impacts will be similar in nature to those of construction								

Table 11.47 Interaction between impacts – phase and lifetime assessment

Receptor	Highest residual significance level			Phase assessment	Lifetime assessment
	Construction	Operation	Decommissioning		
Fish and shellfish	Moderate Impact 4(ii): Underwater noise from piling for foundation installation (TTS and behavioural) for Downs Herring	Minor	Minor	No greater than individually assessed impacts **Construction** Underwater noise impacts will be greatest in spatial extent for piling and UXO clearance, but these will occur only during a short part of the construction phase and therefore there is limited potential for interaction with habitat disturbance from seabed preparation, installation of cables etc and associated effects (increased SSC and resuspension of contaminants). The effects resulting from habitat disturbance will be localised and episodic with limited potential for interaction. Any reduction in fishing effort would be beneficial to fish ecology although likely to be of low magnitude. It is therefore considered that these impacts would not interact to increase in the significance level overall. **Operation** Operational noise impacts from WTGs will be highly localised to within close proximity of each WTG, whilst the majority of disturbance to or loss of habitat for fish will also be confined to the immediate footprint of the Project infrastructure. This relates to largely the same spatial footprint. Therefore, there is no greater impact as a result of any interaction of these impacts. EMF effects and disturbance to or loss of habitat for fish will be localised to the cables and relates to largely the same spatial footprint. It is therefore considered that these impacts would not interact to increase in the significance level overall.	No greater than individually assessed impacts The greatest magnitude of impact will be the spatial footprint of construction noise (i.e. UXO clearance and piling) and the habitat disturbance from seabed preparation, installation of cables etc. Once this disturbance impact has ceased all further impact during construction and operation will be small scale, highly localised and episodic. There is no evidence of long term displacement of fish or shellfish from operational wind farms. It is therefore considered that over the Project lifetime these impacts would not combine and represent an increase in the significance level.

11.10 Summary

401. This chapter has provided a characterisation of the existing environment for fish and shellfish ecology. The assessment has determined that the majority of impacts were assessed as minor, however, the impact of piling on the Downs herring resulted in a moderate significance.

402. The potential effects on fish and shellfish ecology during the construction, operation, maintenance and decommissioning phases of the Project are summarised in Table 11.48.

Table 11.48 Summary of potential impacts on fish and shellfish receptors

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation	Residual impact
Construction						
Impact 1: Physical disturbance and temporary habitat loss	Fish in general	Low	Low	Negligible	N/A	Negligible
	Sandeels	Medium	Low	Minor	N/A	Minor
	Herring (Downs and Blackwater)	Medium (Downs) Low (Blackwater)	Low	Minor (Downs) Negligible (Blackwater)	N/A	Minor (Downs) Negligible (Blackwater)
	Thornback ray	Low	Low	Negligible	N/A	Negligible
	Oysters / cockles	Medium	Low	Minor	N/A	Minor
	Shellfish in general	Low	Low	Negligible	N/A	Negligible
Impact 2: Increased suspended sediment concentrations	Fish and shellfish in general	Low	Negligible	Negligible	N/A	Negligible
	Sandeels	Medium	Negligible	Minor	N/A	Minor
	Herring (Downs and Blackwater)	Medium (Downs) Low (Blackwater)	Negligible	Minor (Downs) Negligible (Blackwater)	N/A	Minor (Downs) Negligible (Blackwater)
	Other species with spawning grounds in the offshore project area	Low	Negligible	Negligible	N/A	Negligible
	Oysters / cockles	Medium	Negligible	Minor	N/A	Minor
	Shellfish in general	Low	Low	Negligible	N/A	Negligible
Impact 3: Remobilisation of contaminated sediments	Fish and shellfish in general	Negligible	Negligible	Negligible	N/A	Negligible
Impact 4(i): Underwater noise from piling for foundation installation	Fish with no swim bladder	Low (General)	Negligible (F / S)	Negligible (F / S)	N/A	Negligible (F / S)
		Medium (sandeels)		Minor	N/A	Minor

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation	Residual impact
(mortality/recoverable injury) (F: Fleeing animal modelling) (S: Stationary animal modelling)				(F / S)		(F / S)
	Fish with swim bladder not involved in hearing	Low (General)	Negligible (F) Low (S)	Negligible (F) Minor (S)	N/A	Negligible (F) Minor (S)
		Medium (Gobies)		Minor (F / S)	N/A	Minor (F / S)
	Fish with swim bladder involved in hearing	Low	Negligible (F) Low (S)	Negligible (F) Minor (S)	N/A	Negligible (F) Minor (S)
	Eggs and larvae	Medium	Negligible (F) Low (S)	Minor (F / S)	N/A	Minor (F / S)
	Shellfish	Medium	Negligible	Minor	N/A	Minor
Impact 4(ii): Underwater noise from piling for foundation installation (TTS and behavioural) *outcomes of the assessment apply to both a fleeing animal or stationary animal modelling scenario.	Plaice, lemon sole and mackerel	Low	Low	Negligible	N/A	Negligible
	Dover sole	Medium	Low	Minor	N/A	Minor
	Sandeels	Medium	Low	Minor	N/A	Minor
	Sea bass	Low	Low	Negligible	N/A	Negligible
	Cod, whiting and sprat	Low	Low	Negligible	N/A	Negligible
	Herring (Downs and Blackwater)	High (Downs) Medium (Blackwater)	Low	Moderate (Downs) Minor (Blackwater)	N/A	Moderate (Downs) Minor (Blackwater)
	Elasmobranchs	Low	Low	Negligible	N/A	Negligible
	Diadromous species	Low	Low	Negligible	N/A	Negligible
Impact 5: Underwater noise from other construction activities	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible
Impact 6: Underwater noise from UXO clearance	Fish and shellfish in general	Medium	Low	Minor	N/A	Minor

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation	Residual impact
Impact 7: Changes in fishing activity	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible
Operation						
Impact 8: Temporary habitat loss/ physical disturbance	Fish and shellfish in general	Low	Negligible	Negligible	N/A	Negligible
	Herring (Downs and Blackwater)	Medium (Downs) Low (Blackwater)	Negligible	Minor (Downs) Negligible (Blackwater)	N/A	Minor (Downs) Negligible (Blackwater)
	Sandeels	Medium	Negligible	Minor	N/A	Minor
	Oysters / cockles	Medium	Negligible	Minor	N/A	Minor
Impact 9: Long term habitat loss	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible
	Herring (Downs and Blackwater)	Medium (Downs) Low (Blackwater)	Low	Minor (Downs) Negligible (Blackwater)	N/A	Minor (Downs) Negligible (Blackwater)
	Sandeels	Medium	Low	Minor	N/A	Minor
Impact 10: Increased suspended sediment concentrations and re-deposition	Fish and shellfish in general	Low	Negligible	Negligible	N/A	Negligible
	Downs herring	Medium	Negligible	Minor	N/A	Minor
	Sandeels	Medium	Negligible	Minor	N/A	Minor
	Oysters / cockles	Medium	Negligible	Minor	N/A	Minor
Impact 11: Re-mobilisation of contaminated sediments	Fish and shellfish in general	Negligible	Negligible	Negligible	N/A	Negligible
Impact 12: Underwater noise and vibration	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible
	Fish species in general	Low	Low	Negligible	N/A	Negligible

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation	Residual impact
Impact 13: Electromagnetic Fields (EMFs)	Elasmobranchs	Medium	Low	Minor	N/A	Minor
	Lamprey	Low	Low	Negligible	N/A	Negligible
	European eel	Low	Low	Negligible	N/A	Negligible
	Salmon and sea trout	Low	Low	Negligible	N/A	Negligible
	Shellfish	Low	Low	Negligible	N/A	Negligible
Impact 14: Introduction of hard substrate	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible
Impact 15: Changes in fishing activity	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible
Decommissioning						
Impact 16: Temporary habitat loss/ physical disturbance	Fish and shellfish in general	Low to Medium	Low	Negligible to Minor	N/A	Negligible to Minor
Impact 17: Remobilisation of contaminated sediments	Fish and shellfish in general	Negligible	Negligible	Negligible	N/A	Negligible
Impact 18: Underwater noise and vibration	Fish and shellfish in general	Low to High	Low	Negligible to Moderate	N/A	Negligible to Moderate
Impact 19: Changes in fishing activity	Fish and shellfish in general	Low	Low	Negligible	N/A	Negligible

11.11 References

Ager, O.E.D. (2008). Buccinum undatum Common whelk. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1560. Accessed 06/06/2022.

Anderson, J.M., T.M. Clegg, L.V.M.V.Q. Véras, and K.N. Holland. (2017). Insight into shark magnetic field perception from empirical observations. Scientific Reports 7(1):11042, https://doi.org/10.1038/s41598-017-11459-8.

APEM. (2018). Tilbury Energy Centre Subtidal and Intertidal Fish Survey Report. Preliminary Environmental Information Report: Appendix 10.7. APEM Scientific Report P00001435 WP4- 5 prepared for RWE Generation UK.

Armstrong, J.D., Hunter, D.C., Fryer, R.J., Rycroft, P. and Orpwood., J.E. (2016). Behavioural Responses of Atlantic Salmon to Mains Frequency Magnetic Fields. Scottish Marine and Freshwater Science Vol 6 No 9. Published by Marine Scotland Science. ISSN: 2043-7722. DOI:10.7489/1621-1.

Behrens, J., Stahl, Steffensen, J., Glud, R. (2007). Oxygen dynamics around buried lesser sandeels Ammodytes tobianus (Linnaeus 1785): mode of ventilation and oxygen requirements. Journal of Experimental Biology, vol. 210(6), pp. 1006-14.

Department for Business, Energy and Industrial Strategy (2021a) Draft NPS for Renewable Energy Infrastructure (EN-3)

Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/243576/9780108508516.pdf

Department for Business, Energy and Industrial Strategy (2021b) Draft Overarching NPS for Energy (EN-1)

Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015233/en-1-draft-for-consultation.pdf

Department for Business, Energy and Industrial Strategy (2021c) Draft NPS for Electricity Networks Infrastructure (EN-5)

Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47788/1934-aos-main-report-en5.pdf#:~:text=National%20Policy%20Statement%20for%20Electricity%20Networks%20Infrastructure%20%28EN-5%29.,is%20one%20of%20five%20energy%20NPSs%20covering%20specific

Bergström, L., Sundqvist, F., and Bergström, U. (2013). Effects of an offshore wind farm on temporal spatial patterns in the demersal fish community. Mar. Ecol. Prog. Ser. Vol 485: 199-210. http://www.int-res.com/articles/meps_oa/m485p199.pdf.

BioConsult (2006). Hydroacoustic Monitoring of Fish Communities at Offshore Wind Farms, Horns Rev Offshore Wind Farm, Annual Report 2005.

BERR (2008). Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry – Technical Report. Available at: 186 © Wood Group UK Limited Rampion 2 PEIR. Volume 2, Chapter 8: Fish and shellfish ecology http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file43527.pdf [Accessed 06/06/2022].
Bodznick, D. and Preston, D.G.1983. Physiological characterization of electroreceptors in the lampreys Ichthyomyzon uniscuspis and Petromyzon marinus. Journal of Comparative Physiology152, pp. 209-217.
Bodznick, D. and Northcutt, R.G. (1981). Electroreception in lampreys: evidence that the earliest vertebrates were electroreceptive. Science 212, pp. 465-467.
BOEM (2016). Assessment of Potential Impact of Electromagnetic Fields from Undersea Cable on Migratory Fish Behaviour. Final Technical Report, September 2016. Bureau of Ocean Energy Management (BOEM)Publication Number: OCS Study BOEM 2016-041.
Bohnsack, J.A. (1989). Are High Densities of Fishes at Artificial Reefs the Result of Habitat Limitation or Behavioural Preference? Bulletin of Marine Science, 44(2), pp. 631–645.
Bohnsack, J.A. and Sutherland, D.L. (1985). Artificial reef research: a review with recommendations for future priorities. Bulletin of Marine Science, 37(1), pp.11–39.
Boles, L., and Lohmann, K. (2003). True navigation and magnetic maps in spiny lobsters. Nature, vol. 421(6918), pp. 60-63.
Byrne Ó Cléirigh Ltd, Ecological Consultancy Services Ltd (EcoServe) and School of Ocean and Earth Sciences, University of Southampton (2000) Assessment of Impact of Offshore Wind Energy Structures on the Marine Environment. Prepared for the Marine Institute.
Centre for Environment, Fisheries and Aquaculture Science (2009). Strategic review of offshore wind farm monitoring data associated with FEPA licence conditions. Fish. Contract ME1117.
Centre for Marine and Coastal Studies (2003). A baseline assessment of electromagnetic Environmental Statement Norfolk Boreas Offshore Wind Farm 6.1.11 June 2019 Page 109 fields generated by offshore Windfarm cables COWRIE Report EMF –01-2002 66.
Centre for Marine and Coastal Studies (2012). East Anglia ONE Offshore Windfarm Environmental Statement. Volume 2 Chapter 8 Underwater noise and Vibration and Electromagnetic Fields Appendices. Appendix 8.1.
Collaborative Offshore Wind Research into the Environment (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2. EMF-sensitive fish response to EM emissions from sub-sea cables of the type used by the offshore renewable energy industry. Ref: EP-2054- ABG.
Cresci, A., Allan, B.J.M., Sherma, S.D., Skiftesvik, A.B and Browman, H.I. (2020) Orientation behaviour and swimming speed of Atlantic herring larvae (Clupea harengus) in site and in laboratory exposures to rotated artificial magnetic fields. Journal of Experimental Marine Biology and Ecology. 526, 151358.

Cresci, A., Paris, C.B., Foretich, M.A., Durif, C.M.F., Shema, S., O'Brien, C.J. E, Vikebø, F.B., Skiftesvik, A.B and Browman, H.I. 2019. Atlantic haddock (Melanogrammus aeglefinus) larvae have a magnetic compass that guides their orientation. iScience. 19, 27, 1173-1178.
Crown Estate (2021) The area involved – 24th annual report. Marine Aggregate Extraction 2021. Available from: https://www.thecrownestate.co.uk/media/4242/the-area-involved-24th-annual-report.pdf [Accessed 12 December 2022].
Department of Energy and Climate Change (DECC) (2011) National Policy Statement for Renewable Energy Infrastructure (EN-3). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47856/1940-nps-renewable-energy-en3.pdf
Department for Business, Energy & Industrial Strategy (BEIS) (2021) Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015236/en-3-draft-for-consultation.pdf
Dulvy, N., Simpfendorfer, C., Davidson, L., Fordham, S., Brautigam, A., Sant, G., and Welch, D. (2017). Challenges and Priorities in Shark and Ray Conservation. Current Biology. 27. R565-R572. 10.1016/j.cub.2017.04.038.
Edmonds, N., Firmin, C., Goldsmith, D., Faulkner, R. and Wood, T. 2016. A review of crustacean sensitivity to high amplitude underwater noise: Data needs for effective risk assessment in relation to UK commercial species. Marine Pollution Bulletin, 108(1-2), pp. 5-11.
Ellis, J., Clarke, M., Cortés, E., Heessen, H., Apostolaki, P., Carlson, J.K., and Kulka, D. (2008). Management of elasmobranch fisheries in the North Atlantic. In: Advances in Fisheries Science 50 years on from Beverton and Holt.
Everley, K.A., Radford, A.N. and Simpson, S.D. (2015). Pile-Driving Noise Impairs AntiPredator Behaviour of the European sea Bass *Dicentrarchus labrax*. A.N. Popper, A.D. Hawkins (Eds.), The Effects of Noise on Aquatic Life II, Springer, New York (2015), pp. 273- 279.
Fugro. (2021) North Falls Array, ECR and Intertidal Benthic Ecology/Monitoring Report. December 2021.
Gill, A.B. and Bartlett, M. (2010). Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage Commissioned Report No.401
Gill, A.B. and Taylor, H. (2001). The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes, Countryside Council for Wales, Contract Science Report 488.
Gill A., Gloyne-Phillips, I., Neal, K. and Kimber, J. (2005). The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. Report to Collaborative Offshore Wind Research into the Environment (COWRIE) group, Crown Estates.

Gill, A.B. Huang, Y. Gloyne-Philips, I. Metcalfe, J. Quayle, V. Spencer, J. and Wearmouth, V. (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Commissioned by COWRIE Ltd (project reference COWRIE-EMF-1-06.
Glarou, M., Zrust, M. and Svendsen, J.C. (2020). Using Artificial-Reef Knowledge to Enhance the Ecological Function of Offshore Wind Turbine Foundations: Implications for Fish Abundance and Diversity. Journal of Marine Science and Engineering, 8(5), 332, pp. 1–26.
Graham, J., Rowland, C., Ribbens, J., and Colclough, S. (2021). European smelt Osmerus eperlanus L., Recovery Management Plan for the Solway Firth Marine Conservation Zone (MCZ). Galloway Fisheries report for Natural England. Natural England.
Hawkins, A. D., Pembroke, A. E., and Popper A., N. (2014) Information gaps in understanding the effects of noise on fishes and invertebrates, Rev. Fish Biol. Fisheries, http://dx.doi.org/10.1007/s11160-014-9369-3, Springer International Publishing.
Hiddink J. G., Jennings S., Sciberras M., Bolam S., McConnaughey R. A., Mazor T., Hilborn R. (2019). The sensitivity of benthic macroinvertebrates to bottom trawling impacts using their longevity. Journal of Applied Ecology, 56: 1075–1084.
Hirata K (1999). Swimming speeds of some common fish. National Maritime Research Institute (Japan). Data Sourced from Iwai T, Hisada M (1998). Fishes – Illustrated Book of Gakken (in Japanese), Gakken. Accessed 8th March 2017 at http://www.nmri.go.jp/eng/khirata/general/ speed/speede/htm
Hoffman, E., Astrup, J., Larsen, F. and Munch-Petersen, S. (2000). Effects of Marine Windfarms on the distribution of fish, shellfish and marine mammals in the Horns Rev area. Baggrundsrapport nr 24 to ELSAMPROJEKT A/S. pp. 42.
Hutchison, Z. L., Sigray, P., He, H., Gill, A. B., King, J. and Gibson, C. (2018). Electromagnetic Field (EMF) Impacts on Elasmobranch (shark, rays, and skates) and American Lobster Movement and Migration from Direct Current Cables. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2018-003.
Hutchison, Z.L., D.H. Secor, and A.B. Gill. (2020). The interaction between resource species and electromagnetic fields associated with electricity production by offshore wind farms. Oceanography. Vol 33 No 4, pp. 96–107.
Hvidt, C.B. Kaustrup, M. Leonhard, S.B. and Pedersen, J. (2005). Fish along the cable trace. Nysted Offshore Wind Farm. Final Report 2004.
ICES. (2019). Greater North Sea Ecoregion – Ecosystem overview. In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, Section 9.1, https://doi.org/10.17895/ices.advice.5750
ICES. (2021). Working Group on Elasmobranch Fishes (WGEF). ICES Scientific Reports. 3:59. 822 pp. https://doi.org/10.17895/ices.pub.8199

Jensen, H., Rindorf, A., Wright, P.J. and Mosegaard, H. (2011). Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery. ICES Journal of Marine Science 68(1), pp. 43–51
Jones, I.T., Stanley, J.A. and Mooney, T.A. 2020.Impulsive pile driving noise elicits alarm responses in squid (Doryteuthis pealeii). Marine Pollution Bulletin 150:110792.
Jørgensen, T., Løkkeborg, S. and Soldal, A. (2002). Residence of fish in the vicinity of a decommissioned oil platform in the North Sea. ICES Journal of Marine Science: Journal du Conseil, vol. 59, suppl. pp. S288-S293.
Kastelein, R.A.,van der Heul, S.,Verboom, W.C., Jennings, N., van der Veen, J. and de Haan, D. (2008). Startle response of captive North Sea fish species to underwater tones between 0.1 and 64 kHz. Mar. Environ. Res., 65 (2008), pp. 369-377
Kiørboe, T., Frantsen, E., Jensen, C. and Sorensen, G. (1981).Effects of suspended sediment on development and hatching of herring (Clupea harengus) eggs. Eastuarine, Coastal and Shelf Science. 13(1), 107-111.
Kosheleva, V. (1992). The impact of air guns used in marine seismic explorations on organisms living in the Barents Sea. Fisheries and Offshore Petroleum Exploitation 2nd International Conference, Bergen, Norway.
Leonhard, S. and Pedersen, J. (2006). Benthic Communities at Horns Rev Before, During and After Construction of Horns Rev Offshore Wind Farm.
Lindeboom, H., Kouwenhoven, H., Bergman, M., Bouma, S., Brasseur, S., Daan, R., Fijn, R.C. de Haan, D., Dirksen, S., van Hal, R., Hille Ris Lambers, R., ter Hofstede, R., Krijgsveld, K., Leopold, M. and Scheidat, M. (2011). Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environmental Research Letters, vol. 6(035101), pp. 13
Linley E.A.S., Wilding T.A., Black K., Hawkins A.J.S. and Mangi S. (2007). Review of the reef effects of offshore wind farm structures and their potential for enhancement and mitigation. Report from PML Applications Ltd and the Scottish Association for Marine Science to the Department for Business, Enterprise and Regulatory Reform (BERR), Contract No: RFCA/005/0029P.
Maitland, P.S. (2003). The Status of Smelt *Osmerus eperlanus* in England. English Nature Research Report 516. Natural England, West Yorkshire, UK
McQuaid, N., Briggs, R., Roberts, D. (2009). Fecundity of Nephrops norvegicus from the Irish Sea, Journal of the Marine Biological Association of the United Kingdom. vol. 89, pp. 1181
Messieh, S., Wildish, D., and Peterson, R. (1981). Possible Impact from Dredging and Soil Disposal on the Miramichi Bay Herring Fishery. Can. Tech. Rep. Fish. Aquat. Sci., vol. 1008, pp. 33 Cited in: Engel-Sørensen, K., and Skyt, P. (2001). Evaluation of the Effect of Sediment Spill from Offshore Wind Farm Construction on Marine Fish. Report to SEAS, Denmark, pp. 18.
Mohr, H. (1971). Behaviour patterns of different herring stocks in relation to ship and midwater trawl. Modern fishing gear of the world 3. pp. 368-371.

Neal, K and Wilson, E (2008). Cancer pagurus. Edible crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme. Plymouth: Marine Biological Association of the United Kingdom.]. Available at: http://www.marlin.ac.uk/speciesimportance.php?speciesID=2872. Accessed 10/10/2022.
Neo, Y.Y., Ufkes, E., Kastelein, R.A., Winter, H.V., ten Cate, C. and Slabbekoom, H. (2015). Impulsive sounds change European seabass swimming patterns: influence of pulse repetition interval. Mar. Pollut. Bull., 97 (2015), pp. 111-117
Nordmann, G.C., T. Hochstoeger, and D.A. Keays. (2017). Magnetoreception—A sense without a receptor. PLOS Biology 15(10):e2003234, https://doi.org/ 10.1371/journal.pbio.2003234.
Nottestad, L., Aksland, M., Beltestad, A., Ferno, A., Johannessen, A., and Misund, O. (1996). Schooling dynamics of Norwegian Spring spawning Herring (Clupea harengus L.) in a coastal spawning area. Sarsia, vol. 80, pp. 277-284.
Orpwood, J.E., Fryer, R.J., Rycroft, P. and Armstrong, J.D. (2015) Effects of AC Magnetic Fields (MFs) on swimming activity in European Eels *Anguilla anguilla*. Scottish Marine and Freshwater Science Vol. 6. No.8.
Peña, H., Handegard, N. and Ona, E. (2013). Feeding herring schools do not react to seismic air gun surveys. ICES Journal of Marine Science: Journal du Conseil, vol. 70(6), pp. 1174- 1180. Popper, A.N
Perry, F., Jackson, A. and Garrard, S.L. (2017). Ostrea edulis Native oyster. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity 195 © Wood Group UK Limited Rampion 2 PEIR. Volume 2, Chapter 8: Fish and shellfish ecology Key Information Reviews. Plymouth: Marine Biological Association of the United Kingdom. Available at: https://www.marlin.ac.uk/species/detail/1146 [Accessed 06/06/2022].
Payne, J., Andrews, C., Fancey, L., Cook, A., Christian, J. (2007). Pilot study on the effects of seismic air gun noise on lobster (Homarus americanus), Environmental Studies Research Funds. Canadian Technical Reports Fisheries and Aquatic Sciences. Vol. 2712, pp. 46.
PINS. (2021). Scoping Opinion for Proposed North Falls Offshore Wind Farm. The Planning Inspectorate. August 2021. Available: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010119/EN010119-000054-EN010119%20-%20Scoping%20Opinion.pdf (Accessed 10/03/2022)
Popper, A. N., Salmon, M. and Horch, K. W. (2001) Acoustic detection and communication by decapod crustaceans. Journal of Comparative Physiology A, 187 (2): 83-89.
Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D.A., Bartol, S., Carlson, T.J., Coombs, S., Ellison, W.T., Gentry, R.L., Halvorsen, M.B., Løkkeborg, S., Rogers, P.H., Southall, B.L., Zeddies, D.G. and Tavolga, W.N (2014). Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI.

Popper, A. N., & Hawkins, A. D. (2018). The importance of particle motionto fishes and invertebrates. The Journal of the Acoustical Society ofAmerica,143, 470–486
Royal HaskoningDHV (2021) North Falls Offshore Windfarm Environmental Impact Assessment Scoping Report.
Righton, D., Westerberg, H., Feunteun, E., Økland, F., Gargan, P., Amilhat, E., Metcalfe, J., LobonCervia, J., Sjöberg, N., Simon, J., Acou, A., Vedor, M., Walker, A., Trancart, T., Brämick, U. and Aarestrup, K. (2016) Empirical observations of the spawning migration of European eels: The long and dangerous road to the Sargasso Sea. Science Advances 2(10): e1501694. DOI: 10.1126/sciadv.1501694.
Roach, M., Cohen, M., Forster, R., Revill, A. S., and Johnson, M. (2018) The effects of temporary exclusion of activity due to wind farm construction on a lobster (Homarus gammarus) fishery suggests a potential management approach. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsy006.
Roberts, L., Cheesman, S., Elliott, M. and Breithaupt, T. (2016). Sensitivity of *Pagurus bernhardus* (L.) to substrate-borne vibration and anthropogenic noise. Journal of Experimental Marine Biology and Ecology, 474, pp. 185–194.
Sayer, M., Magill, S., Pitcher, T., Morisette, L. and Ainsworth, C. (2005). Simulation-based investigations of fishery changes as affected by the scale and design of artificial habitats. Journal of Fish Biology, vol. 67 (Supplement B), pp. 218–243.
Scott, K., Harsanyi, P. and Lyndon A.R. (2018). Understanding the effects of electromagnetic field emissions from Marine Renewable Energy Devices (MREDs) on the commercially important edible crab, *Cancer pagurus* (L.). Marine Pollution Bulletin, 131(A), pp.580–588.
Sguotti, C., Lynam, C.P., García-Carreras, B., Ellis, J.R., and Engelhard, G.H. (2016). Distribution of skates and sharks in the North Sea: 112 years of change. Global change biology. 22(8). 2729-2743.
Skaret, G., Nottestad, L., Ferno, A., Johannessen, A., and Axelsen B.J. (2003). Spawning of herring: day or night, today or tomorrow? Aquatic Living Resources, vol. 16, pp. 299- 306.
Solan, M., Hauton, C., Godbold, J.A., Wood, C.L., Leighton, T.G. and White, P. 2016. Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. Scientific Reports, Vol 6, 20540.
C.J.B. Sorte, S.L. Williams, J.T. Carlton (2010) Marine range shifts and species introductions: comparative spread rates and community impacts. Global Ecol. Biogeogr., 19, pp. 303-316
Spiga, I., Caldwell, G.S. and Bruintjes, R. (2016). Influence of Pile Driving on the Clearance Rate of the Blue Mussel, Mytilus edulis (L.). Proceedings of Meeting on Acoustics, Acoustical Society of America, 27, 040005.
Stenberg, C., Støttrup, J.G., van Deurs, M., Berg, C.W., Dinesen, G.E., Mosegaard, H., Grome, T.M. and Leonhard, S.B. (2015). Long-term effects of an

offshore wind farm in the North Sea on fish communities. Mar Ecol Prog Ser. 528: 257-265.

Stenberg, C., van Deurs, M., Støttrup, J.G., Mosegaard, H., Grome, T., Dinesen, G.E., Christensen, A., Jensen, H., Kaspersen, M., Berg, C. W., Leonhard,S., Skov, H., Pedersen, J., Hvidt, C.B., Klaustrup, M., Jsianne, G. (2011) Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities. Follow-up Seven Years after Construction. DTU Aqua. Institute for Akvatiske Ressourcer. DTU Aqua Report, No. 246-2011.

Swedpower (2003). Electrotechnical studies and effects on the marine ecosystem for BritNed Interconnector. Cited in- CMACS (2005). East Anglia THREE Environmental Statement. Appendix 9.2: Electromagnetic Field Environmental Appraisal. Volume 3. Document Reference–6.3.9(2)

Tasker, M. L., Amundin, M., Andre, M., Hawkins, A., Lang, W., and Merck, T. (2010) Marine Strategy Framework Task Group 11 Report and Other Forms of Energy. Underwater noise. Group. doi:10.2788/87079.

Teal, L., van Hal R., van Damme, C. ter Hofstede R, L. (2009). Review of the spatial and temporary distribution by life stage for 19 North Sea fish species. Report No. C126/09. IMARES, Ijmuiden.

Tidau, S. and Briffa, M. 2016. Review on behavioural impacts of aquatic noise on crustaceans. Proc. Mtgs. Acoust. 27(1): 010028.

Tyler-Walters, H. (2007). Nucella lapillus Dog whelk. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1501. Accessed 06/06/2022.

Ueno, S., Lövsund, P. and Åke Öberg, P. (1986). Effect of time-varying magnetic fields on the action potential in lobster giant axon. Medical and Biological Engineering and Computing vol. 24(5), pp. 521-526.

Vandendriessche, S., Derweduwen, J. & Hostens, K., (2012). Monitoring the effects of offshore wind farms on the epifauna and demersal fish fauna of soft-bottom sediments. pp. 55-71. In- Offshore Wind Farms in the Belgian part of the North Sea. Heading for an understanding of environmental impacts. Degraer, S., Brabant, R. & Rumes, B., (Eds.) (2012), Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models, Marine ecosystem management unit. 155 pp. + annexes.

van Hal, R.; Griffioen, A.B.; van Keeken, O.A. (2017). Changes in fish communities on a small spatial scale, an effect of increased habitat complexity by an offshore wind farm. Marine Environmental Research, 126, pp. 26–36.

Walker, T. (2001). Review of Impacts of High Voltage Direct Current Sea Cables and Electrodes on Chondrichthyan Fauna and Other Marine Life. Basslink Supporting Study No. 29. Marine and Freshwater Resources Institute No. 20. Marine and Freshwater Resources Institute, Queenscliff, Australia.

Walker, R.; Judd, A.; Warr, K.; Doria, L.; Pacitto, S.; Vince, S.; Howe, L. (2009). Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA

Licence Conditions: Fish (Report No. ME1117). Report by Centre for Environment Fisheries and Aquaculture Science (CEFAS).
Wilber, D.H. and Clarke, D.G. (2001). Biological Effects of Suspended Sediments: A review of Suspended Sediment Impacts on Fish and Shellfish with Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management. 21: 855-875.
Winslade, P. (1971) Behavioural and embryological studies on the lesser sandeel Ammodytes marinus (Raitt). PhD thesis, Univ. East Anglia. pp. 174.
Wyman, M.T., Klimley, A.P., Battleson, R.D., Agosta, T.V., Chapman, E.D., Haverkamp, P.J., Pagel, M.D. and Kavet, R. (2018). Behavioral responses by migrating juvenile salmonids to a subsea high-voltage DC power cable. Marine Biology, 165(8), 134.
ZSL. (2018). The Thames European Eel Project Report 2018. Available: https://www.zsl.org/sites/default/files/media/2018-12/ZSL%202018%20eel%20report_FINAL.pdf (accessed 24/03/22)
ZSL. (2021). Thames Tideway Aquatic Ecology Research Smelt surveys on the Thames. Available: https://www.tideway.london/media/5274/zsl_tideway_smeltreport_final_dec20.pdf (Accessed 25/03/2022)