Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Environmental Statement

Volume 1

Chapter 9 - Fish and Shellfish Ecology

August 2022
Document Reference: 6.1.9
APFP Regulation: 5(2)(a)

China Resources
Better Life Together

Masdar
A MUBADALA COMPANY

equinor

Title:	
Sheringham Shoal and Dudgeon Offshore Wind Farm Extensions Environmental Statement Chapter 9: Fish and Shellfish Ecology	
PINS document no.: 6.1.9	
Document no.: C282-RH-Z-GA-00029	
Date:	Classification
August 2022	**Final**
Prepared by:	
Royal HaskoningDHV	
Approved by:	Date:
Sarah Chandler, Equinor	August 2022

Table of Contents

Table of Tables

Volume 2

Volume 3

Glossary of Acronyms

BGS	British Geological Survey
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
COWRIE	Collaborative Offshore Wind Research into the Environment
CPUE	Catch Per Unit Effort
CSCB	Cromer Shoal Chalk Beds
CSIMP	Cable Specification and Installation Monitoring Plan
DCO	Development Consent Order
Defra	Department for the Environment and Rural Affairs
DEP	Dudgeon Extension Project
DOW	Dudgeon Offshore Wind Farm
dph	Days Post Hatch
DTI	Department of Trade and Industry
EC	European Commission
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIFCA	Eastern Inshore Fisheries and Conservation Authority
EMF	Electromagnetic Field
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Topic Group
EU	European Union
FEPA	Food and Environmental Protection Act
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IBTS	International Bottom Trawl Survey
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Survey
IMARES	Institute for Marine Resources and Ecosystem Studies
IPMP	In-Principle Monitoring Plan
km	Kilometre

MarESA	Marine Evidence based Sensitivity Assessment
MarLIN	Marine Life Information Network
MCEU	Marine Consents and Environment Unit
MCZ	Marine Conservation Zone
ML	Marine Licence
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
mT	Millitesla
MW	Megawatts
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
ORJIP	Offshore Renewables Joint Industry Programme
OS	Ordnance Survey
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PTS	Permanent Threshold Shift
SAC	Special Area of Conservation
SEP	Sheringham Shoal Extension Project
SIP	Site Integrity Plan
SNC	South Norfolk Council
SNS	Southern North Sea
SOW	Sheringham Shoal Offshore Wind Farm
TAC	Total Allowable Catches
THC	Total Haemocyte Count
TNT	Trinitrotoluene
TTS	Temporary Threshold Shift
UK	United Kingdom
UN	United Nations
UXO	Unexploded ordnance
WFD	Water Framework Directive

WTG	Wind Turbine Generator
μT	Microtesla

Glossary of Terms

Beam Trawl	A trawl net whose lateral spread during trawling is maintained by a beam across its mouth.
Clupeid	Fish species of the family Clupeidae, which are ray-finned fishes, including herring, sprat, sardine and shad.
Crustacean	An arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp, or barnacle.
DCO boundary	The area subject to the application for development consent, including all permanent and temporary works for SEP and DEP. The DCO boundary will be subject to an updated impact assessment and further development of mitigation proposals to inform the ES.
Demersal	Living on or near the sea bed.
Diadromous	Migrating between fresh and salt water.
Dudgeon Offshore Wind Farm Extension Project (DEP) offshore site	The Dudgeon Offshore Wind Farm Extension consisting of the DEP wind farm site, interlink cable corridors and offshore export cable corridor (up to mean high water springs).
Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
Dudgeon Offshore Wind Farm Extension Project (DEP) onshore site	The Dudgeon Offshore Wind Farm Extension onshore area consisting of the DEP onshore substation site, onshore cable corridor, construction compounds, temporary working areas and onshore landfall area.
DEP North array area	The wind farm site area of the DEP offshore site located to the north of the existing Dudgeon Offshore Wind Farm
DEP South array area	The wind farm array area of the DEP offshore site located to the south of the existing Dudgeon Offshore Wind Farm
DEP wind farm site	The offshore area of DEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary

	Works Area. This is also the collective term for the DEP North and South array areas.
Elasmobranch	Any cartilaginous fish of the subclass Elasmobranchii which includes sharks, rays and skates.
Evidence Plan Process (EPP)	A voluntary consultation process with specialist stakeholders to agree the approach, and information to support, the EIA and HRA for certain topics.
Gadoid	A bony fish of an order (Gadiformes) that comprises the cods, hakes, and their relatives.
Gravid	Carrying eggs or young.
Grid option	Mechanism by which SEP and DEP will connect to the existing electricity network. This may either be an integrated grid option providing transmission infrastructure which serves both of the wind farms, or a separated grid option, which allows SEP and DEP to transmit electricity entirely separately.
Horizontal directional drilling (HDD) zones	The areas within the onshore cable route which would house HDD entry or exit points.
ICES Rectangles	Statistical rectangles measuring 30 minutes of latitude, by 1 degree of longitude in size (approximately 30 nautical miles by 30 nautical miles). They are the smallest spatial unit for which fisheries data is collected.
Infield cables	Cables which link the wind turbine generators to the offshore substation platforms.
Interlink cables	Cables linking two separate project areas. This can be cables linking: 1) DEP South array area and DEP North array area 2) DEP South array area and SEP 3) DEP North array area and SEP 1 is relevant if DEP is constructed in isolation or first in a phased development.

	2 and 3 are relevant where both SEP and DEP are built.
Interlink cable corridor	This is the area which will contain the interlink cables between offshore substation platform/s and the adjacent Offshore Temporary Works Area.
Landfall	The point on the coastline at which the offshore export cables are brought onshore and connected to the onshore export cables.
Mollusc	An invertebrate of a large phylum which includes snails, slugs, mussels, and octopuses. They have a soft unsegmented body; live in aquatic or damp habitats with, most species having an external calcareous shell.
Offshore cable corridors	This is the area which will contain the offshore export cables or interlink cables, including the adjacent Offshore Temporary Works Area.
Offshore export cable corridor	This is the area which will contain the offshore export cables between offshore substation platform/s and landfall, including the adjacent Offshore Temporary Works Area.
Offshore export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall. 220 – 230kV
Offshore substation platform	A fixed structure located within the wind farm site/s, containing electrical equipment to aggregate the power generated by the wind turbines and increase the voltage before transmitting the power to shore.
Offshore Temporary Works Area	An Offshore Temporary Works Area within the offshore order limits in which vessels are permitted to carry out activities during construction, operation and decommissioning encompassing a 200m buffer around the wind farm sites and a 750m buffer around the offshore cable corridors. No permanent infrastructure would be installed within the Offshore Temporary Works Area.
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.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
Study area	Area where potential impacts from the project could occur, as defined for each individual EIA topic.
The Applicant	Equinor New Energy Limited
Sequential piling	A scenario where one pile is installed after another pile in the same 24 hour period (e.g. two monopiles in the same 24 hour period or four pin-piles in the same 24 hour period).
Single piling	A scenario where one pile is installed in a 24 hour period.
Simultaneous piling	A scenario where two piles are installed at the same time at different locations.
Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
Sheringham Shoal Offshore Wind Farm Extension Project (SEP) offshore site	Sheringham Shoal Offshore Wind Farm Extension consisting of the SEP wind farm site and offshore export cable corridor (up to mean high water springs).
Sheringham Shoal Offshore Wind Farm Extension Project (DEP) onshore site	The Sheringham Shoal Wind Farm Extension onshore area consisting of the SEP onshore substation site, onshore cable corridor, construction compounds, temporary working areas and onshore landfall area.
SEP wind farm site	The offshore area of SEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area.
Sound Exposure Level (SEL)	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.

Sound Pressure Level (SPL)	The sound pressure level or SPL is an expression of the sound pressure using the decibel (dB) scale, and the standard reference pressures of 1 μPa for water and 20 μPa for air.
Species of Conservation Interest	Marine species that are particularly threatened, rare, or declining.
Swim bladder	A gas-filled sac present in the body of many bony fish, used to maintain and control buoyancy and is also involved in hearing in some fish species.

9 FISH AND SHELLFISH ECOLOGY

9.1 Introduction

1. This chapter of the Environmental Statement (ES) describes the potential impacts of the proposed Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and Dudgeon Offshore Wind Farm Extension Project (DEP) on fish and shellfish ecology. The chapter provides an overview of the existing environment for the proposed offshore sites, followed by an assessment of the potential impacts and associated mitigation for the construction, operation and decommissioning phases of SEP and DEP.
2. This assessment has been undertaken with specific reference to the relevant legislation and guidance, of which the primary sources are the National Policy Statements (NPS). Details of these and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Impact Assessment (CIA) are presented in **Chapter 5 EIA Methodology** and **Section 9.4**.
3. The assessment should be read in conjunction with following linked chapters:
   - **Chapter 6 Marine Geology, Oceanography and Physical Processes**;
   - **Chapter 7 Marine Water and Sediment Quality**;
   - **Chapter 8 Benthic Ecology**;
   - **Chapter 10 Marine Mammal Ecology**;
   - **Chapter 11 Offshore Ornithology**; and
   - **Chapter 12 Commercial Fisheries**.
4. Additional information to support the fish and shellfish ecology assessment is included in **Appendix 9.1 Fish and Shellfish Ecology Baseline Technical Report** and **Appendix 10.2 Underwater Noise Modelling Report**.

9.2 Consultation

5. Consultation with regard to fish and shellfish ecology has been undertaken in line with the general process described in **Chapter 5 EIA Methodology** and the **Consultation Report** (document reference 5.1). The key elements to date have included scoping and the ongoing Evidence Plan Process (EPP) via the Sea bed Expert Topic Group (ETG), with meetings held in October 2019, June 2020, February 2021, August 2021 and March 2022, and the Preliminary Environmental Information Report (PEIR).
6. The feedback received throughout this process has been considered in preparing the ES. This chapter has been updated following consultation in order to produce the final assessment submitted within the Development Consent Order (DCO) application. **Table 9-1** provides a summary of the consultation responses received to date relevant to this topic, and details of how the Project team has had regard to the comment and how they have been addressed within this chapter.
7. The consultation process is described further in **Chapter 5 EIA Methodology**. Full details of the consultation process are presented in the **Consultation Report** (document reference 5.1), which has been submitted as part of the DCO application.

Table 9-1: Consultation Responses

Consultee	Date	Comment	Project Response
Scoping Responses			
The Planning Inspectorate	November 2019	Table 2-13 Physical disturbance and temporary loss of sea bed habitat, spawning or nursery grounds during intrusive works - operation. The Inspectorate is content that intrusive works during operation are not likely to occur on a scale that would result in significant effects and this matter can be scoped out of the assessment.	Noted
The Planning Inspectorate	November 2019	Permanent habitat loss - construction and decommissioning. The Scoping Report proposes to assess permanent habitat loss during operation and decommissioning only. A number of construction activities have the potential to result in a degree of habitat loss during construction. The Inspectorate considers that 'temporary habitat loss' should be scoped in for all phases of the Proposed Development as any interaction with the sea bed may cause loss of habitat for some species. This should include as assessment of likely significant effects from cable protection. The consultation responses from the MMO) and NE support this position. The Inspectorate therefore does not agree that construction and decommissioning phase effects can be scoped out of the assessment.	Potential temporary habitat loss / disturbance during construction is assessed in **Section 9.6.1.1**. Potential decommissioning impacts are assessed in **Section 9.6.3**.
The Planning Inspectorate	November 2019	Introduction of wind turbine foundations, scour protection and hard substrate – construction and decommissioning. During construction/decommissioning, turbines would be incrementally constructed/removed, with turbine foundations and scour protection also being installed/removed. As such, there is potential for effects to occur after installation of the first turbines (during construction) and until removal of the last (during decommissioning). Based on the information provided at this stage, the Inspectorate is unable to rule out a significant effect and does not agree that this matter can be scoped out of the ES. The ES should explain the assumptions that have been used to inform the assessment.	Noted. The impacts from introduction of hard substrates will start once the first piece of infrastructure is installed, as such the effects will start during construction. However, the worst-case scenario regarding the impacts of introduced hard substrates is once all infrastructure is in place. This has been assessed in **Section 9.6.2.4.**

Consultee	Date	Comment	Project Response
The Planning Inspectorate	November 2019	Underwater noise during foundation piling - operation and decommissioning. The Inspectorate is content that this matter is only relevant to the construction phase with no significant effects anticipated during operation and decommissioning and therefore can be scoped out of the assessment for operation and decommissioning.	Noted
The Planning Inspectorate	November 2019	Impacts from EMF - construction and decommissioning. The Inspectorate is content that this matter is only relevant to the operational phase with no significant effects anticipated during operation and decommissioning and therefore can be scoped out of the assessment for construction and decommissioning	Noted
The Planning Inspectorate	November 2019	Site specific surveys. The Scoping Report concludes that the existing data described in Table 2-14 is sufficient to undertake a robust assessment and therefore the Applicant does not propose to undertake further site specific surveys. Table 2-14 refers to characterisation surveys for the existing Dudgeon and Sheringham Shoal Offshore Wind Farm (OWF) ES's (undertaken in 2008 and 2005 respectively) and post-construction surveys at Sheringham Shoal (2012 and 2013). The table also identifies numerous other sources, including MMO landings data. The Inspectorate agrees that new fish characterisation surveys are not necessary as the sources of data proposed to inform the desk-based assessment will be adequate. The Applicant must ensure that the ES presents a robust baseline upon which to base its assessment and should acknowledge any limitations associated with the data sources. The Applicant should make effort to agree the baseline used in the assessment with the relevant consultation bodies.	Noted, further details are provided in **Section 9.4.2** and in **Section 9.1.2** of **Appendix 9.1**.
The Planning Inspectorate	November 2019	The Scoping Report identifies species of commercial importance and spawning and nursery areas. In accordance with NPS EN-3, the ES should also identify any feeding grounds, over-wintering areas for crustaceans and migration routes that could be significantly affected by the Proposed Development.	Evidence suggests that the brown crab (*Cancer pagurus*) migrate to offshore overwintering grounds where eggs are hatched, moving back to coastal areas in the spring. Mature females undertake long-distance migrations to the north

Consultee	Date	Comment	Project Response
		The location of these areas, in relation to the Proposed Development, should be depicted in the ES using appropriate figures.	(**Appendix 9.1**). Potential impacts on brown crab migrations are assessed in **Sections 9.6.1.1** and **9.6.1.2**
The Planning Inspectorate	November 2019	Cromer Shoal MCZ is predominantly designated for subtidal chalk habitat with a thin veneer of gravelly sand on top of the bedrock. The Inspectorate recommends the Applicant makes efforts to agree necessary pre-application surveys with NE in order to provide confidence that cable installation will be feasible within the site.	Noted. The pre-application benthic characterisation survey scope was shared and agreed with Natural England and the MMO. In addition, in Q4 2021, the Applicant undertook a geotechnical survey (cone penetrometer testing and vibrocores), including within the export cable corridor as it passes through the Cromer Shoal Chalk Beds (CSCB) Marine Conservation Zone (MCZ). A survey of this type would usually be undertaken post-consent nearer to the point of construction but has been brought forward in this case in order to provide further information to inform the cable burial studies and the associated environmental considerations. The results of the geotechnical survey are described in the **Outline CSCB MCZ Cable Specification and Installation Monitoring Plan (CSIMP)** (document reference 9.7).
The Planning Inspectorate	November 2019	The Applicant should ensure that benthic surveys are undertaken at appropriate times of year, taking into account weather conditions and the ability to collect satisfactory datasets.	Noted. As detailed in **Appendix 8.1** (document reference 6.3.8.1) and **Appendix 8.2** (document reference 6.3.8.2) of **Chapter 8 Benthic Ecology**, benthic surveys were undertaken in August 2020 and were not affected by weather conditions. Therefore, benthic datasets are appropriate.
The Planning Inspectorate	November 2019	The most recently published International Herring Larvae Survey 2019 should be used to inform the baseline. The assessment of herring potential spawning habitat should be undertaken using the method described in MarineSpace (2013) and informed by Particle Size Analysis data from the geophysical and	An assessment of potential herring spawning habitat based on MarineSpace *et al*. (2013) is included in **Appendix 8.3 SEP and DEP Habitat Mapping** and summarised in **Section 9.5.2.3.1**. **Appendix 9.1** includes 2019 International Herring Larvae Survey data and is used to inform the

Consultee	Date	Comment	Project Response
		benthic sampling surveys. Any likely significant effects on these areas should be assessed in the ES.	baseline. An assessment of potential impacts on herring spawning grounds is provided **Sections 9.6.1.1, 9.6.1.2** and **9.6.1.4** of this chapter.
The Planning Inspectorate	November 2019	The potential for impacts from suspended sediment during cable and foundation installation works has been scoped into the assessment. The ES should assess the likely significant smothering effects this could have on fish populations, including spawning and nursery areas, present within the zone of influence.	Potential impacts from a temporary increase in suspended sediment concentrations (SSC) is assessed in **Section 9.6.1.2**.
The Planning Inspectorate	November 2019	Underwater noise. The Inspectorate considers that increased underwater noise during construction has the potential to result in temporary threshold shift, recoverable injury and mortality to sensitive species. Significant effects associated with these impacts should be assessed in the ES. The Applicant is encouraged to make effort to discuss and agree the approach to this assessment with relevant consultation bodies including the MMO.	Potential underwater noise impacts are assessed in **Sections 9.6.1.4** to **9.6.1.6**.
The Planning Inspectorate	November 2019	The Scoping Report proposes to assess the effects of disturbance and displacement of acoustically sensitive fish species and spawning and nursery areas from underwater noise. The effects of mortality, injury, behavioural changes and auditory masking should also be assessed, where significant effects are likely. The Scoping Report provides little information on how the assessment will be undertaken. The assessment should explain how the characteristics of the receptors have been taken into account e.g. fish species and their capability to flee from noise sources. The Applicant should make efforts to agree the approach with the MMO.	Potential underwater noise impacts are assessed in **Sections 9.6.1.4** to **9.6.1.6**. Consideration of fish receptor capability to flee from underwater noise sources is provided in **Section 9.6.1.4.** In consultation with the MMO, the Applicant has, as a worst-case, considered a stationary animal model (i.e. non-fleeing) in formulation of the assessment conclusions.
The Planning Inspectorate	November 2019	Inter-relationships –fishing pressure. Reduced fishing pressure within the array has the potential to result in positive effects to commercially targeted species. The ES should assess any benefits associated with the reduced pressure, where significant effects are likely.	This is assessed in **Sections 9.6.1.7**, **9.6.2.9** and **9.6.3**.
The Planning Inspectorate	November 2019	The MMO notes that sandeel are of ecological importance as prey species for marine mammals and birds. It highlights that sand eel has a spatial dependency on a specific substrate and show site	This is assessed in **Section 9.6** of this chapter and **Section 9.3.3.9.1** in **Appendix 9.1**.

Consultee	Date	Comment	Project Response
		fidelity. The Inspectorate considers that the ES should include information to characterise the sandeel habitat in the array and export cable corridor and assess any likely significant effects to the species from the project alone and cumulatively with other plans or projects.	Potential inter-relationships with other topic assessments are discussed in **Section 9.9** and an assessment of potential impacts on marine mammal and offshore ornithology prey availability is provided in Chapters 10 and 11 respectively.
The Planning Inspectorate	November 2019	The ES should assess any likely significant effects to migratory fish transiting the area e.g. to/from the Wash and River Humber.	**Section 9.1.4.2** of **Appendix 9.1** describes the baseline for diadromous (migratory) fish, which is summarised in this chapter in **Section 9.5**. **Section 9.5.5** describes the diadromous fish species taken forward to the assessment in **Section 9.6**. The **HRA screening document** (document reference 5.4.2) screens for likely significant effects on Special Areas of Conservation (SAC) that have fish receptors as qualifying features. The screening exercise resulted in all sites with fish receptors as qualifying features being screened out of the assessment.
Marine Management Organisation	November 2019	The commercial and ecological importance of sandeel has not been discussed in any detail in the Scoping Report. The ecological and commercial importance of sandeel should be acknowledged in the ES and an appropriate species-specific impact assessment should be undertaken for sandeel.	Baseline characterisation is provided in **Section 9.5** and sandeel is further described in **Section 9.1.3.3.9** in **Appendix 9.1**. Potential impacts from changes to prey availability (i.e. fish species) are assessed in **Chapter 10 Marine mammal Ecology** and **Chapter 11 Offshore Ornithology**.
Marine Management Organisation	November 2019	Sandeel, as well as juvenile herring and sprat, are of ecological importance as a prey source for marine mammals and birds, some of which are protected and qualifying features of nearby Special Protection Areas (SPA) or Special Areas of Conservation (SAC) such as the Greater Wash SPA and The Wash & North Norfolk Coast SAC. Sandeel have a spatial dependency on a specific substrate and it is recognised that sandeel show site fidelity to defined areas of sea bed, and do not tend to travel to other locations to spawn.	

Consultee	Date	Comment	Project Response
Marine Management Organisation	November 2019	Otter and beam trawls are not considered suitable survey gears to adequately sample sandeel species. Catches of sandeel (e.g. from grabs, trawls) in the area can provide information on presence, however this method does not provide information about abundance and distribution. The most accurate method for assessing the SEP and DEP areas as a sandeel habitat would be through a sandeel dredge survey. Surveys would need to be carried out either during night-time or during seasonal hibernation periods, using specific sandeel dredge gear. To provide a statistically robust study these surveys would have to be carried out over a number years pre- and post-construction. This may be disruptive for the population, and the study would be expensive, so this is not recommended by the MMO. Instead, the EIA would be expected to characterise sandeel habitat following the method described in MarineSpace (2013b) which uses broadscale sediment data and site-specific PSA data from the array and export cable corridor. As per the assessment of herring potential spawning habitat, PSA data collected during the proposed benthic sampling surveys can be used to inform the area's suitability as sandeel habitat. Any catches of sandeel observed in grabs will provide anecdotal evidence of their presence in the array and export cable route areas.	An assessment of potential sandeel habitat is included in **Appendix 8.3 SEP and DEP Habitat Mapping** based on Latto *et al*. (2013) as agreed with Cefas at the Seabed ETG 3 on the 3rd of February 2021. An alternative method is also presented using grab samples assessed for sandeel preference based on Greenstreet *et al*. (2010), and mapping between samples based on recent site specific geophysical survey data. This assessment is summarised in **Section 9.5.2.3.2**.
Marine Management Organisation	November 2019	Whilst there are a number of broad areas of the Southern North Sea that are considered suitable as sandeel habitat, many areas are already subjected to anthropogenic activities such as windfarm construction, trawling and aggregate dredging. Additionally, many areas may not provide suitable habitat due to physical parameters such as incompatible substrate composition or water depth. The cumulative impact assessment should consider these factors when assessing the impacts of the windfarm development on sandeel.	Cumulative impacts are assessed in **Section 9.7**.
Marine Management Organisation	November 2019	Migratory fish species should be included in the assessment and the various conservation statuses of these species should also be considered. Potential impacts from construction and operational activities should be adequately assessed in relation to migratory fish transiting the area e.g. to/from the Wash and River Humber.	Throughout the assessment in **Section 9.6** certain species or groups are assessed individually, however where receptors are not specific, they are included under "all fish species" assessments.

Consultee	Date	Comment	Project Response
		The Environment Agency carry out fisheries surveys to monitor coastal and transitional waters, including the River Humber and the Wash. Data can be downloaded via; https://data.gov.uk/dataset/41308817-191b-459d-aa39-788f74c76623/trac-fish-counts-for-all-species-for-all-estuaries-and-all-years.	**Section 9.5.5** describes the diadromous fish species taken forward to the assessment.
Marine Management Organisation	November 2019	Generally, the approach to the scoping assessment is appropriate in that it sets out the proposed methods to be used to inform and undertake the EIA. However, given that the scoping report is intended to support an application for the construction of up to two nationally significant infrastructure projects (NSIPs), more detailed descriptions of the potential impacts to fisheries and fish ecology as well as more detailed explanations of how the potential impacts to key sensitive species will be assessed would have been beneficial.	Noted. Further details are included in this chapter in **Sections 9.6.1.7**, **9.6.2.9, 9.6.3** and **in Chapter 12 Commercial Fisheries**.
Marine Management Organisation	November 2019	The table of data sources (Table 2-14) proposed for the characterisation of the existing environment for fish is generally appropriate. However, there are some concerns with the timeliness of data collected during the Dudgeon and Sheringham Shoal OWF EIA characterisation surveys and the Sheringham Shoal OWF Post- construction surveys for the reasons outlined below: The Environmental Statement (ES) should recognise the limitation that the data collected for EIA fish characterisation surveys for Dudgeon OWF (2008) and Sheringham Shoal OWF (2005) are now in excess of 10 years old, and that the surveys were carried out prior to the placement and operation of OWF infrastructure. Factors such as loss of habitat, introduction of hard substrates, and temporal and natural variations in fish assemblages may have changed over this period. However, the MMO advise there is no requirement for new fish characterisation surveys to be undertaken, as the various sources of data proposed to inform the desk-based assessment will be adequate to provide a general description of the fish species typically found in the SEP and DEP areas.	Limitations of data sources are discussed in **Section 9.4.2** and in **Section 9.1.2** of **Appendix 9.1**.

Consultee	Date	Comment	Project Response
Marine Management Organisation	November 2019	Point 292 of the Scoping Report refers to the Sheringham Shoal post-cable installation elasmobranch survey which recorded a single starry smooth-hound (*Mustelus asterias*) in the export cable corridor just south of the wind farm array (Brown & May Marine, 2013). Conversely, starry smooth-hounds represented the greatest numbers caught in the pre-construction cable installation elasmobranch survey report (Brown & May Marine, 2010). The MMO recommend that if data from the Sheringham Shoal Post-cable Installation Elasmobranch Survey 2013 are to be used to inform the EIA, then so too should data from the Post-Cable Installation Elasmobranch Survey Reports from 2012 and 2015 and the Pre-construction Cable Installation Elasmobranch Survey Report (Brown & May Marine, 2010).	This has been included in **Section 9.4.2.1** and in **Section 9.1.2.4.4** of **Appendix 9.1**.
Marine Management Organisation	November 2019	It should also be noted that there are no recent confirmed records of common smooth-hound (*Mustelus mustelus*) (listed in Table 2-11) being captured in UK waters. A genetic study (Farrell *et al.*, 2009) confirmed that all specimens investigated were found to be starry smooth-hounds (*Mustelus asterias*). Therefore, it may be more appropriate to refer to *Mustelus spp*. in the ES.	Noted, this is discussed further in **Section 9.1.2.4.4** of **Appendix 9.1**.
Marine Management Organisation	November 2019	When using any fisheries data collected from past surveys, it is important that the data are interpreted and presented appropriately and that all survey limitations are acknowledged within the ES, as per point 1.3.9. It is recommended that any trawl or longline catch data should be presented in standardised units, for example, Catch Per Unit Effort (CPUE). The survey methods, timings and limitations of survey and gear types as well as gear selectivity should be discussed or acknowledged within the ES, especially with regard to the influence on species and life stages captured by individual gear types/sampling methods. For example, a 2m epibenthic beam trawl will not adequately target large/adult fish, or pelagic fish; otter trawls and epibenthic beam trawls will not adequately target sandeels and the season in which a survey is undertaken may influence species abundance in that particular area.	These are stated in **Table 9.1.1** in **Appendix 9.1**.

Consultee	Date	Comment	Project Response
Marine Management Organisation	November 2019	The Scoping Report has correctly identified that herring are sensitive to activities that disturb the sea bed and are sensitive to noise and vibration, making them vulnerable to the impacts of OWF (OWF) construction and operation activities. Comments and recommendations are provided below on how the assessment of impacts for this species should be carried out.	Potential impacts on herring are assessed in **Section 9.6**.
Marine Management Organisation	November 2019	The nearest herring spawning ground to the DEP and SEP sites, is that of the Banks/Dogger population off the coast of Flamborough Head. Some smaller, localised herring spawning grounds also exist at locations along the Norfolk and Lincolnshire coasts and outside the Wash, although due to a lack of recent larval data for these locations it is not known whether these sites are currently 'active'. The MMO recommend that an assessment of herring potential spawning habitat is undertaken to inform the EIA, using the method described in MarineSpace (2013). The assessment should be supported by 10 years of International Herring Larval Survey (IHLS) data (data up to 2018 are available). The applicant's intention to undertake a program of geophysical and benthic sampling across the proposed wind farm areas and export cable corridors in order to characterise the sea bed is noted. PSA data from these surveys can be used to inform the potential herring spawning habitat assessment.	An assessment of potential herring spawning habitat based on MarineSpace *et al*. (2013) is included in **Appendix 8.3 SEP and DEP Habitat Mapping** and summarised in **Section 9.5.2.3.1**.
Marine Management Organisation	November 2019	Little information is presented on how the assessment of impacts of noise and vibration on fish will be carried out, or what resources will be used, or the proposed methods for modelling. An accurate description of the physiological and behavioural impacts to fish caused by noise and vibration should be presented in the ES, and fish species relevant to the development should be assigned into one of the four categories described in Popper *et al.* (2014).	Potential impacts from underwater noise are assessed in **Section 9.6.1.4**.
Marine Management Organisation	November 2019	We recommend that fish are treated as a stationary receptor in any modelling used to make predictions for noise propagation on fish spawning and nursery grounds. The MMO does not support the use of a fleeing animal model for fish for the reasons outlined below:	The conclusions of the assessment are based on modelling of fish as stationary receptors. This is assessed in **Section 9.6.1.4**.

Consultee	Date	Comment	Project Response
		It is known that fish will respond to loud noise and vibration, through observed reactions including schooling more closely, moving to the bottom of the water column, swimming away and burying in the substrate (Popper *et al.* 2014). However, this is not the same as fleeing, which would require a fish to flee directly away from the source over the distance shown in the modelling. The MMO is not aware of scientific or empirical evidence to support the assumption that fish will flee in this manner.	
Marine Management Organisation	November 2019	The assumption that a fish will flee from the source of noise is overly simplistic as it overlooks factors such as fish size and mobility, biological drivers and philopatric behaviour which may cause an animal to remain/return to the area of impact. This is of particular relevance to herring, as they are benthic spawners which spawn in a specific location due to its substrate composition	Noted. The underwater noise modelling has considered a stationary receptor which forms the basis of the assessment conclusions in **Section 9.6.1.4**. However, as noted in section 2.2.2.2 of the underwater noise modelling report (**Appendix 10.2** (document reference 6.3.10.2), basing the modelling on a stationary (zero flee speed) receptor is likely to greatly overestimate the potential risk to fish species (including herring), 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.
Marine Management Organisation	November 2019	Eggs and larvae have little to no mobility, which makes them vulnerable to barotrauma and developmental effects. Accordingly, they should also be assessed and modelled as a stationary receptor, as per the Popper *et al.* (2014) guidelines.	Potential impacts on fish eggs and larvae has been considered assuming a stationary receptor and is assessed in **Section 9.6.1.4**.
Marine Management Organisation	November 2019	The outputs of modelling should be presented in map-form depicting the predicted noise contours. 10 years of IHLS data (2008-2018) should be presented in the form of a 'heat map' which should be overlaid with the mapped noise contours. This will provide a better understanding of the likely extent of noise propagation into herring spawning grounds and allow for a more robust assessment of impacts to be made.	This is discussed in **Section 9.6.1.4.2** and presented in **Figure 9.6**.

Consultee	Date	Comment	Project Response
Marine Management Organisation	November 2019	The applicant should clearly state in their ES (and PEIR if applicable) whether they propose to undertake simultaneous piling, i.e. the installation of more than one pile at a time, for the installation of WTGs or other offshore platform structures. If simultaneous piling is proposed, then underwater noise modelling for impacts to fish should be based on this scenario.	Simultaneous piling is possible should SEP and DEP be constructed concurrently. In this scenario, as a worst-case, one piling operation could occur in the SEP wind farm site at the same time (i.e. simultaneously) as a piling operation in the DEP wind farm site (one piling operation per project). This is discussed and assessed in **Section 9.6.1.4.2**.
Marine Management Organisation	November 2019	The applicant should also consider the use of embedded mitigation and good practice measures to remove or reduce impacts and effects on fish. Such measures might include; The use of soft start procedures on commencement of piling. The MMO's technical advisers Cefas recommend a 20-minute soft-start in accordance with the Joint Nature Conservation Committee (JNCC) protocol for minimising the risk of injury to marine mammals and other fauna from piling noise (JNCC 2010). Should piling cease for a period greater than 10 minutes, then the soft-start procedure must be repeated. Cable burial to a minimum depth of 1.5 m (subject to local geology and obstructions) to minimise the effects of EMF, as recommended in the Department of Energy and Climate Change report (2011). The use of air bubble curtains to reduce or mitigate the impacts of noise and vibration from piling.	Mitigation is described in **Section 9.3.3**.
Marine Management Organisation	November 2019	Potential impacts are categorised by development phase in the report. Whilst a number of potential impacts are identified these are not associated with specific species. Further detail and clarification should be provided as the application progresses. Generally, all relevant impacts to shellfish species and shell-fishers have been scoped in.	Addressed in **Section 9.6**.
Marine Management Organisation	November 2019	Permanent habitat loss to shellfish has been scoped in during the operation stage but scoped out for both construction and decommissioning. "Permanent habitat loss" suggests that the habitat will never recover. The MMO advise changing this to	Noted. Temporary habitat loss has been assessed along with physical disturbance for all project phases in **Sections9.6.1.1, 9.6.2.2** and **9.6.3**. Permanent habitat loss has been included in the

Consultee	Date	Comment	Project Response
		"temporary habitat loss" and scoping the impact into both the construction and decommissioning phases as any interaction with the sea bed may cause loss of habitat for some species and all phases of the project could result in temporary habitat loss for shellfish. It is notable from the report that "permanent habitat loss" is intended to complement "Physical disturbance and temporary loss of sea bed habitat, spawning or nursery grounds during intrusive works", however, the two are not similar and should not be considered so.	assessment for infrastructure that may be decommissioned *in situ*, in **Section 9.6.2.2**..
Natural England	November 2019	General. Overall the proposed approach seems appropriate. Please see the following two comments, and otherwise, Natural England defers to the expert advice at Cefas with regards to the need for surveys or additional assessment work for Fish and Shellfish.	Noted
Natural England	November 2019	Potential impacts here should also include impacts from disposal activities, such as smothering of larvae or potential changes to habitat.	This is discussed in **Sections 9.6.1.2**, **9.6.2.5** and **9.6.3**.
Natural England	November 2019	Data from the most recently published International Herring Larvae Survey 2019 report should also be included to confirm what spawning, if any, is occurring at the identified potential spawning area. September 2019 is the latest publication at time of writing. Table 2-14 suggests that only up to 2018 will be considered.	International Herring Larvae Survey data has been used with data up to and including 2022 (see Appendix 9.1).
ETG Meetings			
Cefas & MMO	October 2019	Cefas stated that the assessment has to acknowledge limitations of the existing data. MMO also stated that fish surveys from previous projects encountered access problems on cable routes due to fishing activity, resulting in some stations being missed. This limitation should also be acknowledged.	This is discussed in **Section 9.4.2** and in **Appendix 9.1**.
Cefas & EIFCA	June 2020	Cefas and EIFCA stated that there might be whelk fishery present in the area. There is anecdotal information from members of fishing community that the whelk community was affected by installation of pipelines and that organotins could be present at depth. Cefas	A subset of sediment samples were tested for organotins. Full details are presented in **Chapter 7 Marine Water and Sediment Quality**. The impacts of any sediment bound contaminants are assessed in **Section 9.6.1.3.**

Consultee	Date	Comment	Project Response
		stated that organotins should not be excluded from sediment sample chemical analysis.	
Cefas	February 2021	Cefas commented on levels of herring spawning in area and noted that the previous (Dudgeon and Sheringham Shoal) survey results should not be treated as conclusive as they were not consistent, however agreed that herring spawning is not prevalent in the areas considered for SEP and DEP. The potential relevance of the Flamborough Head grounds to this project was noted, which should be considered alongside the outputs of the UWN modelling and the available IHLS data. Assessment should acknowledge data gaps.	Limitations of the data are acknowledged in **Table 9-5** and **Appendix 9.1**. The likelihood of herring spawning in the SEP and DEP offshore sites is discussed in **Section 9.5.2.2.2**. The spatial overlaps of underwater noise impact ranges and the herring spawning areas is shown in **Figure 9.6** and **9.7**, and the spatial overlap of underwater noise impact ranges and the IHLS Small Larvae Abundance area are shown in **Figures 9.43** to **9.46**.
Cefas	February 2021	Commercial landing results collected in the past were not always consistent and therefore feedback will be provided based on the interpretation of results within the PEIR. However, Cefas stated that they are happy with the species identified. And stressed that data used within the assessment should not normally be older than 5 years, or where it is that the limitations are noted.	Various reports and regional survey data have been included to inform the baseline and are presented in **Section 9.4.2** and **Section 9.1.2** of **Appendix 9.1.**
Cefas	August 2021	Sandeel and herring habitat / spawning habitat to be expressed in terms of percentage of habitat which is considered to be *suitable* rather than areas being defined explicitly as habitat or spawning ground.	Permanent habitat loss is assessed in **Section 9.6.2.2.** Habitat / spawning habitat is expressed as being potentially suitable rather than areas being defined explicitly as habitat or spawning ground.
Cefas / MMO and Natural England	August 2021	Underwater noise modelling from concurrent piling between SEP and DEP to be undertaken and included in the assessment. Behavioural contours to also be included.	Both simultaneous piling (i.e. one piling operation occurring in the SEP wind farm site at the same time (i.e. simultaneously) as a piling operation in the DEP wind farm site) and sequential piling within a 24 hour period have been considered within the updated underwater noise modelling (**Appendix 11.2**).

Consultee	Date	Comment	Project Response
			Behavioural response impact ranges based on observed levels from Hawkins *et al.* (2014) have been used to inform the single piling scenarios (**Table 9-22**). Whilst the authors note that the results of the study cannot yet be used to define sound exposure criteria for use in EIA, in the absence of reliable numerical criteria for behavioural disturbance in fish, it is considered that the values provide a useful metric to inform the assessment. It should be noted that the study was conducted under conditions in quiet inland waters which are unlikely to be equivalent to those around the SEP and DEP offshore sites. As requested by the MMO impact contours are shown on **Figure 9.8** for a 135dB SEL single strike (SS) scenario in relation to potential herring spawning grounds. Contours for the 1st strike and maximum hammer energies are presented. The impact contours do not extend into the IHLS survey areas to the north east where herring spawning activity is presumed to be concentrated.
Cefas / MMO	March 2022	Include IHLS data for 2021 and 2022.	**Appendix 9.1** and associated herring IHLS data figures have been updated.
Cefas / MMO	June 2022 (response to March 2022 ETG meeting minutes)	The calculation of total spawning habitat and defining the extent of an affected habitat as a percentage, can either over or underrepresent spawning grounds. Efforts to quantify impacts to spawning grounds are likely to provide inaccurate and/or misleading figures for the following reasons: • Spawning areas can change over time or become recolonised.	Noted. Where appropriate, the Applicant has indicated percentages of the specific areas of the offshore sites that may be subject to disturbance or habitat loss as a result of construction activities or project infrastructure however this has not been directly associated with an equivalent loss in spawning habitat. The assessment therefore determines magnitude of effect on spawning grounds on a qualitative basis. **Section 9.5.2.3** has been updated to include the potential

Consultee	Date	Comment	Project Response
		• Whilst spawning and nursery ground maps are used to provide the most recent and appropriate information to identify spawning areas, they do not fully define/consider/identify: ○ All potential areas of spawning. ○ Any habituation that may occur i.e., identify areas where higher densities of spawning are present. ○ Specific substrate requirements e.g., substrates which are more suitable within wider broadscale sediments. ○ More suitable topography e.g., ridges/edges of sandbanks where sandeel may spawn or furrows where herring may spawn. ○ Environmental factors that may influence spawning intensity such as temperature, oxygenation, natural disturbance, anthropogenic disturbance etc.	limitations of attempting to quantify this, as outlined by the MMO/Cefas. The Applicant has retained the percentage calculations of potentially suitable spawning habitat / habitat based on the methods used for herring (**Section 9.5.2.3.1**) and sandeel (**Section 9.5.2.3.2**) in order to provide site context given the differing geographical areas of the SEP and DEP offshore sites.
Section 42 responses			
MMO	June 2021	8 Chapter 11. Fish Ecology Observations 8.1 The PEIR appears to have considered all the relevant finfish biota receptors, with a few key species taken forward for consideration and other species reviewed in more depth within the technical reports. Appropriate impacts have been identified. As previously advised for the scoping opinion certain impacts have been appropriately scoped out, particularly where they are not relevant for the development stage applicable/relevant to that stage of the development. This was an acceptable approach.	Noted
MMO	June 2021	8.2 MMO note that SEP and DEP could be constructed at the same time or sequentially with a maximum 4 year gap start to start and 1 year gap in offshore construction, which has potential implications for potential piling impacts upon fish receptors. The PEIR details	The offshore construction programme is described in **Chapter 4 Project Description.** Offshore construction works would require up to two years per project (excluding pre-construction

Consultee	Date	Comment	Project Response
		that simultaneous piling could also be possible (one piling operation per project).	activities such as surveys), assuming SEP and DEP were built at different times. If built at the same time, offshore construction could be completed in two years. Accounting for the development scenarios described in **Section 4.1.1 of Chapter 4 Project Description**, there could be a gap of up to one year between the completion of offshore construction works on the first Project and the start of offshore construction works on the second Project. The noise modelling has been updated to account for potential simultaneous piling between SEP and DEP and **Section 9.6.2.7** has been updated accordingly. Simultaneous piling is possible should SEP and DEP both be constructed concurrently. In this scenario, as a worst-case, one piling operation could occur in the SEP wind farm site at the same time (i.e. simultaneously) as a piling operation in the DEP wind farm site (one piling operation per project).
MMO	June 2021	8.3 MMO recognise and support that the Applicant has taken previous consultation comments regarding evidence sources on board when discussing the data available on the fish species present within the proposed development areas. The Applicant has also utilised the following data sources: spawning and nursery grounds identified in Coull *et al*., (1998) and Ellis *et al*., (2012), ICES International Herring Larval Survey (IHLS), Sheringham shoal elasmobranch surveys (pre and post cable installation), Project benthic characterisation survey. MMO support the inclusion of these sources of evidence in the PEIR assessment. 8.4 MMO note that the Applicant has included data from the pre- and post-construction surveys for fish and elasmobranchs for Dudgeon and Sheringham Shoal operational windfarms, including	Noted.

Consultee	Date	Comment	Project Response
		their associated limitations in both Chapter 11 and the associated technical report, which is suitable.	
MMO	June 2021	8.5 The Applicant has identified mitigation measures in respect to fish biota in Table 11-3. MMO note that any requirement for UXO removal will require a separate Marine licence application. The final requirement for mitigation measures should be informed by the outcomes of the EIA. MMO support the current mitigation measures proposed.	Noted. As agreed at the marine mammals ETG meeting on the 20th July 2020, UXO clearance requirements will be addressed through a separate Marine Licence application post consent. An assessment has been provided within **Section 9.6.1.6** for information purposes only.
MMO	June 2021	8.6 The MMO broadly support the cumulative and inter-related descriptions which will be discussed in further detail in the EIA.	Noted. Cumulative impacts are assessed in **Section 9.7** and Inter-relationships in **Section 9.9**.
MMO	June 2021	8.7 The distribution of fish species included in the assessment are independent of national geographical boundaries. The assessment for DEP and SEP has been undertaken, taking into account the distribution of fish stocks and populations, irrespective of national jurisdictions. The assessment has demonstrated that the spatial extent of impacts from the construction, operation and decommissioning of DEP and SEP do not stretch beyond UK waters. As such, no transboundary impacts are anticipated with respect to fish ecology. MMO support this conclusion.	Noted
MMO	June 2021	With regard to Paragraph 379 – It is stated that *'elasmobranchs typically having wide distribution range and defined nursery grounds. Literature on elasmobranch spawning is limited and elasmobranch abundance is overall low within the area of the SEP and DEP sites'.* While the MMO generally agree that there is limited information on elasmobranch abundance in the vicinity of SEP and DEP, there are some data sources available that may help elucidate this. Bird *et al*. (2020) reviewed fifty years of skate mark-recapture tagging data and show there to be skate movements in ICES division Area 4.c and in the vicinity of SEP and DEP. Further information can be found in the Thornback Ray Cefas Fisheries Science Partnership Report.	Additional information in reference to Bird *et al.* (2020) and McCully *et al.* (2013) has been added to **Section 9.5.1** and **9.6.2.8.2**.
MMO	June 2021	The MMO note that the study area for the desk-based finfish assessment is generally focused to International Council for the Exploration of the Seas (ICES) statistical rectangles scale of 34F1	Noted.

Consultee	Date	Comment	Project Response
		and 35F1 (local) and 34F0 and 35F0 (regional), which is appropriate. MMO landings data are discussed for both study areas, though International Bottom Trawl Survey (IBTS) is mainly considered only for the local area. While the MMO consider this to be satisfactory for most of the impacts assessed, the potential impact ranges associated with piling, in particular Temporary Threshold Shift (TTS) seems to overlap into the regional study area. As IBTS data have been included from both quarter 1 and quarter 3 surveys and standardised catch per unit effort (CPUE) plots are presented in the technical report for key species (e.g., herring Figure 11.5), it would be useful to include IBTS from the regional study area in Chapter 11 to improve the robustness of the assessment. This is particularly of interest for potential piling impacts upon herring and sandeel.	**Section 9.5.2.2.2** provides detail of IBTS surveys for the regional study area (as defined by ICES rectangles 34F0 and 35F0). **Appendix 9.1** has also been updated to reflect the findings of the surveys in this area noting that there are no IBTS data available for 34F0.
MMO	June 2021	There is potential for concurrent piling to take place at SEP and DEP. The Applicant has identified that the noise exposure contours for the monopile worst-case maximum hammer energy scenario (5,500 kilojoules ‘kJ’) for the two sites do not overlap for mortal injury or injury but do for TTS (Chapter 11, point 261). However, it is not clear to the MMO if the Applicant has modelled a concurrent piling scenario or just considered the overlap of the SEP and DEP separate modelled impact ranges for TTS, mortal injury etc.	Additional modelling has been carried out to investigate the potential impacts of two pile installations occurring simultaneously at separated foundation locations. This is described in **Section 9.6.1.4** (and in more detail in **Section 5.3** of **Appendix 10.2**). Using the worst-case monopile and pin pile scenarios (**Table 9-2)**, modelling has been carried out for simultaneous piling at both the SEP E and the DEP SE modelling locations, representing the worst-case locations of each site. The modelling assumed that the two piling operations start at the same time. **Section 9.6.1.4** has been updated to consider a simultaneous piling scenario.
MMO	June 2021	It does not appear to the MMO that specific behavioural contours have been modelled for piling impacts, though note that the Applicant has acknowledged that behavioural impacts may extend beyond the TTS impact ranges. At present the MMO do not consider that this has not been fully assessed and express potential concerns for Banks gravid adult herring which are likely to	Behavioural response impact ranges based on observed levels from Hawkins *et al.* (2014) have been used to inform the single piling scenarios (**Table 9-22**). Further detail and results are provided in **Appendix 10.2**. Whilst the authors note that the results of the study cannot yet be

Consultee	Date	Comment	Project Response
		exhibit behavioural responses to noise and vibration from piling. The TTS contours presented in Figure 11.6 show that they extend towards the southern extent of the Flamborough Head herring spawning ground (towards IHLS data area) and it is not clear if behavioural impacts from piling may impact herring on this spawning ground.	used to define sound exposure criteria for use in EIA, in the absence of reliable numerical criteria for behavioural disturbance in fish, it is considered that the values provide a useful metric to inform the assessment. It should be noted that the study was conducted under conditions in quiet inland waters which are unlikely to be equivalent to those around the SEP and DEP offshore sites.
MMO	June 2021	MMO would have expected the Applicant to also model behavioural impacts from the percussive piling. TTS and behaviour are neither the same nor assessed using the same noise exposure criteria: the biological basis for TTS can involve reversible damage to the ear whereas behavioural effects can cause avoidance. Please see below for further comments.	
MMO	June 2021	The MMO have concerns relating to behavioural responses in herring from piling: 8.13.1 Spawning – It is not known exactly how herring will react to the noise on reaching the spawning grounds, so it cannot be concluded with confidence that there will not be any impact. If herring were to exhibit avoidance/fleeing behaviour, then they may be unable to reach their spawning grounds potentially resulting in spawning failure that year. 8.13.2 Migration - Herring migrate through the North Sea in a north-south direction with spawning occurring during this time at suitable spawning grounds. Accordingly, the timing of spawning occurs earlier in the season in the northern spawning grounds and occurs later in the season as the stock migrates south.	**Section 9.6.1.4** provides an assessment of potential underwater noise impacts which has been updated for the ES and includes consideration of potential impacts on herring spawning.
MMO	June 2021	8.14 The MMO note that concerns of TTS relate less so to eggs and larvae given their immobility and/or reduced motility.	Noted.
MMO	June 2021	8.15 The MMO would like to request further information is provided for additional noise modelling depicting the behavioural noise contours based on monopiling for a stationary receptor. Noise modelling should be presented for the received levels of single strike sound exposure levels (SELss) at the herring spawning grounds based on 135 decibels (dB) in order to determine the likely range in which behavioural responses in herring could occur.	A stationary receptor has been assumed for all relevant (i.e. SEL_{cum}) underwater noise modelling criteria and assessments in **Table 9-22.** SELss impact ranges (to which neither a fleeing or stationary animal model apply since this measures a single noise event) based on 135dB are

Consultee	Date	Comment	Project Response
			presented in **Table 9-22** and indicate that behavioural responses could occur at a maximum range of up to 39km. As requested, impact contours are shown on **Figure 9.8** for a 135dB SELss scenario at the SEP North and DEP North modelling locations (i.e. those closest to the herring spawning ground to the north west) in relation to potential herring spawning grounds. Contours for the 1st strike and maximum hammer energies are presented. The impact contours do not extend into the IHLS survey areas to the north east where herring spawning activity is presumed to be concentrated.
MMO	June 2021	8.16 The Applicant has outlined mitigation to reduce the impact of Electromagnetic Fields (EMF) on elasmobranchs by burying the cable to between 0.5 – 1.5 m (Point 22). The ideal depth to reduce the impact to is 1.5 m, but this may not be possible in all areas depending on ground conditions. The MMO note that the burial risk assessment was a draft and that once further geotechnical and geological investigations have been undertaken that further information on burial depth techniques and options will be presented.	The Applicant will make reasonable endeavours to bury offshore cables, reducing the effects of EMF and also reducing the need for surface cable protection which reduces the introduction of hard substrate and modification of habitat. The **Outline CSCB MCZ CSIMP** (document reference 9.7) and its appendices provide further detail on the anticipated cable installation and protection requirements within the CSCB MCZ. Post consent, a CSIMP covering the full extent of the SEP and DEP offshore sites will be produced and will provide detailed cable laying plans and burial specifications.
MMO	June 2021	8.17 With regard to potential impacts to elasmobranchs from EMF, there is limited information and great uncertainty on impacts to marine fauna and their life stages, consequently significant uncertainties concerning electromagnetic effects remain (Gill and Desender, 2020). The MMO would like to highlight a recent study by Hutchison et al., (2020), which found multiple statistically	The assessment of potential impacts from EMF has been updated (**Section 9.6.2.8**). The Hutchison et al. (2020) study examined HVDC cables which tend to emit higher strength EMF than HVAC cables that will be installed at SEP and

Consultee	Date	Comment	Project Response
		significant differences in the behavioural parameters of little skate (*Leucoraja erinacea*) and American lobster (*Homarus americanus*) when exposed to EMF from sub-sea cables with a target burial depth of 1.2–1.8 m.	DEP. However, that study, together with Hutchison *et al.* (2018), Gill and Dessender (2020) and other recent studies have been used to bolster the EMF assessment.
Natural England	June 2021	Summary of Main Points 4) Impacts on the Natural Environment Fish and Shellfish Natural England have focused on the impacts to herring and sandeel, in particular spawning grounds. Sandeel and herring are both important prey species for fish, birds and marine mammals. We have concerns that the PIER does not take into consideration that scour and rock protection will result in permanent habitat change and will reduce the available spawning grounds for these species. We are particularly concerned about the DEPN area as this is key spawning habitat for sandeels.	Permanent habitat loss and long term habitat loss are considered as separate impacts in **Sections 9.6.2.2** and **9.6.2.3** respectively. Consideration of the potential loss of habitat suitable for herring and sandeel spawning is provided in these sections. See below for responses to Natural England's specific comments on these matters.
Natural England	June 2021	Chapter 11 Fish Ecology Detailed Comments Subject: 11.5.2.3 Comment: Gravel and sandy gravel are preferred spawning habitats for herring. “Areas identified as ‘Preferred’ herring spawning habitat comprise approximately 21% of the DEP wind farm sites and 10% of the SEP wind farm site.” Given that sandeel are an important prey species for fish, birds and marine mammals, we have concerns that work within the windfarm sites will result in temporary habitat loss/disturbance from construction activities, and permanent habitat loss/change through the ongoing presence of turbines and rock protection. Recommendation:	Permanent change in habitat is scoped in and assessed in **Section 9.6.2.2**. As described in **Chapter 4 Project Description,** scour protection would only be used in areas subject to scour and therefore scour protection would be minimised throughout the SEP and DEP wind farm sites. The installation of external cable protection would be required where cables cannot be buried due to ground conditions or where minimal burial depths cannot be achieved. Within the MCZ the Applicant has committed to remove any external cable protection installed. A realistic worst-case of up to 1,800m^2 of external

Consultee	Date	Comment	Project Response
		Scope in the permanent change in habitat from rock protection. We would welcome further information and/or discussions around minimising the use of cable protection and scour prevention in habitat suitable for herring spawning. Consider seasonal restrictions to avoid construction activities in habitat suitable for herring spawning during peak herring spawning (Aug-Oct).	cable protection within the MCZ for the duration of SEP and DEP is assessed in **Section 9.6.2.3.** The **Outline CSCB MCZ CSIMP** (document reference 9.7) describes the experience of the Dudgeon Offshore Wind Farm (DOW) export cable installation which did not require any external cable protection. As described in the **Outline CSCB MCZ CSIMP**, the SEP and DEP export cable route runs parallel to the DOW export cables in an area of similar sea bed sediments and therefore the likelihood of needing external cable protection at SEP and DEP is relatively low.
Natural England	June 2021	Chapter 11 Fish Ecology Detailed Comments Subject: 11.5.2.3 Comment: Sand and gravelly sand is preferred spawning habitat for sandeel. The majority of sediment samples from the DEP wind farm sites are assessed as 'Preferred' sandeel habitat. "Areas identified as sandeel Preferred habitat comprise approximately 61% of the DEP wind farm sites and less than 4% of the SEP wind farm site." Given that sandeel are an important prey species for fish, birds and marine mammals, we have concerns that work in the DEP windfarm site will result in temporary habitat loss/disturbance from construction activities, and permanent habitat change/loss through rock protection. We are particularly concerned about Dudgeon North area as this is key spawning habitat. Recommendation: Scope in the permanent habitat loss from rock protection. We would welcome further information and/or discussions around minimising the use of cable protection and scour prevention in habitat suitable for sandeel spawning.	Permanent change in habitat is scoped in and assessed in **Section 9.6.2.2**. Further detail on sandeel has been added to the assessment. An impact of minor adverse significance is predicted and therefore the Applicant does not consider that seasonal restrictions on construction activities are necessary. **Table 4-1** of **Chapter 4 Project Description** identifies the development scenarios and how they relate to the grid options. The Applicant agrees that the development/build out scenarios have implications for the scale of impacts and for this reason has carefully considered and assessed each option (see **Table 9-2**). This ensures that the worst-case scenario is addressed and allows mitigation to be specific to each scenario. It should be noted that the focus is on identifying and assessing the worst-case scenario (in line with the PINS s51 advice on this matter dated 21 May 2021). In this manner, differences are assessed by

Consultee	Date	Comment	Project Response
		Consider seasonal restrictions to avoid construction activities in habitat suitable for sandeel spawning during peak sandeel spawning (Nov-Feb). In addition, we would welcome the assessment of impacts due to DEPN, DEPS, SEP and SEP & DEP combined, set out in tabular format	exception. The fish ecology assessment details how each scenario has been considered and, where appropriate, e.g. in consideration of suitable herring spawning and sandeel habitat, the differing sensitivities of each of the wind farm sites have been considered within the impact assessment. In addition, the **Offshore In-Principle Monitoring Plan (IPMP)** (document reference 9.5) includes provision for monitoring of potential changes in sandeel habitat suitability.
Natural England	June 2021	Chapter 11 Fish Ecology Detailed Comments Subject: 11.3 Table 11-2 Comment: Natural England note that no final decision has been made regarding the final decommissions policy for the offshore project infrastructure. The Applicant has stated that scour protection is likely to be decommissioned in situ. Previous discussions with other OWF project engineers have highlighted that it is considered almost impossible to recover rock armouring at the time of decommissioning. Therefore, consideration should be given to identifying those options for scour prevention and cable protection which would enable decommissioning in areas which impact on prey availability to designated sites features. Recommendation: Natural England would welcome consultation on the decommissioning plan and confirmation about removal of	As noted by Natural England, it is difficult to remove rock-dump scour and cable protection at decommissioning although this can be achieved by using a suction dredger but not without disturbing the underlying sediments. Natural England will be consulted on the Decommissioning Programme at the pre-construction phase. Given the sensitivities associated with the CSCB MCZ, the Applicant has committed to using removeable external cable protection systems within the MCZ. No scour protection will be installed within the MCZ. As described in **Chapter 4 Project Description,** scour protection would only be used in areas subject to scour and therefore scour protection would be minimised throughout the SEP and DEP wind farm sites. See above regarding cable burial depth and cable protection within the MCZ. In addition, the **Outline**

Consultee	Date	Comment	Project Response
		scour/rock protection in areas considered to be of importance to Sandeel and Herring spawning habitat.	**CSCB MCZ CSIMP** (document reference 9.7) provides further information on cable installation and protection within the MCZ. The Applicant notes the recent Natural England commissioned report (Peritus International Limited, 2022) on scour and cable protection decommissioning which has informed production of the **Outline CSCB MCZ CSIMP** and its **Appendix 3 Decommissioning Feasibility Study** (document reference 9.7.3).
Natural England	June 2021	Chapter 11 Fish Ecology Detailed Comments Subject: 14.6.2.5 Comment: We agree that “Long-term changes to benthic habitat due to rock protection and other infrastructure at specific locations within the wind farm sites and offshore cable corridors may affect spawning and nursery grounds, most notably for demersal spawners.” Natural England queries why the issue of impacts on spawning herring and sandeel are then not discussed further. Recommendation: Please see our comments above.	Potential impacts on herring and sandeel spawning and nursery grounds are assessed in **Section 9.6.2.2** and **9.6.2.3**. The referenced text in **Chapter 12 Commercial Fisheries** has been updated to reflect that the assessment of potential permanent habitat loss impacts has been undertaken for demersal spawning species within this Fish Ecology ES chapter.
Natural England	June 2021	Chapter 11 Fish Ecology Appendix Subject: 11.1.2.4.1 Comment: Data from otter trawl surveys in 2005 and 2008 showed that herring was the most abundant species caught. We have concerns over the relevance of this data 13-16 years later.	Comment noted, however no site specific fish surveys are proposed at this time. At the Sea bed ETG on 30/10/2019 it was agreed that *"New fish characterisation surveys are not necessary as the sources of data proposed to inform the desk-based assessment will be adequate"*. The Applicant is not aware of any more recent fish survey data covering the wind farm sites.

Consultee	Date	Comment	Project Response
		Recommendation: NE would welcome more up to date data	
Natural England	June 2021	Chapter 11 Fish Ecology Detailed Comments Subject: 11.1.1 Comment: Similar to the above, there was a pre-construction survey in 2009 and a post-construction herring spawning survey in 2010. We have concerns over the relevance of this data 11-12 years later. Recommendation: NE would welcome more up to date data	Comment noted however no site specific fish surveys are proposed at this time. At the Sea bed ETG on 30/10/2019 it was agreed that *"New fish characterisation surveys are not necessary as the sources of data proposed to inform the desk-based assessment will be adequate".* The Applicant is not aware of any more recent herring spawning survey data covering the wind farm sites.
EIFCA	June 2021	"Within the project there are aspects which may have an impact on the ability of diadromous fish to undertake their normal migratory movements (such as EMF effects on species with an ability to detect these). We defer to the advice and comments of the relevant authority, who we understand to be the Environment Agency in connection with these potential impacts, with some specific comments in relation to this, as identified in the section "Specific Points".	Noted.
EIFCA	June 2021	Issues relating to Cables & EMF We think that the issue of potential effects from cables & EMF has been dismissed rather too lightly. This is especially the case for the cable route within the MCZ, where we note that "….. there is unprotected surface lay of cable (which is proposed as an option within the Cromer Shoal MCZ). …." (Chapter 14 Commercial Fisheries, section 327). Our concerns arise from three main points – 1. The potential danger to fishers posed by the snagging risk of surface laid cables interacting with fishing gear. We do not	There would be no unprotected surface laid cable within the MCZ and export cable corridor. This has been amended in **Chapter 12 Commercial Fisheries**. Cable burial requirements for the purpose of the environmental assessment have been informed through the completion of an export cable burial risk assessment (Pace Geotechnics, 2020) which has been produced by the Applicant at an early stage to inform the design and environmental

Consultee	Date	Comment	Project Response
		necessarily accept that this is a risk only for mobile gear, and suggest that there needs to be full consideration of the potential impacts of snagging surface laid cables for potting gear.	assessment processes on advice from relevant stakeholders. In addition, geotechnical surveys undertaken in October 2021 have further informed cable burial and protection requirements within the MCZ as detailed in the **Outline CSCB MCZ CSIMP** (document reference 9.7). The **Outline CSCB MCZ CSIMP** provides further detail on offshore export cable installation within the MCZ including potential external cable protection requirements. The **Outline CSCB MCZ CSIMP** describes the experience of the DOW export cable installation which did not require any external cable protection. As described in the CSIMP, the SEP and DEP export cable route runs parallel to the DOW export cables in an area of similar sea bed sediments and therefore the likelihood of needing external cable protection at SEP and DEP is relatively low. Potential gear snagging risk to fishing vessels is assessed in **Section 12.6.2.4** of **Chapter 12 Commercial Fisheries**. In addition, **Section 12.3.3** of **Chapter 12 Commercial Fisheries** details mitigation measures that will be implemented to mitigate potential impacts on commercial fisheries.
EIFCA	June 2021	2. The EMF effects experienced by organisms within the sea diminishes with distance from the cable source of such EMFs. This is recognised within the PEIR by the proposal of cable burial as a mitigation measure, with statements such as “The Applicant is committed to burying offshore export cables where possible,	The assessment of potential EMF impacts has been updated and the assumptions around EMF clarified (see **Section 9.6.2.8**).

Consultee	Date	Comment	Project Response
		reducing the effects of electromagnetic fields (EMF) .. Typical burial depth for SEP and DEP cables, .. is expected to be between 0.5m to 1.5m (or up to 1m for the export cables)" (Chapter 11 –Within Table 11-3: "Embedded Mitigation Measures"). When the cable is surface laid, the EMF effects have the potential to be much greater than would be the case for buried cables. This calls into question calculations such as those in Chapter 11, Table 11-27: "Calculated maximum magnetic fields for offshore SEP and DEP export cable circuit scenarios", which indicates a maximum magnetic field (μT) at cable surface of 1653. The document then proceeds to calculate "At 0 m. distance above sea bed, max field strength = 26.54 μT". Would it not be the case that for a surface laid cable, the maximum field strength within the water column would be the same as at the cable surface, as there would be no separation distance between water column and cable surface?	As noted above, there would be no unprotected surface laid cable within the MCZ. **Table 9-27** provides the results from the project specific EMF assessment (Tripp, 2021). All calculations were performed assuming maximum load, minimum circuit separation and assume a cable buried at 1m below the sea bed. Where loose rock dump burial occurs, there is a possibility that small fish or shellfish could be exposed to higher levels, if small enough to swim through the rocks. The magnetic field at the cable surface represents the highest possible exposures and ranged between 1217 and 1653 μT, depending on the scenario (see **Table 9-27**). However, it should be noted that the Applicant has committed to installing removable external cable protection systems within the MCZ and so no loose rock dump would be installed. This would prevent or limit the ability of small fish and shellfish to penetrate the cable protection within the MCZ and be subject to the highest possible exposures. The magnetic fields from all options reduced to very low levels within a few metres from the circuits and it is important to note that these levels do not take account of shielding factors of the cable sheath which would further reduce EMF.
EIFCA	June 2021	3. We think that there may well be more uncertainty over effects arising from EMF than presented in the PEIR. This is especially the case for cables potentially on the sea bed or shallow buried, as identified above may be the case within the MCZ. Bearing in mind the potential effects on elasmobranchs, and the fact that it is recognised that "It should be noted that Dover sole and thornback	As noted above, there would be no unprotected surface laid cable within the MCZ. The **Outline CSCB MCZ CSIMP** (document reference 9.7) provides further information on

Consultee	Date	Comment	Project Response
		ray nursery areas are restricted to shallower inshore waters" (Chapter 11 – Fish Ecology, section 68) there are legitimate concerns over the residual uncertainty in understanding of effects from EMF. There are several scientific sources which raise the issues of uncertainty, or even identified effects, regarding EMF and a range of marine species. For instance – 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, pp.580-588. "Crabs showed a clear attraction to EMF exposed shelter (69%) compared to control shelter (9%) and significantly reduced their time spent roaming by 21%. Consequently, EMF emitted from Marine Renewable Energy Devices (MREDs) will likely affect edible crabs both behaviourally and physiologically, suggesting that the impact of EMF on crustaceans must be considered when planning MREDs." Normandeau, Exponent, T. Tricas, and A. Gill. 2011. Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09. "Summary of case history impact assessment. "Invertebrates: Spiny lobster / (Type of effect possible) – Navigational miscue during migration or homing / (Certainty) - Sensory threshold overlaps with predicted fields." (It would appear that this same paper is quoted in Chapter 11 – Fish Ecology, Section 388, as "Although there is no direct evidence of effects to invertebrates from undersea cable EMF (Normandeau *et al*. 2011),…". This would seem at odds with the text identified above).	cable laying and potential cable protection requirements within the MCZ. At Dudgeon OWF, 93% of the export cable length had burial depth >1.0 m). At one location 3km to 4km from shore, subcropping chalk was encountered at about 0.3m below sea bed, resulting in a reduced burial depth in this area of 0.3m. This was accepted due to the burial depth being in solid ground conditions, which from a cable burial risk assessment perspective offers greater protection from damage from anchoring and fishing activity. No remedial cable protection (either through burial or with external protection) was performed. Post-construction surveys do not show any exposed export cables, nor visibility of the trenched route on the sea bed. To date, no cable repair or remedial reburial works have been undertaken since the wind farm has been in operation. Potential EMF impacts are assessed in **Section 9.6.2.8** which has been updated for the ES. Reference to Scott, Harsanyi and Lyndon (2018); Scott *et al.* (2021); and Gill, Bartlett and Thomsen (2012) has been added to **Section 9.6.2.8** and the referenced statement to section 388 has been deleted. As noted in **Section 9.6.2.8**, SEP and DEP will involve installing offshore (and onshore) export cable circuits using HVAC technology. Fish and shellfish species are less likely to exhibit responses to HVAC cables when compared to

Consultee	Date	Comment	Project Response
		Gill, A.B., Bartlett, M. and Thomsen, F., 2012. Potential interactions between diadromous fishes of UK conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments. Journal of Fish Biology, 81(2), pp.664-695. “The information on which to base the review was found to be limited with respect to all aspects of these fishes’ migratory behaviour and activity, especially with regards to MRED deployment, making it difficult to establish cause and effect relationships. The main findings, however, were that diadromous species can use the Earth’s magnetic field for orientation and direction finding during migrations. Juveniles of anadromous brown trout (sea trout) Salmo trutta and close relatives of S. trutta respond to both the Earth’s magnetic field and artificial magnetic fields. Current knowledge suggests that EMFs from subsea cables may interact with migrating Anguilla sp. (and possibly other diadromous fishes) if their movement routes take them over the cables, particularly in shallow water (<20 m). The only known effect is a temporary change in swimming direction. Whether this will represent a biologically significant effect, for example delayed migration, cannot yet be determined. Diadromous fishes are likely to encounter EMFs from subsea cables either during the adult movement phases of life or their early life stages during migration within shallow, coastal waters adjacent to natal rivers..” Hutchison, Z., 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): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM, 3, p.2018. “Homarus americanus (the American lobster) exhibited a statistically significant but subtle change in behavioral activity when exposed to the EMF of the HVDC cable, which operated at a constant power of 330 MW (1175 Amps). At the treatment enclosure (B), lobsters were on average closer to the sea bed and	High Voltage Direct Current (HVDC) transmission cables due to the higher strength EMF emitted by HVDC cables (Normandeau, Tricas and Gill, 2011). However, reference to Hutchison *et al.* (2018) and Hutchison *et al.* (2020) have been added to **Section 9.6.2.8**.

Consultee	Date	Comment	Project Response
		exhibited a higher proportion of changes in the direction of travel (termed large turns), when second in the sequence, compared to the control enclosure (A). They also made more use of the central space of the treatment enclosure (B) compared to the control (A). Leucoraja erinacea (the Little skate) exhibited a strong behavioral response to the EMF from the CSC. The cable was powered for 62.4% of the study and most frequently transmitted electrical current at 16 Amps (at 0 MW, 37.5% of time), 345 Amps (100 MW, 28.6%) and 1175 Amps (330 MW, 15.2%). In comparison to the control enclosure (A), the skates at the treatment enclosure (B) traveled further but at a slower speed, closer to the sea bed and with an increased proportion of large turns which suggested an increase in exploratory activity and/or area restricted foraging behavior. The increased distance travelled and increased proportion of large turns was associated with the zone of high EMF (>52.5 µT, i.e. above the Earth's magnetic field) where they were more frequently recorded and spent more time.""	
North Norfolk Coast District Council (NNDC)	June 2021	Chapter 11 - Fish Ecology NNDC would defer to the advice of Natural England, Marine Management Organisation, Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and other experts in respect of matters within this Chapter of the PEIR.	Noted

9.3 Scope

9.3.1 Study Area

8. The SEP and DEP offshore infrastructure is located within ICES rectangles 35F1 and 34F1. These rectangles define the 'local study area' as shown in **Figure 9.1** these are the primary focus of this assessment. Further to the west, ICES rectangles 34F0 and 35F0 are also considered as part of the wider 'regional area'. As ICES rectangle boundaries are used to determine the study area, the data acquired will account for a wide variety of species in and around SEP and DEP. Species included will range from primarily permanent residents; seasonal residents that use these areas for foraging, spawning and nursery grounds; and transient (migratory) species. In describing the fish and shellfish ecology baseline, historic fish surveys at the Sheringham Shoal Offshore Wind Farm (SOW) and DOW have been used due to their proximity to SEP and DEP, whilst acknowledging that the data were collected between August 2010 and August 2015. In addition, in certain cases a wider geographical area is used for environmental baseline descriptions and impact assessment, for example the distribution of spawning grounds in the southern North Sea.

9.3.2 Realistic Worst-Case Scenario

9.3.2.1 General Approach

9. The final design of SEP and DEP will be confirmed through detailed engineering design studies that will be undertaken post-consent to enable the commencement of construction. 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 Planning Inspectorate Advice Note Nine: Rochdale Envelope (v3, 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 lesser options will have less impact. Further details are provided in **Chapter 5 EIA Methodology**.

10. The realistic worst-case scenarios for the Fish and Shellfish Ecology assessment are summarised in **Table 9-2**. These are based on the project parameters described in **Chapter 4 Project Description**, which provides further details regarding specific activities and their durations.

11. In addition to the design parameters set out in **Table 9-2**, consideration is also given to:

- How SEP and DEP will be built out as described in **Section 9.3.2.2** to **Section 9.3.2.4** below. This accounts for the fact that whilst SEP and DEP are the subject of one DCO application, it is possible that only one Project could be built out (i.e. build SEP or DEP in isolation) or that both of the Projects could be developed. If both are developed, construction may be undertaken either concurrently or sequentially.

- A number of further development options which either depend on pre-investment or anticipatory investment, or that relate to the final design of the wind farms.
- Whether one OSP or two OSPs are required.
- The design option of whether to use all of the DEP North and DEP South array areas, or whether to use the DEP North array area only.

12. In order to ensure that a robust assessment has been undertaken, all development scenarios and options have been considered to ensure the realistic worst-case scenario for each topic has been assessed. Further details are provided in **Chapter 4 Project Description**.

13. For underwater noise impacts from piling, three scenarios have been considered in the assessment as follows:
    - Single piling – A scenario where only one pile is installed, either at SEP or at DEP, within a 24 hour period.
    - Sequential piling – A scenario where one pile is installed after another pile in the same 24 hour period (e.g. two monopiles in the same 24 hour period or four pin-piles in the same 24 hour period).
    - Simultaneous piling - A scenario where two piles are installed at the same time at different locations (i.e. one at SEP at the same time as one at DEP).

14. In relation to the different OSP scenarios where both SEP and DEP are built (i.e. where there are one or two OSPs), each scenario has been presented, however only the overall realistic worst-case for each impact has been assessed in **Section 9.6**. The worst-case parameter for each activity / footprint in the SEP and DEP one or two OSP scenario has been denoted with an asterisk and underlined in **Table 9-2**. In addition, cells have been shaded grey to indicate which scenario represents the worst-case in relation to each of the impacts assessed.

9.3.2.2 Construction Scenarios

15. In the event that both SEP and DEP are built, the following principles set out the framework for how SEP and DEP may be constructed:
    - SEP and DEP may be constructed at the same time, or at different times;
    - If built at the same time both SEP and DEP could be constructed in four years;
    - If built at different times, either Project could be built first;
    - If built at different times, each Project would require a four year period of construction;
    - If built at different times, the offset between the start of construction of the first Project, and the start of construction of the second Project may vary from two to four years;
    - Taking the above into account, the total maximum period during which construction could take place is eight years for both Projects; and
    - The earliest construction start date is 2025.

16. The impact assessment for benthic ecology considers the following development scenarios in determining the worst-case scenario for each topic:

- Build SEP or build DEP in isolation – one OSP only; and
- Build SEP and DEP concurrently or sequentially – with either two OSPs, one for SEP and one for DEP, or with one OSP only to serve both SEP and DEP

17. For each of these scenarios it has been considered whether the build out of the DEP North and DEP South array areas, or the build out of the DEP North array area only, represents the worst-case for that topic. Any differences between SEP and DEP, or differences that could result from the manner in which the first and the second projects are built (concurrent or sequential and the length of any gap) are identified and discussed where relevant in the impact assessment section of this chapter (**Section 9.6**). For each potential impact, where necessary, only the worst-case construction scenario for two Projects is presented, i.e. either concurrent or sequential. The justification for what constitutes the worst-case is provided, where necessary, in **Section 9.6**.

9.3.2.3 Operation Scenarios

18. Operation scenarios are described in detail in **Chapter 4 Project Description**. Where necessary, the assessment considers the following three scenarios:

- Only SEP in operation;
- Only DEP in operation; and
- The two Projects operating at the same time, with a gap of two to four years between each Project commencing operation.

19. The operational lifetime of each Project is expected to be 40 years.

9.3.2.4 Decommissioning Scenarios

20. Decommissioning scenarios are described in detail in **Chapter 4 Project Description**. Decommissioning arrangements will be agreed through the submission of a Decommissioning Programme prior to construction, however for the purpose of this assessment it is assumed that decommissioning of SEP and DEP could be conducted separately, or at the same time.

Table 9-2: Realistic Worst-Case Scenarios

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP: Two OSPs (one in SEP wind farm site and one in DEP North array area)	SEP and DEP: One OSP (located in SEP wind farm site)	Notes and Rationale
Construction					
Impact 1: Temporary habitat loss / disturbance	**Offshore cables:** Up to **263km** of offshore cables comprising: • One High Voltage Alternating Current (HVAC) export cable up to **62km** in length • **135km** of infield cables (DEP North array area: 90km; DEP South array area: 45km) • Up to 3 parallel interlink cables between DEP South array area and offshore substation platform (OSP) in DEP North array area: up to **66km** in length (combined) • Burial depth: 0.5 to 1.5m (excluding burial in sand waves up to 20m); and up to 1.0m for the export cables. • Cable installation maximum width of disturbance: 15m • Maximum area disturbed: **3.95km²** (Export cable 0.93km², Infield cables 2.025km², Interlink cables 0.99km²)	**Offshore cables:** Up to **130km** of cables comprising: • One HVAC export cable up to **40km** in length • **90km** of infield cables • No interlink cables • Burial depth: Same as DEP in isolation • Cable installation maximum width of disturbance: Same as DEP in isolation • Maximum area disturbed: **1.95km²** (Export cable 0.60km², Infield cables 1.35km²)	**Offshore cables:** Up to **393km**: • 2 HVAC export cables up to **102km** in length • Up to **225km** of infield cables (DEP North array area: 90km; DEP South array area 45km; SEP 90km) • Up to 3 interlink cables from DEP South array area to the OSP in DEP North array area **66km** total length • Burial depth: Same as SEP or DEP in isolation • Cable installation maximum width of disturbance: Same as SEP or DEP in isolation • Maximum area disturbed: **5.90km²** (Export cable: 1.53km², infield 3.38km², interlink cables 0.99km²)	**Offshore cables:** Up to **448km**: • 2 HVAC export cables from SEP up to **80km** in length • Up to **225km** of infield cables (DEP North array area: 90km; DEP South array area 45km[1]; SEP 90km) • Up to 7 interlink cables from DEP North array area (up to 5) and DEP South array area (up to 3) to OSP in SEP, up to **143km*** total length[2] • Burial depth: Same as SEP or DEP in isolation • Cable installation maximum width of disturbance: Same as SEP or DEP in isolation • Maximum area disturbed: **6.73km²*** (Export cable: 1.20km², infield 3.38km², interlink cables 2.15km²)	The temporary disturbance relates to sea bed preparation and cable installation. As described in **Section 4.4.7.2** of **Chapter 4 Project Description**, the number of interlink cables includes an extra cable for contingency purposes with the maximum total number of interlink cables for any one scenario being seven. In addition, under a 1 OSP scenario where both the DEP North and South array areas are developed, there could be: • Up to 5 (22km in length each) cables between the DEP North array area and the SEP wind farm site; and • Up to 3 cables (16.5km in length each) between the DEP South array area and the SEP wind farm site. • If contingency is in the DEP North array area, the DEP South array area has only 2 cables (5 + 2 = 7) • If contingency is in the DEP South array area, the DEP North array area has only 4 cables (4 + 3 = 7) The worst-case is for contingency in the DEP North array area so therefore the maximum length of all interlink cables for a 1 OSP scenario where both the DEP North and South array areas are developed is 5x22km + 2x16.5km = 143km.

[1] Build out of DEP North and South array areas is worst-case scenario for infield cable disturbance
[2] While a scenario where only the DEP North array area is built out would require a greater length of interlink cables (154km compared to 143km), overall, the worst-case area subject to temporary habitat loss / disturbance would be a scenario where both DEP North and South array areas are built out (see **Section 4.4.7.2** of **Chapter 4 Project Description** for details on interlink cables).

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	Sea bed preparation • Sand wave clearance: **0.93km²** (infield area: 0.42km²; interlink area: 0.17km²; export cable area: 0.34km²) • Worst-case is for GBS foundations: **0.073km²** (for up to 24 18MW wind turbines) • Boulder clearance (up to 20 across wind farm site and offshore cable corridors): **786m²** **Total = 1km²**	**Sea bed preparation** • Sand wave clearance: **0km²** • Worst-case is for GBS foundations: **0.057km²** (for up to 19 18MW wind turbines) • Boulder clearance (up to 30 across wind farm site and offshore cable corridors): **1,178m²** **Total = 0.058km²**	**Sea bed preparation** • Sand wave clearance: **0.93km²*** (as for DEP in isolation) • Worst-case is for GBS foundations: **0.13km²** (for up to 43 18MW wind turbines) • Boulder clearance (up to 50 across wind farm sites and offshore cable corridors): **1,964m²** **Total = 1.06km²***	**Sea bed preparation** • Sand wave clearance: **0.76km²** (infield area: 0.42km²; interlink area: 0.34km²) • Worst-case is for GBS foundations: **0.13km²** (for up to 43 18MW wind turbines) • Boulder clearance (up to 50 across wind farm sites and offshore cable corridors): **1,964m²** **Total = 0.89km²**	The maximum area of sea bed preparation disturbance from a single 18MW GBS foundation = 3,019m². Sea bed preparation disturbance from a 15MW GBS foundation = 1,735m² and therefore despite there being a higher number of 15MW foundations (30 for DEP and 23 for SEP) the worst-case is associated with the 18MW GBS foundation of which there could be up to 24 for DEP and 19 for SEP. Sand wave clearance (pre-sweeping) is confined to the DEP wind farm site, the northern portion of the interlink cable corridor between the DEP North array area and SEP and the interlink cable corridor between the DEP North and DEP South array areas. Therefore, no sand wave clearance is required in the SEP wind farm site. The WCS is based on a two OSP scenario and is estimated based on analysis of existing geophysical data to determine where sand wave clearance is likely to be required (details provided in **Chapter 4 Project Description**). The width of sea bed disturbance along the pre-lay grapnel run (PLGR) is estimated to be up to 3m, which would be encompassed by the 15m cable installation disturbance width accounted for in the row above. Calculations assume boulders of 5m diameter and an equivalent disturbance footprint at the origin boulder location and at the location to which it is moved.
	Vessels *Jack up vessels* • Up to two jack-up deployments at each turbine/OSP	**Vessels** *Jack up vessels* • Up to two jack-up deployments at each turbine/OSP	**Vessels** *Jack up vessels*	**Vessels** *Jack up vessels*	Worst-case scenario is a jack-up barge with six legs per barge (200m² per leg) equating to a

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	(**worst-case associated with 30 15MW turbines + one OSP = 74,400m²**) *Anchoring* (**Total = 76,080m²**) • Turbines (30) and OSP (1) installation vessel anchoring (up to 12 lines per location) = **22,320m²** • Export cable installation vessel anchoring (seven lines) (62km) = **26,040m²** • Interlink cable installation vessel anchoring (seven moorings) (66km) = **27,720m²** **Total** sea bed disturbance footprint from vessels for DEP in isolation = **0.150km²**	(**23 15MW turbines + one OSP: 57,600m²**) *Anchoring* (**Total = 34,080m²**) • Turbines (23) and OSP (1) installation vessel anchoring (up to 12 lines per location) = **17,280m²** • Export cable installation vessel anchoring (seven lines) (40km) = **16,800m²** **Total** sea bed disturbance footprint from vessels for SEP in isolation = **0.092km²**)	• Up to two jack-up deployments at each turbine/OSP (**53 15MW turbines + two OSPs: 132,000m²***) *Anchoring* (**Total = 110,160m²**) • Turbines (53) and OSP (2) installation vessel anchoring: (up to 12 lines per location) **39,600m²**. • Export cable installation vessel anchoring (seven lines) (62km + 40km) = **42,840m²** • Interlink cable installation vessel anchoring (seven moorings) (66km) = **27,720m²** **Total** sea bed disturbance footprint from vessels = **0.242km²**	• Up to two jack-up deployments at each turbine/OSP. (**53 15MW turbines + one OSP: 129,600m²**) *Anchoring* (**Total = 137,160m²***) • Turbines (53) and OSP (1) installation vessel anchoring: (up to 12 lines per location) **38,880m²**. • Export cable installation vessel anchoring (seven lines) (40km + 40km) = **33,600m²** • Interlink cable installation vessel anchoring (seven moorings) (154km)[3] = **64,680m²** **Total** sea bed disturbance footprint from vessels = **0.267km²***	total footprint of 1,200m² per installation. Individual anchor footprint = 30m². Up to two anchor deployments required at each wind turbine location. For offshore cables, vessels would have up to seven anchor / mooring lines, each with an anchor footprint of 30m² and requiring repositioning every 500m.
	HDD Exit Point • Initial trench (600m²) • Transition zone (50m²) • Jack-up footprint (128m²) • Deposited material on sea bed (200m²) **Total = 978m²**	**HDD Exit Point** • Initial trench (600m²) • Transition zone (50m²) • Jack-up footprint (128m²) • Deposited material on sea bed (200m²) **Total = 978m²**	**HDD Exit Point** • Initial trench (600m²) • Transition zone (100m²) • Jack-up footprint (256m²) • Deposited material on sea bed (400m²) **Total = 1,356m²***		HDD beneath the intertidal zone with offshore exit point approximately 1,000m offshore. For SEP and DEP , the initial trench assumes both export cables are within the same initial trench, meaning the area of disturbance is the same as SEP or DEP in isolation scenarios. However, for the transition zone it assumes two trenches and therefore the area of disturbance is double the SEP or DEP in isolation scenarios. Jack-up footprints for SEP and DEP include total jack-up leg footprints and jack-up movements required. Disturbance from the HDD exit point activities are within the CSCB MCZ, therefore footprint of temporary habitat loss / disturbance within the MCZ has been provided (below).

[3] The greater overall length of interlink cables in a scenario where both the DEP North and South array areas are developed results in a greater area of disturbance from vessel anchoring compared to a DEP North array area only scenario and therefore this represents the worst-case for seabed disturbance footprints from vessels

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	Total Disturbance within the DEP offshore site Worst-case scenario total temporary disturbance footprint for DEP in isolation = **5.10km²** **Disturbance in the MCZ** Worst-case scenario total temporary disturbance footprint for DEP in isolation in the CSCB MCZ due to cable installation = **0.17km²**	**Total Disturbance within the SEP offshore site** Worst-case scenario total temporary disturbance footprint for SEP in isolation = **2.10km²** **Disturbance in the MCZ** Worst-case scenario total temporary disturbance footprint for SEP in isolation in the CSCB MCZ due to cable installation = **0.17km²**	**Total Disturbance within the SEP and DEP offshore sites** = **7.22km²** **Disturbance in the MCZ** Worst-case scenario total temporary disturbance footprint for SEP and DEP in the CSCB MCZ due to cable installation = **0.33km²**	**Total Disturbance within the SEP and DEP offshore sites** = **7.89km²*** **Disturbance in the MCZ** Worst-case scenario total temporary disturbance footprint for SEP and DEP in the CSCB MCZ due to cable installation = **0.33km²**	Long term habitat loss in the Cromer Shoal Chalk Beds MCZ is assessed under operational impacts. Temporary disturbance within MCZ includes: • Area of disturbance from jetting within MCZ (accounting for contingency) • Boulder clearance in offshore export cable corridor • Total jack-up footprint • Temporary moorings anchor footprint within MCZ • Sea bed footprint of deposited material • Initial exit point trench area of disturbance • Further transition zone area of disturbance
Impact 2: Increased suspended sediments and sediment re-deposition	**Sea bed preparation** for 24 18MW GBS foundations = 407,150m³ Drill arisings at one OSP = 425m³ **Displaced sediment during export cable trenching** • Export cable = 31,000m³ • HDD exit point = 650m³ (600m³ initial exit point trench and 50m³ further transition zone) • Sand wave levelling = 144,200m³ **Displaced sediment during infield and interlink cable trenching** • Infield = 151,875m³ • Interlink = 74,250m³	**Sea bed preparation** for 19 18MW GBS foundations = 322,327m³ Drill arisings at one OSP = 425m³ **Displaced sediment during export cable trenching** • Export cable = 20,000m³ • HDD exit point = 650m³ (600m³ initial exit point trench and 50m³ further transition zone) • Sand wave levelling = 0m³ **Displaced sediment during infield and interlink cable trenching** • Infield = 101,250m³ • Interlink = 0m³ • Sand wave levelling = 0m³ **Total increases in SSC**	**Sea bed preparation** for 43 18MW GBS foundations = 729,477m³ Drill arisings at two OSP = 850m³* **Displaced sediment during export cable trenching** • Export cable = 51,000m³* • HDD exit point = 700m³ (600m³ initial exit point trench and 100m³ further transition zone) • Sand wave levelling = 144,200m³ **Displaced sediment during infield and interlink cable trenching** • Infield = 253,125m³ • Interlink = 74,250 m³ • Sand wave levelling = 232,200m³ (216,000m³ infield and 16,200m³ interlink) **Total increases in SSC**	**Sea bed preparation** for 43 18MW GBS foundations = 729,477m³ Drill arisings at one OSP = 425m³ **Displaced sediment during export cable trenching** • Export cable = 40,000m³ • HDD exit point = 700m³ (600m³ initial exit point trench and 100m³ further transition zone) • Sand wave levelling = 0m³ **Displaced sediment during infield and interlink cable trenching** • Infield = 253,125m³ • Interlink = 160,875m³* • Sand wave levelling = 360,200m³* (216,000m³ infield and 144,200m³ interlink) **Total increases in SSC**	The worst-case for a single 18 MW GBS foundation with a 60m base plate diameter = 16,964.60m³. Worst-case for a single 15MW GBS foundation with a 45m base plate diameter = 9,543m³. Therefore, the overall worst-case is associated with 24 18MW GBS foundations at DEP and 19 18MW at SEP. Sea bed 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 represents the greatest potential for increased SSC across the study area as a result of changes to physical processes which could result in impacts on fish and shellfish ecology receptors.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	• Sand wave levelling = 232,200m³ (216,000m³ infield and 16,200m³ interlink) **Total increases in SSC** Worst-case scenario for total temporary increases in SSC for DEP in isolation= **1,041,750m³**	Worst-case scenario for total temporary increases in SSC for SEP in isolation= **444,652m³**	Worst-case scenario for total temporary increases in SSC for SEP and DEP = **1,485,802m³**	Worst-case scenario for total temporary increases in SSC for SEP and DEP = **1,544,802m³***	The worst-case scenario for increased SSC during the construction period is associated with sea bed preparation for 19 18MW (SEP) and 24 18MW (DEP) GBS foundations, drilling for OSPs, jetting for export cable installation, and mechanical cutting for infield and interlink cable installation. Export cables would be buried up to 1m below the sea bed. Infield and interlink cables would be buried up to 1.5m below the sea bed. Calculations are based on an indicative sediment displacement width of 1m for jetting and assume a v-shaped trench. For the HDD exit pit the SEP and DEP scenario assumes both export cables are within the same initial trench meaning the volume of disturbance is the same as SEP or DEP in isolation scenarios. However, for the transition zone it assumes two trenches and therefore the area of disturbance is double the SEP or DEP in isolation scenarios.
Impact 3: Re-mobilisation of contaminated sediments	As described for construction Impact 2				
Impact 4: Underwater noise during foundation piling	**Wind turbine foundations** Up to 30 15MW wind turbines Foundation options: Monopile = 1 pile; or 4 leg-jacket = 4 pin pile Number of piles for wind turbines (15MW) = 30 monopiles or 120 pin piles **OSP foundations** 1 x OSP	**Wind turbine foundations** Up to 23 15MW wind turbines Foundation options: Same as DEP in isolation. Number of piles for wind turbines (15MW) = 23 monopiles or 92 pin piles **OSP foundations** 1 x OSP Foundation options:	**Wind turbine foundations** Up to 53 15MW wind turbines Foundation options: Same as DEP in isolation. Number of piles for wind turbines (15MW) = 53 monopiles or 212 pin piles **OSP foundations** 2 x OSPs Foundation options: 2 x 4 leg-jacket = 16 pin piles*	**Wind turbine foundations** Up to 53 15MW wind turbines Foundation options: Same as DEP in isolation. Number of piles for wind turbines (15MW) = 53 monopiles or 212 pin piles **OSP foundations** 1 x OSP Foundation options: 1 x 4 leg-jacket = 8 pin piles	Hammer piled foundations represent the worst-case scenario for underwater noise. Assumes 100% of foundations are piled. The worst-case underwater noise impact ranges are associated with monopiles.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	Foundation options: 1 x 4 leg-jacket = 8 pin piles **Maximum number of piled foundations:** Up to 30 monopiles plus 8 pin piles; or Up to 128 pin piles	1 x 4 leg-jacket = 8 pin piles **Maximum number of piled foundations:** Up to 23 monopiles plus 8 pin piles; or Up to 100 pin piles	**Maximum number of piled foundations:** Up to 53 monopiles plus 16 pin piles; or Up to 228 pin piles	**Maximum number of piled foundations:** Up to 53 monopiles plus 8 pin piles; or Up to 220 pin piles	
	The worst-case scenarios for Impact 4 are set out in **Chapter 10 Marine Mammal Ecology**. They are underwater noise from piling. Noise levels from piling are summarised in the marine mammals chapter in **Table 10-22**. Underwater noise will be generated by other construction activities including sea bed preparation, cable installation and rock placement, and from vessels. **Piling** Maximum hammer energy for monopiles • Up to 5,000kJ for 15 MW wind turbines • Up to 5,500kJ for 18+MW wind turbines Maximum hammer energy for pin-piles: up to 3,000kJ Further details, including piling durations are set out in **Chapter 10 Marine Mammal Ecology**.				
	Total **monopile** active piling time is up to **120 hours** for 30 wind turbine (4 hours per wind turbine).	Total **monopile** active piling time is up to **92 hours** for 23 wind turbines (4 hours per wind turbine) .	Total **monopile** active piling time is up to **212 hours** (**9 days**) for 53 wind turbines (4 hours per wind turbine).		Total piling time includes soft-start and ramp-up, and provides allowance for issues such as low blow rate, refusal, etc. The most likely monopile scenario is up to 3.2 hours per monopile, totalling 169.6 hours for 53 wind turbines.
	Total **pin pile** active piling time is up to **360 hours** for 30 wind turbines (3 hours per pin-pile x 4 piles per foundation) **Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation = up to **24 hours** per foundation. **Maximum total active piling time** is up to **384 hours** (**15 days**) based on pin pile foundations for **30** wind turbines and **one OSP**	Total **pin pile** active piling time is up to **276 hours** for 23 wind turbines (3 hours per pin-pile x 4 piles per foundation **Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation = up to **24 hours** per foundation. **Maximum total active piling time** is up to **300 hours** (**12.5 days**) based on pin pile foundations for **23** wind turbines and **one OSP**	Total **pin pile** active piling time is up to **636 hours** (**26.5 days**) for 53 WTGs **Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation. Two OSPs = **48 hours*** **Maximum total active piling time** is up to **684 hours (28.5 days)*** based on pin pile foundations for **53** wind turbines and **two OSPs**	Total **pin pile** active piling time is up to **636 hours** (**26.5 days**) for 53 WTGs **Total OSP piling time** 3 hours per pin-pile x 8 piles per foundation. Two OSPs = **24 hours**. **Maximum total active piling time** is up to **660 hours** (**27.5 days**) based on pin pile foundations for **53** wind turbines and **one OSP**	Total piling time includes soft-start and ramp-up, and providing allowance for issues such as low blow rate, refusal, etc. The average active piling time for pin-piles for all wind turbines is 2.5 hours (150 minutes). With soft-start and ramp-up (20 minutes) the total average piling time is 180 minutes per pin-pile, or 720 minutes per wind turbine.
	Potential for simultaneous piling at DEP in isolation	Potential for simultaneous piling at SEP in isolation	Potential for simultaneous piling between SEP and DEP depending on build scenario		Simultaneous or sequential (within a 24 hour period) piling could occur at SEP in isolation, DEP in isolation or SEP and DEP. Due to the larger separation distance between the noise sources in SEP and DEP and resultant larger impact

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
					ranges, both Projects being built is the worst-case scenario. The assessment for fish ecology receptors is based on a precautionary stationary animal model and therefore sequential piling within a 24 hour period between SEP and DEP is the worst-case (see **Section 9.6.1.4.2.1**).
	Number of monopiles to be installed sequentially in same 24 hour period = 2 Number of pin-piles to be installed sequentially in same 24 hour period = 4	Number of monopiles to be installed sequentially in same 24 hour period = 2 Number of pin-piles to be installed sequentially in same 24 hour period = 4	Number of monopiles to be installed sequentially in same 24 hour period = 2 Number of pin-piles to be installed sequentially in same 24 hour period = 4		Note that the underwater noise modelling has applied a stationary animal approach.
Impact 5: Underwater noise from other activities	**Sea bed clearance** Activities could include PLGR, boulder clearance, ploughing, pre-sweeping and dredging.				Maximum number of construction vessels. The worst-case for SEP and DEP considers concurrent construction on account of increased construction activity in the study area at the same time. Construction port/s will not be confirmed until nearer the start of construction.
	Cable installation The intention is to bury cables, however in areas where burial is not possible, the cable will be surface laid with cable protection. Additional methods considered include ploughing, jetting, trenching mechanical cutting.				
	Vessels • Maximum number of vessels on site at any one time: up to 16 vessels • Construction vessel trips to port: 603 over 2 year construction period.	**Vessels** • Maximum number of vessels on site at any one time: up to 16 vessels • Construction vessel trips to port: 603 over 2 year construction period.	**Vessels** • Maximum number of vessels on site at any one time: 25 • Construction vessel trips to port: 1,196 over 4 year construction period if constructed sequentially.		
Impact 6: Underwater noise during UXO clearance	Various possible types and sizes of UXO. Worst-case identified by SOW and DOW: 2,000lb German air dropped bomb (Trinitrotoluene (TNT) equivalent of 525kg). Possible number of UXO unknown at this stage.				As agreed at the marine mammals ETG meeting on the 20th July 2020, UXO clearance requirements will be addressed through a separate Marine Licence application post consent. The assessment in **Section 9.6.1.6** has been provided for information purposes only.
Impact 7: Impacts on commercially exploited species associated with displacement of fishing from the area of activity/ works	The worst-case scenarios for Impact 7 are set out in **Chapter 12 Commercial Fisheries** (**Table 12.2**). The following impacts are relevant to the worst-case for fish ecology: • Impact 1: Construction activities and physical presence of constructed wind farm infrastructure leading to reduction in access to, or exclusion from established fishing grounds; • Impact 2: Offshore cable corridor construction activities leading to reduction in access to, or exclusion from established fishing areas; • Impact 3: Displacement from the wind farm site leading to gear conflict and increased pressure on adjacent grounds; • Impact 4: Displacement from cable corridor leading to gear conflict and increased pressure on adjacent grounds; and				

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	• Impact 6: Increased vessel traffic within fishing grounds as a result of changes to shipping routes and transiting construction vessel traffic leading to interference with fishing activity.				
Operation					
Impact 1: Temporary habitat loss / disturbance	• Up to 10 jack-up deployments per year. Legs footprint up to **12,000m^2** per year • Cable repair, replacement and reburial footprint: **2,403m^2** per year **Total Disturbance** Worst-case scenario total temporary disturbance footprint for DEP in isolation per year = **14,403m^2** Approximate total temporary disturbance footprint for operational lifetime (40 years) = **0.58km^2**	• Up to 10 jack-up deployments per year. Legs footprint up to **12,000m^2** per year • Cable repair, replacement and reburial footprint: **2,070m^2** per year **Total Disturbance** Worst-case scenario total temporary disturbance footprint for SEP in isolation per year = **14,070m^2** Approximate total temporary disturbance footprint for operational lifetime (40 years) = **0.56km^2**	• Up to 20 jack-up deployments per year. Legs footprint up to **24,000m^2** per year • Cable repair, replacement and reburial footprint: **4,473m^2** per year. **Total Disturbance** Realistic worst-case scenario total temporary disturbance footprint for SEP and DEP per year = **28,473m^2** Approximate total temporary disturbance footprint for operational lifetime (40 years) = **1.14km^2**	• Up to 20 jack-up deployments per year. Legs footprint up to **24,000m^2** per year • Cable repair, replacement and reburial footprint: **4,737m^2*** per year. **Total Disturbance** Realistic worst-case scenario total temporary disturbance footprint for SEP and DEP per year = **28,737m^2*** Approximate total temporary disturbance footprint for operational lifetime (40 years) = **1.149km^2**	Based on calculation in **Table 4.31** of **Chapter 4 Project Description**. Assuming a jack-up vessel with a sea bed footprint of 1,200m^2 (up to four legs, each with a footprint of up to 300m^2). Reburial is based on 1% of interlink and infield cables requiring reburial every 10 years up to 3m disturbance width. Export cable reburial is based on up to 200m of export cable subject to reburial works every 10 years with a 3m disturbance width. Disturbance is shown on average per year, however maintenance could vary across years during operation and therefore an approximate total disturbance is shown for the operational life time, which is expected to be 40 years.
Impact 2: Permanent habitat loss	**Wind turbine foundations:** Maximum footprint of 24 GBS foundations (18MW) including foundation scour protection: **0.61km^2** **OSP foundations**: Maximum footprint of OSP foundations including scour protection (jackets with piles): **4,761m^2**	**Wind turbine foundations:** Maximum footprint of 19 GBS foundations (18MW) including foundation scour protection: **0.48km^2** **OSP foundations**: Maximum footprint of OSP foundations including scour protection (jackets with piles): **4,761m^2**	**Wind turbine foundations:** Maximum footprint of 43 18MW GBS foundations including foundation scour protection: **1.09km^2** **OSP foundations**: Maximum footprint of OSP foundations including scour protection (jackets with piles) (2 OSPs): **9,522m^2***	**Wind turbine foundations:** Maximum footprint of 43 18MW GBS foundations including foundation scour protection: **1.09km^2** **OSP foundations**: Maximum footprint of OSP foundations including scour protection (jackets with piles (one OSP)): **4,761m^2**	Infrastructure that may not be removed during decommissioning. Individual GBS footprints including scour protection are 14,313.8m^2 and 25,446.9m^2 for a 15MW and 18MW wind turbine respectively and therefore the worst-case across the wind farm sites is associated with the 18MW wind turbines (based on maximum numbers of 15MW turbines of 30 and 23 at DEP and SEP respectively).

<table>
<tr><th rowspan="2">Impact</th><th rowspan="2">DEP in Isolation</th><th rowspan="2">SEP in Isolation</th><th colspan="2">SEP and DEP</th><th rowspan="2">Notes and Rationale</th></tr>
<tr><th>Two OSPs (one in SEP wind farm site and one in DEP North array area)</th><th>One OSP (located in SEP wind farm site)</th></tr>
<tr><td rowspan="3"></td><td></td><td></td><td></td><td></td><td>For reference, the DEP wind farm site covers an area of 114.8km². The SEP wind farm site covers an area of 97.0km².</td></tr>
<tr><td>Subsea cable surface protection:
Export cables up to 0.5km (including 100m in the MCZ) of cable protection 6m wide = 3,000m². For this impact worst-case = 2,400m² to account for 600m² in the MCZ which is assessed under Impact 3
Interlink cables up to 1.5km of cable protection 6m wide = 9,000m²
Infield cables up to 1km of cable protection 4m wide = 4,000m²
Total = 15,400m² (0.0154km²)

Crossings
Up to 17 crossings (over-trawlable), each crossing has a 2,100m² footprint (21m width x 100m length)
Export cable: 4 crossings = 8,400m²
Infield cables: 7 crossings = 14,700m²
Interlink cables: 6 crossings = 12,600m²
Total crossings protection = 35,700m²

Total maximum footprint of cable protection (export, interlink and infield) and cable crossing protection: 0.051km²</td><td>Subsea cable surface protection:
Export cables up to 0.5km (including 100m in the MCZ) of cable protection 6m wide = 3,000m². For this impact worst-case = 2,400m² to account for 600m² in the MCZ which is assessed under Impact 3
Infield cables up to 1km of cable protection 4m wide = 4,000m²
Total = 6,400m² (0.0064km²)

Crossings
Export cable: 4 crossings = 8,400m²
No interlink or infield cable crossing protection material is required for a SEP in isolation scenario.
Total maximum footprint of cable protection (export, interlink and infield) and cable crossing protection: 0.015km²</td><td>Subsea cable surface protection:
Same as for a DEP in isolation scenario = 15,400m² (0.0154km²)
Crossings
Up to 21 crossings (over-trawlable)
Export cables: 8 crossings = 16,800m²
Infield cables: 7 crossings = 14,700m²
Interlink cables: 6 crossings = 12,600m²
Total crossings protection = 44,100m² (0.0441km²)

Total maximum footprint of cable protection (export, interlink and infield) and cable crossing protection: 0.06km²</td><td>Same as for a two OSP scenario</td><td rowspan="2">Cable protection for crossings will be up to 21m wide and 100m long and consist of either concrete mattressing or rock dumping.

SEP and DEP worst-case crossing locations
Infield cables: up to seven crossings (three in the DEP North array area at Durango-Waveney pipeline, up to four in the DEP South array area)
Interlink cables, up to six crossings (three cables from the DEP South array area crossing two Dudgeon export cables)
Export cable, up to four crossings (two at Dudgeon export cables, two for Hornsea Three export cables). One disused subsea cable crosses the export cable, but no crossing required.
Either SEP or DEP may use the total allowance of external cable protection when both Projects are built.</td></tr>
<tr><td>Total permanent habitat loss: 0.67km²</td><td>Total permanent habitat loss: 0.50km²</td><td>Total permanent habitat loss: <u>1.159km²*</u></td><td>Total permanent habitat loss: 1.155km²</td></tr>
<tr><td>Impact 3: Long term habitat loss</td><td>Cable protection (900m²):
HDD exit transition zone (100m x 3m): 300m²</td><td>Cable protection (900m²):
HDD exit transition zone (100m x 3m): 300m²</td><td colspan="2">Cable protection (1,800m²):
HDD exit transition zone (2 cables): 600m²
External cable protection (2 cables): 1,200m²</td><td>External cable protection systems (designed to be removable on decommissioning (see Appendix 3 Decommissioning Feasibility Study (document reference</td></tr>
</table>

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	• External cable protection (100m x 6m): **600m^2**	• External cable protection (100m x 6m): **600m^2**			9.7.3) of the **Outline CSCB MCZ CSIMP** (document reference 9.7)) may be placed in the HDD exit transition zone and as cable protection for export cables in the MCZ. The impact assessment is based on removal during decommissioning.
Impact 4: Introduction of wind turbine foundations, scour protection and hard substrate	See Operation Impacts 2 and 3.				
Impact 5: Increased suspended sediments and sediment re-deposition	See Operation Impact 1: Temporary habitat loss / disturbance. Temporary increases in SSC will result from periodic jack-up vessel deployment, and cable repair, replacement and reburial activities.				The volume of sediment that could be suspended has not been quantified but will be a much smaller proportion compared with the quantity generated by construction and decommissioning activities.
Impact 6: Re-mobilisation of contaminants from sea bed sediment	The worst-case scenarios for Impact 6 are set out in **Chapter 7 Marine Water and Sediment Quality** (**Table 7.2**). The following impacts are relevant to the worst-case scenario for fish ecology: • Operation Impact 2: Deterioration in water quality through the resuspension of contaminated sediment due to maintenance activities.				
Impact 7: Underwater noise	The worst-case scenarios for Impact 7 are set out in **Chapter 10 Marine Mammal Ecology** (**Table 10.2**). The following impacts are relevant to the worst-case scenario for fish ecology: • Underwater noise from operational turbines • Underwater noise from maintenance activities (cable repair, replacement ad reburial and cable protection works) • Underwater noise from vessels				
Impact 8: EMF	**Offshore cables:** Up to **263km** of offshore cables comprising: • One High Voltage Alternating Current (HVAC) export cable up to **62km** in length • **135km** of infield cables (DEP North array area: 90km; DEP South array area: 45km) • Up to 3 parallel interlink cables between DEP South array area and OSP in DEP North array area: up to **66km** in length (combined)	**Offshore cables:** Up to **130km** of cables comprising: • One HVAC export cable up to **40km** in length • **90km** of infield cables • No interlink cables • Burial depth: Same as DEP in isolation	**Offshore cables:** Up to **393km**: • 2 HVAC export cables up to **102km** in length • Up to **225km** of infield cables (DEP North array area: 90km; DEP South array area 45km; SEP 90km) • Up to 3 interlink cables from DEP South array area to the OSP in DEP North array area **66km** total length • Burial depth: Same as SEP or DEP in isolation	**Offshore cables:** Up to **448km***: • 2 HVAC export cables from SEP up to **80km** in length • Up to **225km** of infield cables (DEP North array area: 90km; DEP South array area 45km; SEP 90km) • Up to 7 interlink cables from DEP North array area (up to 5) and DEP South array area (up to 3) to OSP in SEP, up to **143km*** total length • Burial depth: Same as SEP or DEP in isolation	

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	• Burial depth: 0.5 to 1m (excluding burial in sand waves up to 20m; and up to 1.0m for the export cables.				
Decommissioning					
Impact 1: Temporary habitat loss / physical disturbance	No final 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: • Turbines including monopile, steel jacket and GBS foundations; • OSPs including topsides and steel jacket foundations; • Offshore cables may be removed or left in situ depending on available information at the time of decommissioning; and • Cable protection in the Cromer Shoal Chalk Beds MCZ. 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 outside the Cromer Shoal Chalk Beds MCZ. 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. 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.				Decommissioning arrangements will be detailed in a Decommissioning Programme, which will be drawn up and agreed with the Department for Business, Energy and Industrial Strategy (BEIS) prior to construction.
Impact 2: Permanent habitat loss					
Impact 3: Increased in SSC and deposition					
Impact 4: Re-mobilisation of contaminated sediments					
Impact 5: Underwater noise					
Impact 6: Impacts on commercially exploited species associated with displacement of fishing from the area of activity/works					

9.3.3 Summary of Mitigation Embedded in the Design

21. This section outlines the embedded mitigation relevant to the fish and shellfish ecology assessment, which has been incorporated into the design of the Project (**Table 9-3**). Where other mitigation measures are proposed, these are detailed in the impact assessment (**Section 9.6**).

22. The Applicant has committed to a number of techniques and engineering designs / modifications inherent as part of the project, during the pre-application phase, in order to avoid a number of impacts or reduce impacts as far as possible. Embedding mitigation into the project design is a type of primary mitigation and is an inherent aspect of the EIA process.

23. A range of different information sources have been considered as part of embedding mitigation into the design of the project (for further details see **Chapter 4 Project Description**, **Chapter 3 Site Selection and Assessment of Alternatives**) including engineering requirements, ongoing discussions with stakeholders and regulators, commercial considerations and environmental best practice.

24. Where possible, the embedded mitigation has been taken into account in each relevant impact assessment when assessing the potential magnitude of effect.

Table 9-3: Embedded Mitigation Measures

Parameter	Mitigation Measures Embedded into the Design of SEP and DEP
Electromagnetic Fields	
Cable Burial	The Applicant will make reasonable endeavours to bury offshore export cables, reducing the effects of EMF and also reducing the need for surface cable protection which reduces the introduction of hard substrate and modification of habitat. Typical burial depth for SEP and DEP cables, excluding in areas of sand waves, is expected to be between 0.5m to 1.5m (or up to 1m for the export cables). The use of single 3-core cables, compacting the circuit phases also reduces and localises the EMF significantly (Tripp, 2021). Cable burial requirements for the purpose of the environmental assessment have been informed through the completion of an export cable burial risk assessment (Pace Geotechnics, 2020) which has been produced by the Applicant at an early stage to inform the design and environmental assessment processes on advice from relevant stakeholders. The burial requirements for all cables will be finalised based on an assessment of the risks posed to the Projects in specific areas, following the completion of detailed pre-construction geotechnical and geophysical investigations and the subsequent finalisation of the cable burial risk assessment, prior to the start of construction.
Underwater Noise	
Construction	During construction, overnight working practices would be employed offshore so that construction activities could be 24 hours, thus reducing the overall period for potential impacts to fish communities in proximity to the wind farm sites.
Soft-start and ramp-up during Piling Activities	Each piling event would commence with a soft-start at a lower hammer energy followed, by a gradual ramp-up for at least 20 minutes to the maximum hammer energy required (the maximum hammer energy is only likely to be required at a few of the piling installation locations). The soft-start and ramp-up allows mobile species to move away from the area before the maximum hammer energy with the greatest noise impact area is reached.

Parameter	Mitigation Measures Embedded into the Design of SEP and DEP
	This commitment to soft-start and ramp-up is presented in the **Draft MMMP** (document reference 9.4).

9.4 Impact Assessment Methodology

9.4.1 Policy, Legislation and Guidance

9.4.1.1 National Policy Statements

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

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a);
- NPS for Renewable Energy Infrastructure (EN-3) (DECC 2011b); and
- NPS for Electricity Networks Infrastructure (EN-5) (DECC 2011c).

26. The specific assessment requirements for fish and shellfish ecology, as detailed in the NPS, are summarised in **Table 9-4** together with an indication of the section of the chapter where each is addressed.

27. It is noted that the NPS for Renewable Energy Infrastructure (EN-3) is in the process of being revised. A draft version was published for consultation in September 2021 (BEIS, 2021). A review of this draft version has been undertaken in the context of this ES chapter.

28. **Table 9-4** includes a section for the draft version of NPS (EN-3) in which relevant additional NPS requirements not presented within the current NPS (EN-3) have been included. A reference to the particular requirement's location within the draft NPS and to where within this ES chapter it has been addressed has also been provided.

29. Minor wording changes within the draft version which do not materially influence the NPS (EN-3) requirements have not been reflected in **Table 9-4**.

Table 9-4: NPS Assessment Requirements

NPS Requirement	NPS Reference	Section Reference
EN-3 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 sea bed, to interact with sea bed 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.	EN-3 section 2.6.73	Potential impacts during construction, operation and decommissioning have been assessed in **Section 9.6**

NPS Requirement	NPS Reference	Section Reference
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 • migration routes	EN-3 section 2.6.74	Fish species which may be likely receptors of impact are identified in **Section 9.5.5**
Where it is proposed that mitigation measures of the type set out in paragraph 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.	EN-3 section 2.6.75	**Section 9.6.2.8** identifies and assesses potential impacts on fish and shellfish receptors due to EMF during operation. The use of armoured cables and cable burial as mitigation is discussed in **Section 9.3.3**
EMF during operation may be mitigated by use of armoured cable for inter-array and export cables that 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.	EN-3 section 2.6.76	
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.	EN-3 section 2.6.77	Mitigation measures embedded in the project design are outlined in **Section 9.3.3**
The construction and operation of offshore windfarms can have both positive and negative effects on fish and shellfish stocks.	EN-3 section 2.6.122	**Sections 0** and **9.6.2**
Effects of offshore windfarms can include temporary disturbance during the construction phase (including underwater noise) and ongoing disturbance during the operational phase and direct loss of habitat. Adverse effects can be on spawning, overwintering, nursery and feeding grounds and migratory pathways in the marine area. However, the presence of wind turbines can also have positive benefits to ecology and biodiversity.	EN-3 section 2.6.63	
Assessment of offshore ecology and biodiversity should be undertaken by the applicant for all stages of the lifespan of the proposed offshore windfarm and in accordance with the appropriate policy for offshore windfarm EIAs	EN-3 section 2.6.64	**Sections 0, 9.6.2** and **9.6.3** assess the potential impacts of SEP and DEP during construction, operation and decommissioning on various fish and shellfish receptors.

NPS Requirement	NPS Reference	Section Reference
Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate.	EN-3 section 2.6.65	**Section 9.2** details consultation which has been undertaken with regard to fish and shellfish ecology, including responses to the Scoping Report and feedback provided through the ETG meetings.
Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore windfarm should be referred to where appropriate.	EN-3 section 2.6.66	Such data has been referred in **Sections 0** and **9.6.2.**
The assessment should include the potential for the scheme to have both positive and negative impacts on marine ecology and biodiversity.	EN-3 section 2.6.67	**Sections 0** and **9.6.2** assess the potential impacts (both positive and negative) of SEP and DEP during construction, operation and decommissioning on various fish and shellfish receptors
Ecological monitoring is likely to be appropriate during the construction and operational phases to identify the actual impact so that, where appropriate, adverse effects can then be mitigated and to enable further useful information to be published relevant to future projects.	EN-3 section 2.6.71	Monitoring requirements are addressed in **Section 9.11**.
Draft EN-3 NPS for Renewable Energy Infrastructure (EN-3) (BEIS, 2021)		
There are potential impacts associated with energy emissions into the environment (e.g. noise or EMF)), as well as potential interaction with sea bed sediments.	Draft EN-3 section 2.26.1	Potential impacts associated with noise, EMF and interaction with sea bed sediments have been assessed in **Section 9.6.**
The applicant should identify fish species that are the most likely receptors of impacts with respect to: • protected areas (e.g. HRA sites and MCZs)	Draft EN-3 section 2.26.2	Designated Sites and Protected Species are identified in **Section 9.5.4.**
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.	Draft EN-3 section 2.26.2	Potential impacts associated with noise (piling, other construction and UXO) and EMF have been assessed in **Section 9.6.**

9.4.1.2 Other

30. In addition to the NPS, there are a number of pieces of legislation, policy and guidance applicable to the assessment of fish and shellfish ecology.

31. The Marine Policy Statement (MPS) (HM Government, 2011) sets out the framework for environmental, social and economic considerations that need to be taken into account in marine planning, providing high-level approach to marine planning and general principles for decision making. The high level objective of

'Living within environmental limits' covers the points relevant to fish and shellfish ecology, this requires that:

- Biodiversity is protected, conserved and where appropriate recovered and loss has been halted;
- Healthy marine and coastal habitats occur across their natural range and can support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems; and
- Our oceans support viable populations of representative, rare, vulnerable, and valued species.

32. The East Inshore and East Offshore Marine Plans (HM Government, 2014) have the following objectives that are relevant to this chapter:

- Objective 6 "To have a healthy, resilient and adaptable marine ecosystem in the East Marine Plan areas"; and
- Objective 7 "To protect, conserve and, where appropriate, recover biodiversity that is in or dependent upon the East marine plan areas".

33. These cover policies and commitments on the wider ecosystem, set out in the MPS including those relating to the Marine Strategy Framework Directive (MSFD) and the Water Framework Directive (WFD) (see **Chapter 2 Policy and Legislative Context** and **Chapter 7 Marine Water and Sediment Quality** for more details), as well as other environmental, social and economic considerations.

34. Several policies within the East Marine Plan (HM Government, 2014) are of particular relevance to fish and shellfish ecology and have been considered within this assessment:

- FISH 1: Within areas of fishing activity, proposals should demonstrate in order of preference:
  - That they will not prevent fishing activities on, or access to, fishing grounds;
  - How, if there are adverse impacts on the ability to undertake fishing activities or access to fishing grounds, they will minimise them;
  - How, if the adverse impacts cannot be minimised, they will be mitigated; and
  - The case for proceeding with their proposal if it is not possible to minimise or mitigate the adverse impacts.
- FISH 2: Proposals should demonstrate, in order of preference:
  - That they will not have an adverse impact upon spawning and nursery areas and any associated habitat;
  - How, if there are adverse impacts upon the spawning and nursery areas and any associated habitat, they will minimise them;
  - How, if the adverse impacts cannot be minimised they will be mitigated; and
  - The case for proceeding with their proposals if it is not possible to minimise or mitigate the adverse impacts.

- ECO1: Cumulative impacts affecting the ecosystem of the East marine plans and adjacent areas (marine, terrestrial) should be addressed in decision-making and plan implementation.

35. In addition to the above the following documents have been used to inform the assessment of potential impacts of SEP and DEP on fish and shellfish ecology. These include:

- Guidance document on wind energy developments and EU nature legislation (2020);
- Energy transmission infrastructure and EU nature legislation (2018);
- Guidelines for Ecological Impact Assessment in the UK and Ireland (CIEEM, 2018);
- Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2011) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Contract report: ME5403, September 2011;
- Sound Exposure Guidelines for Fishes and Sea Turtles Monitoring (Popper *et al.* 2014);
- Cefas, Marine Consents and Environment Unit (MCEU), Department for Environment, Food and Rural Affairs (Defra) and Department of Trade and Industry (DTI) (2004) OWFs - Guidance note for Environmental Impact Assessment In respect of the Food and Environmental Protection Act (FEPA) and CPA requirements, Version 2;
- Strategic Review of Offshore Windfarm Monitoring Data Associated with FEPA Licence Conditions (Cefas, 2010);
- Review of post-consent OWF monitoring data associated with licence conditions (MMO, 2014);
- Renewable UK (2013) Cumulative impact assessment guidelines, guiding principles for cumulative impacts assessments in OWFs;
- Monitoring Guidance for Underwater Noise in European Seas, Part II Monitoring Guidance Specifications. JRC Scientific and Policy Report EUR 26555 EN (Dekeling *et al.* 2014);
- Blyth-Skyrme, R.E. (2010) Options and opportunities for marine fisheries mitigation associated with wind farms. Final report for Collaborative Offshore Wind Research into the Environment contract FISHMITIG09. COWRIE Ltd, London; and
- Planning Inspectorate Scoping Opinion (Planning Inspectorate, 2019) which included scoping responses from statutory consultees.

36. Further detail is provided in **Chapter 2 Policy and Legislative Context**.

9.4.2 Data and Information Sources

37. In order to provide site specific and up to date information on which to base the impact assessment, the data sources listed in **Table 9-5** were used. As fish are highly mobile, other data sets with large-scale coverage are of more relevance for characterising the natural fish and shellfish resource. A key source of information used are fisheries landings data; these provide both large spatial coverage and effort, although the data has some limitations (i.e. they are skewed towards commercial species with many non-commercial species being discarded at sea).

38. It was agreed with stakeholders through the EPP that sufficient publicly available information is available to undertake a robust assessment (with any limitations clearly stated where relevant – see **Table 9-5** and **Section 9.4.6**) and, as a result, that site specific fish sampling surveys were not required.

Table 9-5: Data Sources

Data set	Spatial coverage	Year	Notes
MMO landings data (weight and value) by species	ICES rectangles 34F1, 35F1, 34F0 and 34F1	2009 to 2019	34F1 and 35F1 contain SEP and DEP and are the primary data source
North Sea International Bottom Trawl Survey (IBTS)	North Sea	2010 to 2020	ICES rectangles 34F1, 35F1 and 35F0.
Fish spawning and nursery grounds	Southern North Sea	N/A	(Coull *et al.* (1998); Ellis *et al.* (2012); Aires *et al.* (2014))
ICES International Herring Larvae Survey (IHLS) data	North Sea (and other areas)	2010 to 2022	The IHLS data has not covered the area off the North Norfolk coast where the projects are located since the 1970s.
SOW and DOW characterisation and pre-construction surveys fish and shellfish	Sheringham Shoal and Dudgeon OWFs (including export cable corridors)	2005, 2008, 2014	Beam, otter and epibenthic trawls. It is acknowledged that these surveys are several years old.
SOW and DOW herring spawning surveys (Pre- and post-construction)	Sheringham Shoal and Dudgeon OWFs (including export cable corridors and adjacent areas)	2008, 2009, 2010	There were some inconsistences during the herring spawning campaigns as well as encountering access problems due to fishing activity resulting in stations being missed.
SOW elasmobranch surveys (Pre- and post-cable installation)	SOW offshore export cable route	2010, 2012 - 2015	These surveys were spatially and temporally quite limited and therefore only provide additional context to the other available sources of information.
Project Benthic Characterisation Survey	SEP and DEP wind farm sites and offshore cable corridors (excluding	2020	Entire SEP and DEP offshore sites surveyed except the narrow interlink cable corridor between the DEP South and

Data set	Spatial coverage	Year	Notes
	temporary works areas)		DEP North array areas and the temporary works areas.
SEP and DEP aerial surveys	Area encompassing the SEP and DEP wind farm sites plus 4km buffer	2018 to 2020	19 transects, 2.5km parallel transect spacing. Survey at least monthly over a 24-month period.

9.4.2.1 Other available sources

39. Other sources that have been used to inform the assessment are listed below:

- Cefas publications;
- Institute for Marine Resources and Ecosystem Studies (IMARES) publications;
- Collaborative Offshore Wind Research into the Environment (COWRIE) reports;
- International Council for the Exploration of the Sea (ICES) publications;
- East Marine Plan documents (HM Government, 2014);
- Marine Conservation Zone (MCZ) recommendations (Natural England, 2018);
- Offshore Renewables Joint Industry Programme (ORJIP) study on impacts from piling on fish at offshore windfarm sites (Boyle and New, 2018);
- Results of monitoring programmes undertaken in operational wind farms in the UK and other European countries; and
- Other relevant peer-review publications and assessments.

9.4.3 Impact Assessment Methodology

40. **Chapter 5 EIA Methodology** provides a summary of the general impact assessment methodology applied to SEP and DEP. The following sections confirm the methodology used to assess the potential impacts on fish and shellfish ecology as agreed by statutory stakeholders through the EPP.

41. The potential impacts that are relevant to SEP and DEP on fish and shellfish are specified in the Cefas and MCEU (2004) guidelines for offshore wind developments. The following aspects are taken forward for assessment:

- Spawning grounds;
- Nursery grounds;
- Feeding grounds;
- Shellfish production areas;
- Overwintering areas for crustaceans (e.g. lobster and crab);
- Migration routes;
- Conservation importance;
- Importance in the food web; and
- Commercial importance.

42. Assessment of the impacts on the above have been separately applied to the construction, operational and decommissioning phases.

43. Cumulative impacts relevant to fish and shellfish ecology arising from other marine developments are discussed in **Section 9.7** and inter-relationships and interactions with other receptor groups are described in **Section 9.9** and **9.10** respectively.

9.4.3.1 Definitions

44. 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, value and magnitude for the purpose of the fish and shellfish ecology assessment are provided in **Table 9-6, Table 9-7** and **Table 9-8**

9.4.3.2 Sensitivity

45. Receptor sensitivity has been assigned on the basis of species specific adaptability, tolerance, and recoverability, when exposed to a potential impact. The following parameters have also been taken into account:

- Timing of the impact: whether impacts overlap with critical life-stages or seasons (i.e. spawning, migration); and
- Probability of the receptor-effect interaction occurring (e.g. risk as defined by Popper *et al.* (2014)).

46. Throughout the assessment, receptor sensitivities have been informed through review of the available peer-reviewed scientific literature, and assessments available on the Marine Life Information Network (MarLIN) database and the associated Marine Evidence based Sensitivity Assessment (MarESA) framework. It is acknowledged that the MarLIN assessments have limitations and are not available for all species. However, the MarLIN 'evidence base' remains the largest review yet undertaken on the effects of human activities and natural events on marine species and habitats, and includes evidence-based sensitivity assessments that have been used in the impact assessment. Where relevant, limitations have been taken in to account and other information and data accessed where appropriate. Definitions of receptor sensitivity are provided in **Table 9-6**.

47. With regard to noise related impacts, the criteria adopted are based on internationally accepted peer-reviewed evidence and criteria proposed by consensus of expert committees. Fish criteria were adopted from Popper *et al.* (2014) and National Marine Fisheries Service (NMFS, 2016) thresholds and criteria for the modelling of underwater noise from piling activity was also used and consideration has been given to work by Mueller-Blenkle *et al.* (2010) and Halvorsen *et al.* (2012).

Table 9-6: Definition of Sensitivity for Fish and Shellfish 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.
Medium	Individual* receptor (species or stock) has limited capacity to avoid, adapt to, accommodate or recover from the anticipated impact.

Sensitivity	Definition
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*

9.4.3.3 Value

48. In some instances the ecological value of the receptor may also be taken into account within the assessment of impacts. In these instances 'value' refers to the importance of the receptor in the area in terms of conservation status, role in the ecosystem, and geographic frame of reference. Note that for stocks of species which support significant fisheries commercial value is also taken into consideration. Value definitions are provided in **Table 9-7.**

Table 9-7: Definition of Value for Fish and Shellfish Receptor

Magnitude	Definition
High	Internationally or nationally important
Medium	Regionally important or internationally rare
Low	Locally important or nationally rare
Negligible	Not considered to be particularly important or rare

9.4.3.4 Magnitude

49. The magnitude of an effect is considered for each predicted impact on a given receptor and is defined geographically, temporally and in terms of the likelihood of occurrence. The definitions of terms relating to the magnitude of a potential impact on fish and shellfish ecology are provided in **Table 9-8**.

Table 9-8: Definition of Magnitude for Fish and Shellfish Receptor

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the 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 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 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 receptors' character or distinctiveness.

9.4.3.5 Impact Significance

50. In basic terms, the potential significance of an impact is a function of the sensitivity of the fish and shellfish receptors and the magnitude of effect (see **Chapter 5 EIA Methodology** for further details). The determination of significance is guided by the use of an impact significance matrix, as shown in **Table 9-9**. Definitions of each level of significance are provided in **Table 9-9**.

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

Table 9-9: Impact Significance Matrix

		Adverse 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*	*Minor*	*Negligible*	*Negligible*	*Minor*	*Minor*	*Moderate*
	Negligible	*Minor*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Negligible*	*Minor*

Table 9-10: Definition of Impact 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.

9.4.4 Cumulative Impact Assessment Methodology

52. The CIA considers other plans, projects and activities that may impact cumulatively with SEP and DEP. As part of this process, the assessment considers which of the residual impacts assessed for DEP and/or SEP on their own have the potential to contribute to a cumulative impact, the data and information available to inform the cumulative assessment and the resulting confidence in any assessment that is

undertaken. **Chapter 5 EIA Methodology** provides further details of the general framework and approach to the CIA.

53. For fish and shellfish ecology, these activities include other OWFs (tier 1 to tier 6), marine aggregate dredging projects, subsea cables and pipelines and oil and gas exploration.

9.4.5 Transboundary Impact Assessment Methodology

54. The transboundary assessment considers the potential for transboundary effects to occur on fish and shellfish ecology receptors as a result of SEP and DEP; either those that might arise within the Exclusive Economic Zone (EEZ) of European Economic Area (EEA) states or arising on the interests of EEA states e.g. a non UK fishing vessel. **Chapter 5 EIA Methodology** provides further details of the general framework and approach to the assessment of transboundary effects.

55. For fish and shellfish ecology, the distribution of fish stocks and populations of many species cross national geographic boundaries and therefore the main assessment for SEP and DEP has been undertaken irrespective of national jurisdictions. As such, potential transboundary effects are considered as an inherent aspect of the main assessment. See **Section 9.8** for further details.

9.4.6 Assumptions and Limitations

56. There are numerous datasets on fish and shellfish within the study area and from other existing OWF surrounding SEP and DEP that have been used to characterise the species assemblage. However, as fish and some shellfish are highly mobile, and are subject to a range of environmental (seasonal), biological (spawning) and anthropogenic factors, the available data has limitations. These include historic site survey data that are over 15 years old and/or where the surveys were temporally and spatially quite limited, whereby it is acknowledged that such datasets only represent a snapshot of the assemblage at the time of survey (see for **Table 9-5** further details). Similarly, UK MMO landings data provide a good indication of principal commercial species within the study area, but do not necessarily reflect accurately the community or species composition, relative abundance or biomass.

57. However, these limitations are not considered to materially affect the overall confidence in the assessment outcomes which, as set out in **Section 9.4.2**, are based on the best available data and information sources, which are also typical for informing an assessment of this nature.

58. Limitations, sensitivities and gaps of the data sources are further detailed in **Section 11.1.2** of **Appendix 9.1**.

9.5 Existing Environment

59. The characterisation of the existing environment is undertaken using data sources listed in **Table 9-5** plus other relevant literature. **Appendix 9.1** gives further detail on the species typically found within the study area.

9.5.1 Overview

60. Regional and local data sources have been used to describe the fish and shellfish ecology baseline, with a focus on the local study area defined by ICES rectangles 34F1 and 35F1. Regional data includes MMO landings, used to identify commercially important species; and the IBTS, which provides information about demersal species present locally that are effectively sampled by beam trawls, including non-commercial species. Data from historic surveys undertaken pre and post-construction of the existing SOW and DOW have also been included in the baseline. These included several otter, beam and pelagic trawl surveys, and longline surveys for elasmobranchs (see **Table 9.1.1** in **Appendix 9.1** for details).

61. The southern North Sea (ICES Division IVc) is generally shallower than more northerly waters. The dominant fish species are those that are characteristic of inshore, coastal waters (<50m deep). Plaice (*Pleuronectes platessa)*, sole (*Solea vulgaris)*, dab (*Limanda limanda)* and whiting (*Merlangius merlangus)* are some of the dominant commercial species, along with non-commercial species such as lesser weever (*Echiichthys vipera)*, grey gurnard (*Eutrigla gurnardus)* and solenette (*Buglossidium luteum)* all forming important components of the overall fish assemblage (Teal, 2011). Species such as sandeels *(Ammodytidae*) and sand gobies (*Pomatoschistus spp.*) are also abundant and are important prey species for many species of demersal fish, birds and marine mammals (Teal, 2011).

62. There are over 23 different elasmobranch species (sharks, skates and rays) that have been recorded in the North Sea with the most common shark species, spurdog (*Squalus acanthias*), lesser spotted dogfish (*Scyliorhinus canicula*) and starry smoothhound (*Mustelus asterias*) concentrated in the western part of the North Sea (Daan, 2005). Between 1902 – 2013, larger species (thornback ray, tope, spurdog) exhibited long-term declines, and the largest (common skate complex) became locally extirpated (as did angelshark). Smaller species increased (spotted and starry ray, lesser-spotted dogfish) as did smoothhound, likely benefiting from greater resilience to fishing and/or climate change (Sguotti *et al.*, 2016).

63. There have been occasional records of diadromous fish species within the study area, suggesting that such species may transit through the SEP and DEP areas during seasonal migrations between the sea and riverine environments, potentially for spawning and nursery life-history stages.

64. Similarly, there are records of several species of conservation importance in the study area but in low abundance, including possible spawning and nursery grounds of thornback ray (*Raja clavata*), herring (*Clupea harengus*), Dover sole (*Solea solea*), plaice (*Pleuronectes platessa*), mackerel (*Scomber scombrus*), whiting (*Merlangius merlangus*) and lesser sandeel (*Ammodytes tobianus*)*.* Bird *et al.* (2020) used data from mark-recapture tagging studies to evaluate ICES stock units for skate. They found that tags were generally returned from areas less than 50km and usually from within the ICES Division in which they were released. Thornback ray is the most commercially important skate in the UK and out of all skate species recorded, was tagged the greatest number of times across the entire survey area and within ICES Division 4.c (i.e. where SEP and DEP are located) indicating that thornback ray is the most likely skate species to be present within the SEP and DEP offshore sites. McCully *et al.* (2013) identified Thornback ray within the vicinity of

SEP and DEP. Literature on elasmobranch spawning is limited and elasmobranch abundance is overall low within the area of the SEP and DEP offshore sites.

65. The southern North Sea supports commercially important shellfish species such as brown crab (*Cancer pagurus)*, lobster (*Hommarus gammarus*), velvet swimming crab (*Necora puber)*, brown shrimp (*Crangon crangon)*, pink shrimp (*Pandalus montagui),* mussels (*Mytilus edulis)*, cockles (*Cerastoderma edule*) and the edible common whelk (*Buccinum undatum*). Other shellfish species relevant to the SEP and DEP areas include harbour crab (*Liocarcinus depurator*), long-clawed porcelain crab (*Pisidia longicornis*) and slipper shell (*Crepidula fornicata*).

9.5.2 Fish and Shellfish

9.5.2.1 Commercial Species

66. Species and associated quantities available for landings are determined through a system of Total Allowable Catches (TACs) and quotas (**Chapter 12 Commercial Fisheries**), these quotas vary between fleets and vessels. Therefore, landings do not necessarily reflect accurately the community or species composition, relative abundance or biomass. In addition, vessels target certain species and discard others. Species may be absent from statistics due to stock conservation measures and lastly the presence and distribution of fish and shellfish species are dependent on a number of biological and environmental factors, which interact in direct and indirect ways, and are subject to temporal and spatial seasonal and annual variations. It is therefore concluded that commercial landings data does not give an accurate reflection of species composition in an area, therefore, to give a more accurate presentation of the commercial species present, MMO data has been used.

9.5.2.1.1 UK MMO Landings

67. The SEP and DEP offshore infrastructure are within ICES rectangles 35F1 (offshore area) and 34F1 (inshore area). Data from 2009 to 2019[4] (**Table 9.2.1** in **Appendix 9.1**) from the local study area show that the key commercial fish species were herring. **Table 9.2.1** in **Appendix 9.1** also show that the key commercial species for the regional area (ICES rectangles 35F0 and 34F0) were primarily shellfish.

68. Over the decade herring from 34F1 were landed every year along with other key commercial species including cod (*Gadus morhua*), bass (*Dicentrarchus labrax*), mackerel, sprat and Dover sole (**Plate 9.2.3** in **Appendix 9.1**). Whereas key commercial fish landed from 35F1 during 2009 to 2019 vary, species also include herring, cod, bass, Dover sole, plaice, brill and whiting (**Plate 9.2.7** in **Appendix 9.1**).

69. Data from 2009 to 2019 (**Table 9.2.1** in **Appendix 9.1**) from the local study area show that the key commercial shellfish species were whelk, brown crab, lobster, mussels and cockles. **Table 9.2.1** in **Appendix 9.1** also show that the key commercial shellfish species for the regional area (ICES rectangles 35F0 and 34F0)

[4] Landings data from 2020 and 2021 have not been included due to the potential influence of the Covid 19 pandemic on landings of commercial fish species.

also included whelks, cockles, mussels, brown crab and lobster with the addition of brown and pink shrimp and scallops.

70. Over the decade brown crab was landed in the greatest quantities followed by whelks, and lobster from 34F1, whereas whelk dominated the landings from 35F1, followed by brown crab and lobster.

9.5.2.2 International Bottom Trawl Survey

9.5.2.2.1 Local Study Area

71. There were 81 fish and shellfish species recorded by the IBTS in the local study area as defined by ICES rectangles 34F1 and 35F1 from stations shown in **Figure 9.2 of Appendix 9.1** between 2010 to Q1 2020[5]. CPUE data for the principal species recorded is shown in **Table 9.1.3** of **Appendix 9.1**. Of the fish species, greater sandeel CPUE was the highest in ICES rectangle 35F1 with a CPUE of 444 (**Figure 9.25**). Sprat (*Sprattus sprattus*) had the highest CPUE in ICES rectangle 34F1 with a CPUE of 70 (**Figure 9.23**).

72. The CPUE of shellfish species were far less to the above fish species. Brown crab CPUE was the highest in ICES rectangle 34F1 with a CPUE of 12 (**Figure 9.3**). Veined squid had the highest CPUE in ICES rectangle 35F1 with a CPUE of 9.

9.5.2.2.2 Regional Study Area

73. The regional study area is defined by ICES rectangles 34F0 and 35F0. There are no IBTS survey data for ICES rectangle 34F0. As shown in **Figure 9.1 of Appendix 9.1,** this area is largely inshore and therefore no IBTS data are available for this ICES rectangle. **Figure 9.2** of **Appendix 9.1** shows the IBTS sample stations for ICES rectangle 35F0 between 2010 and 2020. **Table 9.1.3** in **Appendix 9.1** shows that, of the fish species, Raitt's sandeel had the highest CPUE in ICES rectangle 35F0 (**Figure 9.26**).

9.5.2.3 Spawning and Nursery Grounds

74. Spawning and nursery grounds defined by Coull *et al.* (1998), Ellis *et al.* (2012) and Aires *et al.* (2014) have been used to indicate which species may have spawning and nursery grounds within the SEP and DEP offshore sites. These data indicate that herring (**Figure 9.6**), Dover sole (**Figure 9.14**), whiting (**Figure 9.22**), sandeel (**Figure 9.30**) and lemon sole (**Figure 9.37**) have defined spawning grounds that overlap with SEP and DEP (see **Table 9.2.3** in **Appendix 9.1** for further details on spawning/nursery grounds and offshore infrastructure overlap as defined by Coull *et al.* (1998), Ellis *et al.* (2012) and Aires *et al.* (2014)). Thornback ray spawning grounds are poorly defined but are thought to generally coincide with nursery areas (Ellis *et al.* 2012). **Table 9-11** shows the spawning periods for each of these species.

75. As noted by the MMO / Cefas in **Table 9-1**, the calculation of total spawning habitat and defining the extent of an affected habitat as a percentage, can either over or underrepresent spawning grounds and therefore the impact assessment (**Section 9.6**) does not attempt to quantify proportions of spawning habitat that are disturbed or lost by project activities or installed infrastructure. Efforts to quantify impacts to

[5] IBTS data from 2020 and 2021 have not been included due to the potential influence of the Covid 19 pandemic on CPUE surveys.

spawning grounds are likely to provide inaccurate and/or misleading figures for the following reasons:

- Spawning areas can change over time or become recolonised.
- Whilst spawning and nursery ground maps are used to provide the most recent and appropriate information to identify spawning areas, they do not fully define/consider/identify:
    - All potential areas of spawning.
    - Any habituation that may occur i.e., identify areas where higher densities of spawning are present.
    - Specific substrate requirements e.g., substrates which are more suitable within wider broadscale sediments.
    - More suitable topography e.g., ridges/edges of sandbanks where sandeel may spawn or furrows where herring may spawn.
    - Environmental factors that may influence spawning intensity such as temperature, oxygenation, natural disturbance, anthropogenic disturbance etc.

76. However, the Applicant has provided percentage calculations of potentially suitable spawning habitat / habitat within the offshore sites based on the methods used for herring (**Section 9.5.2.3.1**) and sandeel (**Section 9.5.2.3.2**) in order to provide site context given the differing geographical areas of the SEP and DEP offshore sites.

Table 9-11: Spawning Periods of Species Present in SEP and DEP Areas.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Herring												
Dover sole				*								
Whiting												
Sandeel												
Lemon sole												
Thornback ray				*	*	*	*	*				

Spawning	
Peak spawning	*

77. SEP and DEP overlap with the defined nursery grounds for the species stated above, and also for cod (**Figure 9.12**), plaice (**Figure 9.16**), mackerel (**Figure 9.20**) and thornback ray (**Figure 9.33**). It should be noted that Dover sole and thornback ray nursery areas are restricted to shallower inshore waters (see also **Figure 9.14** and **Figure 9.33**).

9.5.2.3.1 Herring spawning

78. Herring is a schooling pelagic fish that is an important prey species for piscivorous fish, sharks, marine mammals and seabirds and is also targeted by commercial fisheries. It is listed as a species of principal importance for the purpose of conserving UK biodiversity. Herring are demersal spawners, showing a preference to lay their eggs on gravel and other coarse sediments and substrates (e.g. maerl or shell), characterised by a low proportion of fine sediment and well-oxygenated water (Fugro, 2020a; 2020b). Due to their ecological importance and the specificity of their spawning habitat, potential impacts on herring can be of concern. Eggs can take up to two weeks to hatch, after which the larvae enter a planktonic stage, rising to the surface and drifting to the coastal waters of the eastern North Sea. There are several discrete North Sea stocks of either spring-spawning or autumn-spawning herring. SEP and DEP are in proximity to the spawning grounds of the autumn-spawning (August to October) Banks sub-population.

79. A benthic characterisation survey of the SEP and DEP areas was completed in August 2020 (**Chapter 8 Benthic Ecology Appendix 8.1 and 8.2**). Sediment grab samples were assessed for their suitability as herring spawning habitat based on the distribution of sediment particle sizes.

80. Survey stations have been categorised for herring spawning suitability based on criteria defined by MarineSpace *et al.* (2013) as summarised in **Table 9-12** along with the equivalent Folk (1954) and British Geological Survey (BGS) modified Folk sediment classifications.

Table 9-12: Herring Preference Sediment Categories

Fractional Composition	Folk (1954) Description	Folk (BGS Modified) Description	Herring Preference (MarineSpace *et al.* 2013)
≤10% muds and >30% gravel	Gravel (G) and sandy gravel (sG)	Gravel (G) and sandy gravel (sG)	Preferred
≤10% muds and 5% to 30% gravel	Gravelly sand (gS)	Gravelly sand (gS)	Marginal
>10% muds or ≤10% gravel	All other sediment types	All other sediment types	Unsuitable

81. Within the DEP wind farm site, most stations are classified as being 'Unsuitable' for herring spawning. Nine samples across four stations are considered 'Marginal' and four stations sampled 'Preferred' habitat. The 'Preferred' sites, with a larger gravel component and very little or no mud content are located in the south of the DEP North and DEP South array areas (Fugro, 2020b) (**Figure 9.2**).

82. Within the SEP wind farm site the majority of the sediments towards the northwest were considered 'Unsuitable'. However, samples in the southeast and most easterly extent of the wind farm site are classified as 'Preferred' herring spawning habitat (Fugro, 2020a) (**Figure 9.2**).

83. Along the offshore export cable corridor and interlink cable corridors, the areas of 'Preferred' herring spawning habitat followed the pattern of alternating sand and coarse/mixed sediments observed. Where the sediment was predominantly sand,

the habitat is classed as 'Unsuitable' or 'Marginal', however where the sediment was coarse or mixed with a large gravel component, the habitats are classed as 'Preferred' (Fugro, 2020a; 2020b) (**Figure 9.2**).

84. Two methods have been used to map the distribution of the suitability of herring spawning habitat in the areas between samples:

Herring spawning habitat assessment Method A

85. The first method used geophysical survey data obtained by SEP and DEP surveys in 2019 and 2020. Geostatistical processing and spatial statistical analysis of sidescan sonar and bathymetry data classified the survey area for herring spawning preference, informed by 'ground truthing' benthic sample data. Further details are available in **Chapter 8 Benthic Ecology Appendix 8.3** (Envision, 2021). This method has identified Preferred herring spawning habitat in coarse sediment areas along the offshore export cable corridor, and in relatively small areas within the SEP and DEP wind farm sites and interlink cable corridors (**Figure 9.2**). Areas identified as 'Preferred' herring spawning habitat comprise approximately 21% of the DEP wind farm site (excluding offshore temporary works area) and 10% of the SEP wind farm site (excluding offshore temporary works area).

Herring spawning habitat assessment Method B

86. The second method follows MarineSpace *et al*. (2013) and classifies existing BGS 1:250,000 sediment maps, which show the distribution of BGS modified Folk sediment classes, according to the herring spawning preference categories as described in **Table 9-12**. The results show 'Preferred' herring spawning habitat extending across the majority of the area within the SEP wind farm site and offshore export cable corridor, almost all of the interlink cable corridors area and DEP South array area, and the eastern half of DEP North array area (**Figure 9.2**). In many areas this interpretation contradicts sediment grab samples taken during the 2020 SEP and DEP benthic survey and it is likely that the accuracy of the BGS maps is relatively low. MarineSpace *et al*. (2013) acknowledge that is important to note that the habitat sediment classification is not the only parameter that indicates potential spawning habitat. There are other environmental (physical, chemical and biotic) parameters such as: oxygenation, siltation, overlap with range of spawning populations, micro-scale sea bed morphological features e.g. ripples and ridges; which all contribute to the suitability of sea bed habitat to be used as spawning beds by herring. As such the habitat sediment classes alone will always over-represent the range of habitat with the potential to support spawning events (MarineSpace *et al*. 2013).

Herring spawning areas

87. The existence of suitable herring spawning habitat does not necessarily mean that the area is used as a herring spawning ground. SEP and DEP are located within a potential herring spawning area identified by Coull *et al*. (1998), however the confidence in this evidence is lower than the more recent IHLS data (MarineSpace *et al*. 2013). Unfortunately, the IHLS has not sampled the area near SEP and DEP since 1976. Surveys conducted between 2008 and 2019 recorded no larvae (<11mm in length) from the closest samples to the local study area (see **Appendix 9.1 Figures 9.7**, **9.8** and **9.9**). The September 1976 survey sampled in close proximity to SEP and DEP but recorded no herring larvae at any of the locations

except at one station 3.86km west of the DEP North array area, recording low abundance (4 larvae/m^2). The IHLS indicates that herring spawning is located to the northwest off the North Yorkshire coast (Banks herring) as well as further south in the North Sea (Downs herring). It is reasonable to assume that when the IHLS was scaled down it was to focus on the most important areas. However, areas where the IHLS survey has not been undertaken are not necessarily indicative of no spawning activity (MarineSpace *et al*. 2013).

88. Site specific herring spawning surveys were conducted at the pre- and post-construction stage of the SOW and DOW between 2008 to 2010, with some transects and trawls overlapping with the SEP and DEP wind farms and the offshore section of the offshore export cable corridor north of the Sheringham Shoal sandbank feature (Brown and May Marine, 2009; 2010). Following these surveys, it was concluded that herring spawning did not occur in the survey areas, possibly as a result of changes to North Sea herring spawning patterns in the 1970s (Brown and May Marine, 2009). See **Appendix 9.1** for further details.

89. Following the method similar to that described by MarineSpace *et al*. (2013) potential herring spawning habitat has been further assessed through the overlap of data layers that are deemed indicative of spawning habitat or events. The greater the number of overlapping data layers then the greater the 'heat' mapped and the higher the confidence that the sea bed may be suitable for spawning. The data layers used and the scores they contribute to the heat map, based on a confidence assessment of the data) are presented in **Table 9-13**.

Table 9-13: Indicative Herring Spawning Data Layers and Relative Confidence Scores

Data theme	Source	Score	Notes
Preferred sediment	BGS 1:250,000 sea bed sediment maps	3	Gravel (G) and sandy gravel (sG)
Marginal sediment		2	Gravelly sand (gS)
High number of small larvae (per m^2)	IHLS	5	0-10 mm length. Highest number recorded over period 2009-2017 for each survey station. Score applied within contoured area with >600 larvae per m^2. The IHLS does not cover SEP and DEP area.
Identified spawning grounds	Coull *et al*. (1998)	3	As indicated by the confidence score, these areas are based on relatively old data.

90. The heat mapping method indicates that the SEP wind farm site is located in an area of medium confidence (score 5) along with offshore cable corridors to the north of SEP due to the presence of Preferred sediments and the area having been identified as a herring spawning area by Coull *et al*. (1998) (**Figure 9.3**). However, sediment samples within the SEP wind farm site confirm that much of the area classed as Preferred habitat using BGS sea bed sediment maps are in fact unsuitable, particularly in the west of the site (**Figure 9.2**). Approximately 96% of the SEP wind farm site (excluding offshore temporary works area) is estimated to be preferred habitat using BGS maps (Method B) compared to 10% based on recent site geophysical and benthic characterisation surveys (Method A), suggesting that Method B over-represents the extent of habitat in the SEP wind farm site.

91. The heat mapping method indicates that the DEP wind farm site and the export cable corridor south of the SEP wind farm site are located in an area with a lower confidence score (3 and less) because they are primarily outside the Coull *et al*. (1998) spawning area (**Figure 9.3**). These areas contain areas classed as Preferred habitat using BGS sea bed sediment maps. Again, sediment samples and Method A indicate that heat mapping and Method B over-represent the extent of suitable habitat (**Figure 9.2**). Method A estimates that approximately 68% of the DEP wind farm site (excluding offshore temporary works area) is preferred habitat compared to 21% of the site using BGS maps (Method B).

92. In summary, potentially suitable herring spawning habitat areas have been identified within the SEP and DEP boundaries and are likely present in surrounding areas, although mapping based on BGS base maps and heat mapping is likely to overestimate the extent of this habitat (**Figures 9.2** and **9.3**). The SEP wind farm site in particular has been identified as having preferred herring spawning habitat due to its higher gravel content. There is, however, an absence of evidence that herring spawn in the vicinity of SEP and DEP. Indeed, herring spawning surveys undertaken for the existing SOW and DOW concluded that herring spawning did not occur within the study areas (Brown and May Marine, 2009; Brown and May Marine, 2010). Based on the available evidence outlined above, the area is considered to be unlikely to be a hotspot for herring spawning and if spawning does occur it is likely to be at low levels.

9.5.2.3.2 Sandeel habitat

93. Sandeels are a group of shoaling fish which lie buried in sea bed sediments at night and feed on planktonic prey such as copepods and crustacean larvae in mid-water during daylight hours. There are five species of sandeel in the North Sea, all found in shallow, turbulent areas of suitable sediment. Sandeel show a preference for medium and coarser (0.25 to <2.0m diameter) sandy sediments and avoid areas of fine sediment. Due to high substrate specificity and limited larval exchange between sandeel populations, they are particularly vulnerable to overfishing and other pressures. Sandeels are an important trophic link in the North Sea food chain, between zooplankton and sandeel predators including piscivorous fish, most seabirds and mammals. As many marine predators rely on sandeels, coupled with their vulnerability to changes in habitat, sandeels are of increasing conservation interest and listed as a species of principal importance in the UK and designated as a nationally important marine feature.

94. Sediment grab samples obtained by the benthic characterisation survey of the SEP and DEP areas (**Chapter 8 Benthic Ecology Appendix 8.1 and 8.2**) were assessed for their suitability as sandeel habitat based on the distribution of sediment particle sizes.

95. Survey stations have been categorised based on criteria defined by Latto *et al*. (2013) as summarised in **Table 9-14** along with the equivalent Folk (1954) and BGS modified Folk sediment classifications.

Table 9-14: Sandeel Preference Sediment Categories

Fractional Composition	Folk (1954) Description	Folk (BGS Modified) Description	Sandeel Preference (Latto *et al.* 2013)
≤10% mud and ≤30% gravel	Sand (S), slightly gravelly sand ((g)S) and gravelly sand (gS)	Sand (S) and gravelly sand (gS)	Preferred
≤10% mud and >30% to <80% gravel	Sandy gravel (sG)	Sandy gravel (sG)	Marginal
>10% mud or ≥10% gravel	All other sediment types	All other sediment types	Unsuitable

96. The locations and distribution of sample stations classified as ‘Preferred’ sandeel habitat in the SEP and DEP offshore sites is illustrated in **Figure 9.4**. The large majority of sediment samples from the DEP wind farm site are assessed as ‘Preferred’ sandeel habitat. Sandeels were present in grabs from stations D19 and D25 in DEP North array area, both of which have been classed as ‘Preferred’ sandeel habitat. Examples of ‘Preferred’ sandeel habitat, along with ‘Marginal’ or ‘Unsuitable’ areas were identified in the interlink cable corridors, including ‘Preferred’ habitat at stations at the northern end of the DEP North array area to SEP interlink corridor **Figure 9.4**. Sandeels were also recorded in this area from the grab at station CC19, also assessed as ‘Preferred’ habitat (Fugro, 2020b).

97. All but one sample from the SEP wind farm are assessed as ‘Marginal’ or ‘Unsuitable’ for sandeel (**Figure 9.4**). No sandeels were recorded in grabs or photographic data from the SEP wind farm (Fugro, 2020a). This suggests that although the SEP wind farm site may support some sandeels, it is likely to be less important for the species than the area around the DEP wind farm site.

98. Stations in the export cable corridor are assessed predominantly as ‘Preferred’ and ‘Marginal’ sandeel habitat. Lesser sandeels were observed from the video transect at station EC18 on the offshore export cable corridor, an area which has been classed as ‘Marginal’ sandeel habitat (Fugro, 2020a).

99. Two methods have been used to map the distribution of suitability sandeel habitat in the areas between samples:

<u>Sandeel habitat assessment Method A</u>

100. Like herring spawning habitat assessment Method A, sidescan sonar and bathymetry data obtained by SEP and DEP surveys in 2019 and 2020 were used to predict and map sandeel habitat preference, informed by ‘ground truthing’ benthic sample data. This method classified sea bed as ‘Prime’, ‘Subprime’, ‘Suitable’ or ‘Unsuitable’ depending on the relationship between the percentages of silt and fine sand and of coarse sand in the sediment, based on Greenstreet *et al*. (2010). Further details are available in **Chapter 8 Benthic Ecology Appendix 8.3** (Envision, 2021). ‘Prime’ and ‘Subprime’ habitat categories can be combined to an equivalent Preferred category and Preferred sandeel habitat was identified in large parts of DEP North and DEP South array areas, with smaller areas present in the southeast of the SEP wind farm and in the offshore cable corridors (**Figure 9.4**). Areas identified as sandeel Preferred habitat comprise approximately 61% of the

DEP wind farm site (excluding offshore temporary works area) and less than 4% of the SEP wind farm site (excluding offshore temporary works area).

Sandeel habitat assessment Method B

101. The second method follows Latto *et al*. (2013) and classifies existing BGS 1:250,000 sediment maps, which show the distribution of BGS modified Folk sediment classes, according to the sandeel habitat preference categories as described in **Table 9-14**. The results show 'Preferred' sandeel habitat in the western part of DEP North array area with small areas in the offshore cable corridors and in the SEP wind farm site. However, almost all of the SEP wind farm site, the offshore cable corridors and DEP South array area are marginal sandeel habitat (**Figure 9.4**). In many areas this interpretation contradicts sediment grab samples taken during the 2020 SEP and DEP benthic survey and it is likely that the accuracy of the BGS maps is relatively low.

102. As with herring, the presence of suitable habitat does not necessarily mean that sandeels are present in significant numbers. Sandeels were confirmed to be present at some locations (present in grab samples) by the benthic characterisation survey of the SEP and DEP areas. Otter and beam trawl surveys at SOW and DOW recorded sandeels in relatively low numbers, suggesting that these species are present but not abundant, although it should be noted that the abundance of sandeels in the area may be underrepresented by these survey methods. IBTS data suggest that greater sandeel may be abundant to the north of the DEP wind farm site, and the extent of a historical sandeel fishery overlapped with part of DEP North array area. The presence of suitable sediments supports the possibility that the DEP wind farm site, and particularly the DEP North array area, support sandeel populations. See **Appendix 9.1** for further details.

103. Following the method similar to that described by Latto *et al*. (2013) potential sandeel habitat has been further assessed through the overlap of data layers that are deemed indicative of sandeel presence. The greater the number of overlapping data layers then the greater the 'heat' mapped and the higher the confidence that the sea bed may be suitable and sandeels are present. The data layers used and the scores they contribute to the heat map, based on a confidence assessment of the data) are presented in **Table 9-15**.

Table 9-15: Indicative Sandeel Habitat Data Layers and Relative Confidence Scores

Data theme	Source	Score	Notes
Preferred sediment	BGS 1:250,000 sea bed sediment maps	4	Sand (S) and gravelly sand (gS)
Marginal sediment		2	Sandy gravel (sG)
Sandeel Fishing Grounds	(Jensen *et al*. 2011)	2	Mapping of sandeel habitat based on GPS and VMS records of sandeel fishing vessels, and maps provided by fishers.
Identified spawning grounds	Coull *et al*. (1998)	3	These areas are based on relatively old data.

104. The heat mapping method indicates that the SEP wind farm site is located in an area of medium confidence (score 5) along with most of offshore cable corridors to the north of SEP due to the absence of Preferred sediments from most of these areas and present of marginal sediments (**Figure 9.5**). Sediment samples within the

SEP wind farm site confirm that much of the areas are Marginal or Unsuitable (**Figure 9.4**). Both the assessment of recent site geophysical and benthic characterisation survey data (Method A) and use of BGS maps (Method B) estimate that only approximately 4% of the SEP wind farm site (excluding offshore temporary works area) is preferred habitat.

105. The heat mapping method indicates that the DEP wind farm site is located in an area with a higher confidence ranging from medium confidence (5) to higher confidence (7) in parts of DEP North and DEP South array areas, and high confidence score (9) in part of DEP North array area (**Figure 9.5**). These areas contain areas of both Preferred and Marginal habitat using BGS sea bed sediment maps (**Figure 9.4**). Sandeel fishing grounds are located to the North of the DEP wind farm site and extend into DEP North array area (**Figure 9.5**), accounting for the high confidence score in this area. Sediment samples and Method A indicate that heat mapping and Method B under-represent the extent of suitable habitat and that the extent of sandeel habitat may be greater in the DEP wind farm site. Method A estimates that approximately 61% of the DEP wind farm site (excluding offshore temporary works area) is preferred habitat compared to 32% of the site using BGS maps (Method B).

106. The export cable corridor south of the SEP wind farm site contains some areas of Preferred sediment but has a low confidence score because it is outside of recognised spawning or fishing areas (**Figure 9.5**).

107. In summary, the DEP wind farm site is located in areas identified as being suitable for sandeel. In relation to the SEP wind farm site and the export cable corridor south of SEP, only relatively small areas habitat suitable for sandeel are identified. The DEP North and DEP South array areas are located in an area characterised by Preferred sandeel habitat and DEP North array area is close to, and partially within, identified sandeel fishing grounds.

9.5.3 Historic Site Surveys

108. As described in **Section 9.4.2.1**, a variety of surveys have been undertaken in relation to the existing SOW and DOW. Although these surveys were undertaken as early as 2005, the results provide an indication of the fish and shellfish assemblage that is likely to be present in the vicinity of SEP and DEP.

109. Otter trawl surveys were conducted in at SOW in April 2005 and in DOW in May and October 2008. Over 43 fish and shellfish species were recorded over the three surveys. Whiting (*Merlanguis merlangus*) was the most abundant species caught, followed by velvet crab (*Necora puber*), herring, dab (*Limanda limanda*), harbour crab (*Liocarcinus depurator*), pink shrimp (*Pandalus montagui*) and flying crab (*Liocarcinus holsatus*) (see **Table 9.2.5** in **Appendix 9.1** for full list).

110. Eight beam trawl surveys recording fish and epibenthos were conducted at the SOW and DOW between 2005 to 2014 (using 2m and 7m beams). Over 115 fish and shellfish species were recorded (see **Table 9.1.A.1 Annex 1** of **Appendix 9.1** for full list).

111. Crustaceans, and particularly shrimp species, dominated catches. Pink shrimp was the most abundant species. Across all the surveys 908,216 individuals were caught and recorded, totalling almost ten times the next most abundant species, brown

shrimp (*Crangon crangon*) (see **Table 9.2.6** of **Appendix 9.1**). The shrimp (*Pandalina brevirostris*) was also recorded in abundance from the surveys conducted in October 2008 and September 2014 at Dudgeon OWF, and the December 2012 survey at Sheringham Shoal OWF. Crabs where also abundant, particularly swimming crab species. The harbour crab (*Liocarcinus depurator*) was the third most commonly recorded species across the surveys.

112. The most prevalent fish species caught were lesser weever fish (*Echiichthys vipera*), followed by dragonet (*Callionymus lyra*) and the painted goby (*Pomatoschistus pictus*). The abundance of these species varied across the surveys, with some species being completely absent from some surveys. The non-native invasive slipper limpet (*Crepidula fornicata*) was the most abundant mollusc recorded across all surveys. It was recorded by all but the December 2012 post-construction survey for SOW and was the fifth most abundant species across all beam trawl surveys.

113. SOW and DOW are broadly similar in terms of species composition, with crustaceans being the most abundant group. Variations in the abundance of species recorded may be attributed to differences in habitats between the SEP and DEP areas, but may also be the result of survey gaps and limitations, as well as seasonal and temporal changes in the distribution and abundance of species related to migrations or natural fluctuations in species abundances over time.

9.5.4 Designated Sites and Protected Species

114. Sandeels are designated as a nationally important marine feature (Furness, 1990; Hammond *et al.* 1994; Tollit and Thompson, 1996; Wright and Tasker, 1996; Greenstreet *et al.* 1998; Kerby *et al.* 2013) and, as a prey source, are linked to protected and qualifying features of nearby Special Protection Areas (SPA) and Special Areas of Conservation (SAC) such as the Greater Wash SPA and The Wash & North Norfolk Coast SAC. For these reasons, sandeels are included in the assessment.

115. Designated sites for allis shad (*Alosa alosa*) or twaite shad (*Alosa fallax*) are located in river systems where the species have been recorded and where there is previous evidence of breeding, and where there still appear to be favourable conditions for breeding. However there are no UK designated sites for allis shad or twaite shad on the UK coast of the southern North Sea.

116. River lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*) are qualifying features of the Humber Estuary SAC, approximately 60km north west of the SEP wind farm site at its closest point. Both species breed in the River Derwent, a tributary of the River Ouse and ultimately the Humber, and both these species are qualifying features of the River Derwent SAC. Records of river and sea lamprey in rivers in Norfolk (and East Anglia as a whole) are relatively scarce compared with other areas of the UK (Kelly and King, 2001).

117. The European eel (*Anguilla Anguilla*) is widely distributed throughout the Anglian region, including Norfolk. A fishery for adult eels existed in the past, although few records were kept (DEFRA, 2010).

118. The Atlantic salmon is a widespread species in the UK and is found in several hundred rivers, many of which have adult runs in excess of 1,000 (JNCC, 2020). Scottish rivers are the most important in terms of spawning sites. There are 79 rivers

in England and Wales that support salmon populations. No rivers south of the Esk in Yorkshire or east of the Itchen in Hampshire are classified as salmon rivers, hence East Anglian (including Norfolk) rivers do not support important salmon populations (Cefas, 2019). The nearest UK designated site for salmon is the River Avon SAC on the west coast of Britain.

119. Although sea trout are present in East Anglian rivers, those found off the East Anglian coast, including off Norfolk, are generally thought to originate from the rivers in northeast England and southeast Scotland such as the Esk, Wear, Coquet, Tyne and Tweed (Pawson, 2013). No sea trout were recorded in any of the historic site surveys of SOW and DOW, nor the IBTS in the local study area. However, the species has been recorded occasionally in MMO landings by UK vessels from ICES rectangles 34F1 and 35F1.

9.5.5 Species taken forward for Assessment

120. Key species identified, and the rationale for their inclusion within the assessment, are provided **Table 9-16**. Detailed information about the ecology of these species and the use that they may make of the study area is provided in **Appendix 9.1**. Note that for some impacts, species are not considered on an individual basis but by functional group (e.g. fin fish, shellfish, elasmobranchs or migratory fish).

Table 9-16: Summary of the Principal Fish and Shellfish Species in the Local Study Area to be taken forward for Assessment

Species	Rationale
Molluscs	
Whelk	• Commercially important in the study area; and • Recorded by SOW and DOW surveys.
Crustaceans	
Brown crab	• Commercially important in the study area; and • Recorded by SOW and DOW surveys.
Lobster	• Commercially important in the study area: and • Recorded by SOW and DOW surveys.
Brown shrimp	• Recorded in high abundance by SOW and DOW surveys.
Pink shrimp	• Recorded in high abundance by SOW and DOW surveys.
Fish	
Whiting	• Recorded in high abundance by SOW and DOW surveys; • Of some commercial importance in the study area; • Species of Conservation Interest; and • Low intensity spawning and nursery areas overlap with the SEP and DEP wind farm sites, and offshore corridors.
Herring	• Recorded in seasonally high abundance by SOW and DOW surveys;

Species	Rationale
	• Of some commercial importance in the study area; • Species of Conservation Interest; • Key prey species for fish, birds and marine mammals; • Demersal spawning species; • Suitable spawning habitat within the southeast and most easterly extent of the SEP wind farm site and intermittently along the offshore cable corridors, but spawning surveys suggest no spawning activity; and • Low intensity nursery areas overlap with the SEP and DEP wind farm sites and offshore cable corridors.
Sandeels	• Historic sandeel fishing grounds overlap the DEP North array area; • Greater sandeel, lesser sandeel and Corbin's sandeel recorded by SOW and DOW surveys and recorded in high abundance by nearby surveys to the north; • Key prey species for fish, birds and marine mammals; • Demersal spawning species; • Low intensity sandeel (*A. marinus*) spawning area and with low intensity nursery areas overlap with the SEP and DEP wind farm sites and offshore cable corridors; and • Suitable sandeel habitat spawning habitat in the DEP wind farm site and in the export cable corridor, but most of the SEP wind farm site is unsuitable.
Sprat	• Recorded in seasonally high abundance by SOW and DOW herring spawning surveys; and • Important prey species for fish, birds and marine mammal species.
Elasmobranchs	
Starry smoothhound	• Common throughout the southern North Sea and wider Atlantic, starry smoothound was the most abundant elasmobranch recorded by SOW and DOW surveys, typically present at low densities, but can occasionally be abundant.
Thornback ray	• Present in the study area; • Species of Conservation Interest; and • The most important commercially exploited elasmobranch in the study area, but landings are relatively small.
Diadromous species	
Twaite shad Allis shad	• UK BAP listed species; and • Potential (rarely) transit / feed in the study area during marine migration.
River lamprey Sea lamprey	• Present in some East Anglian Rivers; • UK BAP listed species and sea lamprey listed by OSPAR as declining and/or threatened; and • May transit / feed in the study during marine migration.
European eel	• Present in almost all East Anglian rivers; • UK BAP listed species and listed as ‘critically endangered’ on the IUCN Red List; and

Species	Rationale
	• May transit / feed in the offshore development area during marine migration.
Sea trout	• Present in some East Anglian rivers; and • May transit / feed in the offshore development area during marine migration.

9.5.6 Climate Change and Natural Trends

121. The existing baseline conditions within the local study area described above are considered to be relatively stable in terms of fish and shellfish receptors. The fish and shellfish baseline environment of the southern North Sea is primarily influenced by global environmental factors and by commercial fishing activity.

122. The baseline will continue to evolve as a result of global trends which include the effects of climate change, such as increasing sea levels and sea surface temperature, as well as trends at the regional and European level such as changes in fisheries regulations and policies.

9.6 Potential Impacts

123. An assessment of the potential impacts from SEP and DEP on fish and shellfish receptors is presented in the following sections. This has been informed by a literature review of the potential impacts of offshore wind developments on fish and shellfish species, evidence from research carried out at operational wind farms and information and feedback obtained through consultation with statutory and non-statutory stakeholders. Potential impacts considered within the EIA have been agreed with stakeholders (MMO, Natural England, Cefas and The Wildlife Trusts) through the EPP (18^{th} November 2019). A summary of the potential impacts considered is provided in **Table 9-17**.

Table 9-17: Potential Impact Pathways on Fish and Shellfish Receptors

SEP and DEP Phases	Potential Impact Pathway
Construction	• Physical disturbance; • Temporary habitat loss; • Increased suspended sediments and sediment re-deposition; • Re-mobilisation of contaminated sediment; • Underwater noise; and • Commercially exploited species associated with their displacement from the area of activity/works.
Operation	• Temporary habitat loss; • Permanent habitat loss; • Introduction of wind turbine foundations, scour protection and hard substrate; • Increased suspended sediments and sediment re-deposition; • Re-mobilisation of contaminated sediment; • Underwater noise;

SEP and DEP Phases	Potential Impact Pathway
	• EMF; and • Commercially exploited species associated with their displacement from the area of activity/works.
Decommissioning	• Physical disturbance; • Temporary habitat loss; • Increased suspended sediments and sediment re-deposition; and • Underwater noise.
Cumulative	• Underwater noise; • Habitat loss; • Introduction of wind turbine foundations, scour protection and hard substrate; • EMF; and • Decommissioning impacts.
Transboundary	The assessment has been conducted independent of national geographical boundaries, with a description of the spatial extent of the impacts provided for each phase.

9.6.1 Potential Impacts during Construction

9.6.1.1 Impact 1: Temporary habitat loss / disturbance

124. During the construction phase, activities such as foundation installation (for wind turbines and OSP/s) along with sea bed preparation (including sandwave levelling, boulder removal and UXO clearance) and cable burial, all have the potential to cause temporary habitat loss / disturbance to all fish and shellfish receptors. This may include, for example, interrupting spawning or feeding behaviours, localised mortality of individuals or deterring some species from undertaking established migration routes to or from overwintering grounds. Similarly, the presence of machinery on the sea bed (i.e. jack-up vessels legs, vessel anchors) will result in temporary habitat loss / disturbance.

Magnitude of effect - SEP or DEP in Isolation

125. As detailed in **Table 9-2**, during construction, the maximum area of sea bed habitat that would be temporarily disturbed for DEP would be 5.1km^2 and the maximum area for SEP would be 2.1km^2. This equates to approximately 1.9% of the DEP wind farm site and offshore export cable corridor and 1.5% of SEP wind farm site and offshore export cable corridor.

126. For construction of SEP or DEP in isolation, the disturbance would be temporary for approximately two years (24 months) of offshore construction activity, with the majority of disturbance occurring during installation of foundations and cables. Some elements of disturbance, such as those caused by jack-up vessel legs, will be highly localised and only occur over a short period (see **Chapter 4 Project Description**). Considering the availability of similar suitable habitat both in the

offshore development areas and in the wider context of the southern North Sea together with the intermittent and reversible nature of the effect, the magnitude of physical disturbance during construction activities for either SEP or DEP is considered to be negligible for all species.

Sensitivity of effect - SEP or DEP in Isolation

127. Monitoring from North Hoyle and Barrow OWFs in the UK have shown that commercial fish species and their abundance pre and post construction were broadly comparable and consistent with long term trends in the regional areas (Cefas, 2009). In conjunction with this, sampling undertaken at reference sites associated with both of these wind farms, found no significant difference between the reference and wind farm sampling locations, or between fish species and numbers caught before both the wind farms were constructed (Cefas, 2009).

128. Pre- and post-construction surveys undertaken at the nearby SOW and DOW found that species composition was similar before and after construction. There were variations in abundance of some species that may be attributed habitat heterogeneity across the survey areas as well as seasonal and temporal changes in the distribution and abundance of species related to migrations or natural fluctuations over time. This suggests that construction of OWFs in areas adjacent to SEP and DEP has had no significant impact on the fish and shellfish communities present.

129. In 2014 the MMO reviewed post-consent monitoring data from constructed Round 1 and Round 2 wind farms in UK waters, identifying changes in fish and shellfish populations, although this was attributed to high natural variability rather than presence of wind farms (MMO, 2014). This review and other studies since, have noted an increase in fish and shellfish abundance and diversity in some UK and non-UK wind farms, acting as artificial reefs similar to oil and gas infrastructures (MMO, 2014; Todd *et al.* 2018; Fowler *et al.* 2020). These potential benefits are covered in more detail in operation Impact 3, **Section 9.6.2.4**.

130. Most mobile species will be able to move away from any area of disturbance; however, those that are less mobile, including small crabs and shrimps, and sessile species, such as mussel, cockle and whelk, could be directly impacted by the construction works. These species are likely to be most vulnerable due to their low-mobility.

131. Ovigerous female species such as brown crab carries their eggs under their abdomen (known as 'berried') whereas lobster carry them with their pleopods until hatching. To protect the eggs the crabs bury themselves in the sediment for periods ranging from four to nine months, depending on the species (Haig *et al.* 2015). During this period, they do not feed and remain buried to avoid predation (Tonk and Rozemeijer, 2019). Whereas berried lobster do not bury themselves, they continue to feed but do not appear to make extensive movements (Pawson, 1995).

132. The majority of shellfish 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). During construction, parts of SEP or DEP will be temporarily restricted to fishing activity, this may allow larger, more fecund shellfish to contribute to the spawning stock without fishing pressures (Roach *et al.* 2018). However, it should be noted that the total area from which fishing may be

excluded may change depending on the level of works being carried out and the level of infrastructure installed or partially installed at a given time.

133. In comparison to most finfish species, shellfish have more limited mobility and may not be capable of escaping construction activities causing physical disturbance to the sea bed. In particular, the egg masses of ovigerous species would be potentially vulnerable to physical damage. The sensitivity of effect for shellfish is considered to be medium.

134. Other species that spawn on sedimentary habitats (e.g. herring, sandeel, dragonet and elasmobranch species) also have potential to be disturbed during construction. However, herring and sandeel are substrate specific spawners and are therefore potentially more susceptible to physical disturbance.

135. As stated in **Section 9.5.2.2.2**, SEP and DEP overlap with several defined spawning and nursery areas, including herring (**Figure 9.6**), however historic herring spawning surveys found that there was no significant spawning in the area (see **Section 9.5.2.2.2** and **Section 11.2.4.5** in **Appendix 9.1**).

136. Suitable herring spawning habitat has been identified within the SEP and DEP boundaries and is likely present in surrounding areas, although mapping based on BGS base maps and heat mapping is likely to overestimate the extent of this habitat. There is, however, an absence of evidence that herring spawn in the vicinity of SEP and DEP. Based on the available evidence outlined in **Section 9.5.2.3.1**, the area is considered unlikely to be a hotspot for herring spawning and if spawning does occur it is likely to be at low levels. Both SEP and DEP are within a low intensity herring nursery area and are in close proximity to a high intensity nursery area as defined by Ellis *et al.* (2010) as shown in **Appendix 9.1 Figure 9.6** along with data from Aires *et al.* (2014) presenting the probability of juvenile (0-group) herring.

137. As shown in **Appendix 9.1 Figure 9.30**, SEP and DEP both overlap with sandeel spawning and nursery grounds identified by Coull *et al.* (1998) and the whole offshore development areas of both SEP and DEP overlap with low intensity sandeel spawning and nursery grounds identified by Ellis *et al.* (2010). Due to their limited movement between areas of suitable habitat, and in view of their ecological and conservation status along with their overall spatial distribution throughout the North Sea, they are considered to be of medium sensitivity. Similarly, for herring, whilst they have greater mobility than sandeels, due to their spawning ground specificity, a medium sensitivity has also been assigned.

138. Spawning grounds for elasmobranch species, such as thornback ray, blonde ray and lesser spotted dogfish are not defined by Coull *et al.* (1998) or Ellis *et al.* (2012) (see **Appendix 9.9 Figure 9.33**). However, it has been reported that adult thornback rays occur in shallow inshore waters during summer months, potentially for spawning and mating (Walker *et al*. 1997; HOW03, 2018) before returning to deeper offshore waters leaving juveniles in the shallows. Literature on local elasmobranch spawning is limited and elasmobranch abundance are low within the area. Elasmobranchs can be indirectly affected by physical disturbance as it may reduce available spawning and nursery areas, along with preferred sedimentary habitats. However, although there is limited literature on elasmobranch spawning, sensitivity to temporary, discrete and localised areas of disturbance is considered to be low.

139. Other fish receptors in the study area and southern North Sea are considered to have a low sensitivity as they are able to flee from the areas of disturbance, and have a low vulnerability and high recoverability.

Impact Significance - SEP or DEP in Isolation

140. As stated above, the magnitude of effect for temporary habitat loss / disturbance for SEP or DEP is considered to be negligible for all species. A medium sensitivity has been determined for herring and sandeel, resulting in an impact of **minor adverse** significance. For shellfish the sensitivity is also considered to be medium and therefore the resulting impact is also considered to be of **minor adverse** significance. The sensitivity of elasmobranchs is considered to be low and therefore the resulting impact is considered to be of **negligible adverse** significance. For all other fish species, the negligible magnitude of effect and low sensitivity also results in an impact of **negligible adverse** significance.

Magnitude of effect - SEP and DEP

141. **Table 9-2** details that a maximum area of up to 7.89km^2 of sea bed habitat within the SEP and DEP offshore sites would be disturbed during the construction phase of both SEP and DEP equating to up to approximately 2.2% of the SEP and DEP offshore sites.

142. As stated previously, the majority of disturbance would occur during the installation of foundations and cables with some caused by jack-up vessels or anchors, and disturbance would be temporary, however the approximate length of construction activity is up to four years (48 months) rather than two. As outlined above, there is similar suitable habitat available locally and in the wider context of the southern North Sea, together with the intermittent and reversible nature of the effect, the magnitude of physical disturbance during construction activities for SEP and DEP is considered to be negligible for all species.

Sensitivity of effect - SEP and DEP

143. Although the area and duration of disturbance is collectively larger than if either SEP or DEP were built in isolation, the sensitivity of all species is considered to be the same as that assessed for SEP or DEP in isolation: medium for herring, sandeel and shellfish; and low for elasmobranchs and all other fish species.

Impact Significance - SEP and DEP

144. The potential impact significance for temporary habitat loss / disturbance for all species is the same as has been assessed for SEP or DEP in isolation: **minor adverse** for herring, sandeel and shellfish; and **negligible adverse** for elasmobranchs and all other fish species.

9.6.1.2 Impact 2: Increased suspended sediments and sediment re-deposition

145. Construction activities such as foundation preparation and installation, drilling operations, and cable installation may lead to increased suspended sediment concentrations (SSC) and sediment re-deposition. **Chapter 6 Marine Geology, Oceanography and Physical Processes** describes the anticipated patterns of elevated SSCs and re-deposition across SEP and DEP in further detail.

Magnitude of effect - SEP or DEP in Isolation

146. **Table 9-2** details the worst-case scenario of total volume of sediment released. The sea bed within the SEP and DEP wind farm sites is predominately comprised of medium and coarse grained sand, therefore sediment disturbed at the sea bed would remain localised and fall from suspension rapidly (minutes or tens of minutes). The sediment at both sites also comprises some finer sand and a small proportion of mud, these finer sediment fractions will remain in the water column as a measurable but low concentration plume for up to half a tidal cycle settling within a kilometre of the disturbance or rapidly becoming indistinguishable from background levels.

147. Increases in SSCs caused by the installation of foundations are likely to be low and less than the determined background levels of 10mg/l (mean SSC levels in summer are typically less than 10mg/l, and the mean SSC levels in winter are around 30mg/l). These increases in SSCs will be found in the water column over a short period of time (a matter of days) as they are transported by the wave and tidal action. Disturbed material will remain close to the sea bed and will rapidly settle out (within tens of minutes).

148. Cable installation is a relatively short-term activity and therefore the effect is generally short-lived. Enhanced concentrations will be greatest in the shallowest sections of the offshore export cable corridor. However, in these locations the natural background concentrations are also greater than in deeper waters, typically up to 170mg/l recorded in the vicinity of the coast at Great Yarmouth (ABPmer, 2012). As described in **Chapter 6 Marine Geology, Oceanography and Physical Processes**, the changes in SSCs during cable installation (offshore export, interlink and infield cables) would be less than those expected during the installation of foundations.

149. Disturbance to sea bed sediments during the construction period would be limited in time (within 24 months) and spatial extent due to the temporary nature of the activities and the dominance of sand sized sea bed sediments in the offshore sites.

150. The expert-based assessments of the dynamic and passive plume effects and SSCs for SEP or DEP are consistent with the findings of the earlier modelling studies for DOW (which showed limited extent and duration of increased SSCs), therefore there is high confidence in the assessment of effects. Considering the relatively short duration and limited spatial extent of the effect, together with the low level of change relative to background, the magnitude of effect for all species is assessed as low.

Sensitivity of effect - SEP or DEP in Isolation

151. Adult fish have greater mobility than their juvenile counterparts and shellfish species. They have the ability to avoid the localised areas disturbed by increased SSCs and sediment re-deposition during construction. If displaced, these fish are able to move to adjacent, undisturbed areas within their normal habitat range, whereas juvenile fish are more likely to be affected by increased SSCs, due to their decreased mobility (HOW03, 2018). SEP and DEP both overlap with nursery grounds as defined by both Coull *et al.* (1998) and Ellis *et al.* (2012) of varying fish species (see **Section 9.5.2.2.2**). Such juvenile species are accustomed to background levels of approximately 10mg/l in summer to approximately 30mg/l in winter and also experience natural increased SSCs during winter storm events.

Since the increased SSCs associated with construction are unlikely to exceed background levels other than in very localised areas and for short time periods, it can be expected that both adult and juvenile fish species are unlikely to be affected by a low level increase in SSCs from construction activities. Therefore, they are considered to be of a low sensitivity.

152. Eggs and early larval stages of fish and shellfish however do not have the same capacity to avoid increased SSCs as juveniles or adults, as they are either passively drifting in the water column or present on, or attached to, benthic substrates. There is potential that an increase in SSC could affect their development or survival. Nevertheless as stated above and in **Chapter 6 Marine Geology, Oceanography and Physical Processes**, any increases in SSCs in the area are likely to be less than background levels (tens of mg/l), localised and temporary. Therefore, the risk of potential adverse effects on the development and survival of eggs and/or larvae is considered to be low.

153. The re-deposition of sediments has the potential to smother fish, eggs and larvae. Demersal spawners such as herring and sandeel are more vulnerable to increased SSCs and sediment re-deposition, due to spawning on or near the sea bed and the adhesive properties of the egg membranes to sediment.

154. Sandeels utilise a preferred substrate comprised of medium and coarse sand with low silt content for spawning, predation cover and for hibernation. It has been found that they tend to occupy the top 4cm of the sea bed and regulate their burial depth based on oxygen availability (Behrens *et al.* 2007). Sandeels deposit eggs on the sea bed in the vicinity of their burrows between December and January. Grains of sand tend to cling to the eggs and currents often cause the eggs to be covered 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). Buried eggs experiencing reduced current flow and lowered oxygen concentration, can delay hatching periods, which is considered a necessary adaptation to survival in a dynamic environment (Pérez-Dominguez and Vogel, 2010; Hassel *et al.* 2004). In addition to this, Pérez-Dominguez and Vogel (2010) observed that increased SSCs and smothering to be inconsequential to larval and juvenile sandeels. Taking this into account, along with the expected small increases in SSC (tens of mg/l) and on account of the widely available suitable sandeel habitat, sensitivity is considered to be medium.

155. With regard to the effect of increased SSC and re-deposition of sediments on herring and their spawning activity, previous studies have found that Atlantic herring eggs are tolerant to elevated SSCs as high as 300mg/l and can tolerate short term exposure (one day) at levels up to 500mg/l (Kiørboe *et al.* 1981). Messieh *et al.* 1981 study (as cited in Engell-Sørensen and Skyt, 2001) recorded that herring eggs successfully hatch at SSCs of 7,000mg/l, although the size at hatching was larger when SSCs were lower. Whereas Griffin *et al.* (2009) suggested that larval survival rates could be reduced at SSCs as low as 250mg/l in Pacific herring (*Clupea pallasi*). These studies conclude that herring eggs suffer no adverse effects from suspended sediment concentrations in excess of the maximum levels expected from SEP or DEP construction activities. It should be noted that although the survival and development of herring eggs appear to be insensitive to high SSCs, deposition of sediment is expected to be detrimental unless the sediment is quickly removed by

currents (Birklund and Wijsmam, 2005). Furthermore, as discussed in **Section 9.5.2.2.2** of this chapter and **Section 9.2.4.5** of **Appendix 9.1** there is no evidence of herring actively spawning within the boundaries of SEP and DEP, despite the availability of habitats potentially suitable for spawning (**Figures 9.2** and **9.3**). Taking account of their regional importance, together with their high recoverability but sensitivity to smothering due to re-deposition, a medium sensitivity has been assigned.

156. According to the Marine Evidence based Sensitivity Assessment (MarESA), shellfish species such as brown crab have a low sensitivity to increased SSCs with a high recoverability rate from such impacts (Neal and Wilson, 2008). They are also likely to avoid areas with spoil or increased SSCs as they are reliant on visual acuity to find prey (Neal and Wilson, 2008). Their sensitivity to smothering is also very low with very high recoverability, likely due to their ability to escape from any re-deposition of sediment (Neal and Wilson, 2008). Therefore, brown crab are not considered sensitive to increased SSCs or smothering at the levels expected from SEP and DEP.

157. There is no MarESA information to help define sensitivities or recoverability rates with respect to lobster, however there is for spiny lobster (*Palinurus elephas*) which are of the same taxonomic family (*Nephropidae*) and have a similar size and ecology, and are therefore the most suitable for comparison (NBL, 2019; AQUIND Limited, 2019). Spiny lobster has been found (by MarESA) to be of medium sensitivity and low resilience to increased SSCs as such conditions may alter the proportion of different prey items available, however they do undergo periods of fasting and a temporary change in suspended sediment is unlikely to reduce their total intake (Gibson *et al.* 2020). They are unlikely to be affected by light smothering (up to 5cm) due to their size and mobility (Gibson *et al.* 2020).

158. The most vulnerable shellfish to increased SSCs and re-deposition are berried females, as their eggs oxygen levels require regulation and low levels can affect their development (Green *et al.* 2014). Brown crabs are able to detect oxygen levels and adjust their fanning rate and abdomen movements accordingly. Both lobsters and crabs used changes in maternal behaviour and also physiological adaptation to escape unfavourable egg development conditions (Green *et al.* 2014). Any increased SSCs or re-deposition during construction activities are likely to localised and short lived with sediments settling quickly into the sea bed. With this in mind, both brown crab and lobster are deemed to be of medium vulnerability, high recoverability and of high regional importance in the southern North Sea.

159. Taking those factors together, brown crab and lobster are considered to have a low overall sensitivity.

Impact Significance - SEP or DEP in Isolation

160. Construction activities causing increased SSC and re-deposition of sediment will be localised, temporary/short-lived and intermittent. These are likely to affect a small proportion of fish and shellfish in the area and most species are expected to have some tolerance to these effects. With a low magnitude and low sensitivity, the impact to the majority of fish and shellfish species will be of **minor adverse** significance.

161. As described above, the sensitivity of herring and sandeel eggs and larvae is considered to be medium. However, taking into account the low magnitude of effect predicted, the impact on fish eggs and larvae (taking herring and sandeel eggs and larvae as the worst-case) is assessed to be of **minor adverse** significance.

162. The impact of increased SSCs on fish and shellfish egg and larval development in general is assessed to be of **minor adverse** significance.

Magnitude of effect - SEP and DEP

163. Although there will be a larger release volume of sediment and potentially greater SSCs (above background levels) as a result of SEP and DEP both being built, it is predicted that they will still be less than 10mg/l, localised and short-lived as with SEP or DEP in isolation. Therefore, the magnitude of effect for increased SSCs and sediment re-deposition for SEP and DEP is deemed to remain as low.

Sensitivity of effect - SEP and DEP

164. While the total volume of sediment will be greater than if either SEP or DEP were built in isolation, the effects are predicted to be similar and also short lived. Therefore, the sensitivity of the receptors to these effects are considered to remain the same as assessed for SEP or DEP in isolation.

Impact Significance - SEP and DEP

165. The potential impact significance for increased SSCs and sediment re-deposition to fish and shellfish species if SEP and DEP are both built is considered to be of **minor adverse** significance.

9.6.1.3 Impact 3: Re-mobilisation of contaminated sediments

166. Benthic sampling was undertaken in August 2020 in the SEP and DEP wind farm sites and offshore cable corridors, with selected samples being subject to contaminant analysis (for further details refer to **Chapter 7 Marine Water and Sediment Quality**).

Magnitude of effect - SEP or DEP in Isolation

167. Sediment disturbance could lead to the mobilisation of existing contaminants within the sea bed sediments. Some of these contaminants could potentially be harmful to fish and shellfish. However, the data from the site specific contaminant analysis, as described in **Chapter 7 Marine Water and Sediment Quality**, illustrates that levels of contaminants within the SEP and DEP offshore sites are very low and do not contain elevated levels to cause concern, therefore the magnitude of effect is considered to be negligible.

Sensitivity of effect - SEP or DEP in Isolation

168. In the past when pipelines were installed in the study area, the local whelk community was affected, raising some concern that construction activities for SEP or DEP could release organotins that may be found at depth and cause a similar effect. DEP North, and small parts of the DEP North to DEP South interlink cable corridor and SEP overlap with a portion of whelk fishing grounds as mapped in 2010, as shown in **Appendix 12.1 Commercial Fisheries Technical Report**.

169. The MarESA guide (Tyler *et al.* 2019) shows that, where contaminant levels are within environmental protection standards, marine species and habitats are not sensitive to changes that remain within these standards. All contaminants in all samples analysed from the SEP and DEP offshore sites were below Cefas Action Level 1. However six samples had levels of arsenic that only marginally exceed Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSQC) Threshold Effect Levels (TEL) (7.24mg/kg), with concentrations ranging from 8.73 to 14.3mg/kg, which is below Probable Effect Levels (PEL) (41.6mg/kg). Whalley *et al.* (1999) found that there are elevated arsenic concentrations in sediments off the north east of Norfolk.

170. Several studies have found that organisms higher in the food chain, like fish, have a limited ability for arsenic uptake from the water column, compared to lower trophic organisms (bacteria, plankton, and macroalgae) (De Gieter *et al.* 2002). Fish predominately accumulate via their diet, however arsenic levels do not biomagnify, unlike mercury (De Gieter *et al.* 2002). On balance, the sensitivity of all fish and shellfish receptors to the marginally elevated levels of arsenic found in the SEP and DEP offshore sites is considered to be low.

Impact Significance - SEP or DEP in Isolation

171. All relevant construction activities would be covered by a Project Environmental Management Plan (PEMP), in accordance with the draft DCO, as well as emergency plans in the case of an accidental spillage or leak. In addition to this, all vessels must adhere to the requirements of the MARPOL Convention Regulations with appropriate preventative and control measures. These measures will limit the potential for the introduction of any additional contaminants as a result of project activities (for which there are few sources in any case – see **Chapter 4 Project Description** for further details).

172. Taking into account the absence of significant existing contamination and the application of mitigation to avoid any additional release of contaminants, the re-mobilisation of contaminants from construction works is assessed to be of **negligible adverse** significance.

Magnitude of effect - SEP and DEP

173. As with SEP or DEP in isolation, there are no significant levels of contaminants found in the sediment samples, resulting in a negligible magnitude of effect.

Sensitivity of effect - SEP and DEP

174. The sensitivity of fish and shellfish receptors is considered to remain low, as assessed for SEP or DEP in isolation.

Impact Significance - SEP and DEP

175. With the lack of any significant existing contamination and the application of mitigation to avoid any additional release of contaminants, the re-mobilisation of contaminated sediments during intrusive construction works is assessed to be of **negligible adverse** significance for SEP and DEP.

9.6.1.4 Impact 4: Underwater noise during foundation piling

176. There are a range of foundation options being considered for SEP and DEP, including GBS, monopile and jacket with pin-piles, screw piles or suction buckets (see **Chapter 4 Project Description**). Piling may be required should monopiles or jackets with pin-piles be used. Pile driving is a source of high level underwater noise that can cause: physiological (mortality, permanent injury or temporary injury); behavioural (startled movements; swimming away from noise source; change migratory patterns or cease reproductive activities); and environmental (changes to prey species or feeding behaviours) impacts on fish and shellfish. Therefore, the worst-case scenario (**Table 9-2**) for underwater noise is that all foundations could be piled. There is also potential for simultaneous and sequential (within the same 24 hour period) piling between SEP and DEP, this is described in **Section 9.6.1.4.2.1** and **Appendix 10.2** and is considered in the assessment below.

177. The assessment of the impacts of underwater noise during piling on fish and shellfish is based on the outputs of the underwater noise modelling undertaken by Subacoustech Environmental Ltd and should be read with reference to **Appendix 10.2**. A summary of the sensitivity of the fish receptors found in the SEP and DEP offshore sites and of the noise modelling results are provided below, followed by the impact assessment.

9.6.1.4.1 Fish and shellfish hearing

178. By listening to the sounds around them, fish obtain substantial information about their environment and use sound to communicate (Popper *et al.* 2019; Popper and Hawkins, 2019). Each species has differing sensitivity to noise and therefore the potential impact of noise on fish may vary. Anthropogenic sounds can be so intense as to result in death or mortal injury, or lower sound levels may result in temporary hearing impairment, physiological changes including stress effects, changes in behaviour or the masking of biologically important sounds (Popper and Hawkins, 2019; Kastelein *et al*. 2017).

179. Relatively few experiments on the hearing of fishes have been carried out under suitable acoustic conditions, and only a few species have valid data that provide actual thresholds (Popper and Hawkins, 2019). However, recent studies on how noise affects fish and shellfish species have brought to light that there is a lack of clear evidence supporting defined thresholds. This is due to the focus only on sound pressure and not particle motion, when the latter may be critical to understanding the importance of sound to fishes and invertebrates (Popper and Hawkins, 2018).

180. It is evident that there can be substantial differences in auditory capabilities between different fish species. To understand their hearing, the preferred approach is to distinguish fish groups on the basis of differences in their anatomy and what is known about hearing in other species with comparable hearing systems (Hawkins and Popper, 2016). Hawkins, Johnson and Popper (2020) recommend using the criteria as proposed by Popper *et al.* (2014) (as summarised in **Table 9-18**) until more data becomes available, therefore the following groups have been determined:

- Fish species with no swim bladder or other gas chamber (e.g. flat fishes and elasmobranch 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 chamber (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, Otophysi). These species are susceptible to barotrauma and detect sound pressure as well as particle motion.

Table 9-18: Criteria for Impact Piling used in the Assessment (Source Popper et al. (2014))

Category	Mortality	Recoverable Injury	Temporary Threshold Shift (TTS)[6]	Behaviour[7]
Fish: 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
Fish: 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
Fish: swim bladder involving 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 = Near-field; I = Intermediate-field; F = Far-field				

181. The hearing of shellfish is far less studied than that of fish but studies have shown they are particle motion detectors (Popper and Hawkins, 2018). Of the limited studies, there is growing evidence that shellfish may be capable of detecting sounds traveling through and immediately above substrate but an insufficient number to give a broad overview of potential impacts on them (Popper and Hawkins, 2018; Hawkins

[6] Causing physiological change to the body or tissues of a fish that recovers and returns to normal over a period of time (Boyle and New, 2018)
[7] Qualitative criteria that summarise the effect of the noise as having either a high, moderate or low effect on an individual in either the (N) near-field (tens of metres), (I) intermediate-field (hundreds of metres), or (F) far-field (thousands of metres).

and Popper 2016). What evidence there is suggests that those species studied are primarily sensitive to particle motion at frequencies well below 1kHz (Hawkins and Popper, 2016).

9.6.1.4.2 Summary of SEP and DEP Underwater Noise Modelling

182. Underwater noise modelling was carried out by Subacoustech to estimate the noise levels likely to arise during piling and determine the potential impacts on fish using the INSPIRE v5 (Impulsive Noise Propagation and Impact Estimator) subsea noise propagation model (see **Appendix 10.2**). The INSPIRE model is a semi-empirical noise propagation model based on the use of a combination of numerical modelling and actual measured underwater noise data. It was designed to calculate the propagation of noise in shallow, mixed water, typical of both conditions around the UK.

183. The modelling considers a wide array of input parameters, including variations in bathymetry and source frequency content to ensure as detailed results as possible. It should also be noted that the results presented in this assessment are precautionary as the worst-case parameters have been selected for:

- Piling hammer energies;
- Ramp-up profile and strike rate;
- Duration of piling; and
- Receptor swim speeds.

184. Modelling was undertaken at two representative locations for each of SEP and DEP, including the deepest point of the sites (typically the worst-case location i.e. the deepest location where piling can take place, which tends to give the greatest noise propagation) (**Table 9-19** and **Appendix 10.2**).

Table 9-19: Underwater Noise Modelling Locations

Modelling Locations	SEP		DEP	
	East (E)	North (N)	North east (NE)	South east (SE)
Latitude	53.1219°N	53.2446° N	53.3657°N	53.1775°N
Longitude	001.2841°E	001.0920°E	001.3897°E	001.5335°E
Water depth (mean tide)	21.3m	18.6m	23.2 m	25.5 m

185. The worst-case scenario was based on the maximum impact range modelled across both locations and was used to inform the assessment of the maximum potential impacts on receptor groups, in order to provide a conservative assessment.

186. Both monopile and pin pile worst-case scenarios have been modelled with the following hammer energies:

- Monopile with maximum diameter of 16m, maximum hammer energy of up to 5,500kJ and maximum starting energy of 1,000kJ. It should be noted that the most likely worst-case scenario would be up to 4,500kJ with a starting hammer energy of 600kJ; and
- Pin-pile with diameter of 4m, maximum hammer energy of up to 3,000kJ and maximum starting hammer energy of 400kJ.

187. A worst-case scenario approach to the maximum hammer energy is required to provide a robust assessment. However, there is available evidence from construction surveys that suggest that the maximum hammer energy is rarely required. For example, in 2016 when DOW was constructed, the predicted maximum hammer energy was 3,000kJ when in fact a maximum energy of 2,870kJ was used, with an average of only 1,367kJ over the 93 days of piling (DOWL, 2016). As another example, during construction of the Beatrice OWF in the Moray Firth, the piling strategy implementation report states that the hammer energy that was required to install the pin pile foundations ranged between 435kJ and 2,299kJ, with an average across the site of 1,088kJ. The ES had estimated that during construction the maximum hammer energy would be 2,300kJ, taking into account the worst-case (Beatrice OWF Ltd, 2018).

188. The cumulative sound exposure level (SEL_{cum}) determines the potential for Permanent Threshold Shift (PTS) or Temporary Threshold Shift (TTS) during installation of an entire pile (either monopile or pin-pile). As the soft-start takes place over the first 30 minutes of piling at the starting hammer energy, the hammer energy will increase (ramp-up) gradually to the maximum hammer energy that is required to safely install the pile.

189. As stated above, the worst-case scenario is assumed to be 100% maximum hammer energy applied for the remaining duration of the pile installation (maximum hammer energy to be applied is only likely to be required at a few of the piling installation locations and for shorter periods of time). The soft-start, ramp-up and piling duration used to assess SEL_{cum} for monopiles and pin piles are summarised in **Table 9-20** and most likely hammer energies in **Table 9-21**. The main difference between the worst-case and most likely scenarios is that the most likely scenario uses lower hammer energies and utilises a soft start procedure, whereby single blows of the piling hammer occur at low energy, interspersed with pauses of several minutes before commencing a more continuous strike rate, before ramping up to maximum energy.

Table 9-20: Worst-Case Hammer Energy, Ramp-Up and Piling Duration

Parameter	Starting hammer energy	Ramp-up				Maximum hammer energy
Monopile – worst-case						
Monopile hammer energy	1,000kJ	1,500kJ	2,500kJ	3,500kJ	4,500kJ	5,500kJ
Number of strikes	1,350	2,400	1,600	1,200	1,350	1,350
Strikes per minute	45	60	40	30	30	30
Duration (minutes)	30	40	40	40	45	45

Parameter	Starting hammer energy	Ramp-up				Maximum hammer energy
Total duration	4 hours (9,250 total strikes)					
Pin-pile						
Pin-pile hammer energy	400	920	1,440	1,960	2,480	3,000
Number of strikes	1,200	1,200	1,200	1,200	900	900
Strikes per minute	40	40	40	40	30	30
Duration (minutes)	30	30	30	30	30	30
Total duration	3 hours (6,600 total strikes)					

Table 9-21: Most Likely Hammer Energy, Ramp-Up and Piling Duration for Monopile Only

	Starting hammer energy (kJ)	Ramp up (kJ)				Maximum hammer energy (kJ)
Monopile						
Monopile hammer energy	600	600	1500	2500	3500	4500
Number of strikes	4	900	2400	1600	1200	900
Duration (minutes)	20	20	40	40	40	30
Total duration – 3.2 hours (7,004 total strikes)						

190. Model results based on both a fleeing and stationary receptor are provided in **Appendix 10.2**. A stationary animal model based on observed behavioural impact levels from Hawkins *et al.* (2014) has been considered as a worst-case for the SEL_{cum} criteria following consultation feedback from the MMO (**Table 9-1**). However, it is recognised that most fish species are likely to move away from a sound that is loud enough to cause harm (Dahl *et al.* 2015; Popper *et al.* 2014); some may seek protection in the sediment and others may dive deeper in the water column. 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; with these being the least sensitive species. Therefore, a stationary receptor model is considered highly precautionary. Further information on the parameters used for the underwater noise modelling and methodologies can be found in **Appendix 10.2**.

9.6.1.4.2.1 Results

191. Results of the worst-case underwater noise modelling using a stationary animal approach in terms of area, maximum, minimum and mean impact ranges are shown for a single piling and sequential (the worst-case) piling scenario in **Table 9-22**. The impact ranges for fish mortality and potential mortal injury, recoverable injury and for temporary auditory injury (TTS) are shown for both the installation of monopiles and pin piles, against their respective maximum hammer energies of 5,500kJ and 3,000kJ.

192. The installation of monopiles results in the greatest spatial impact range for stationary fish species for both SPL_{peak} and SEL_{cum} thresholds for both projects. The greatest impact for each threshold criteria are therefore taken forward as the worst-case spatial impact for assessment (**Table 9-22**).

193. Fish species with swim bladders are shown to have the biggest associated impact ranges from piling noise for SPL_{peak} thresholds, with both mortality and recoverable injury impact ranges of 270m and 250m for monopiles at SEP and DEP respectively, and pin pile impact ranges of 220m and 200m at SEP and DEP respectively. The maximum impact ranges for the cumulative impact ranges are again for fish species with swim bladders for monopile installation, with ranges of 4.4km (SEP) and 5km (DEP) for recoverable injury and 16km (SEP) and 19km (DEP) for TTS (**Table 9-22**).

194. In addition to the worst-case spatial impact for fish species as described above, consideration has also been given to the temporal worst-case scenario. This would be the result of the installation of the maximum number of 120 pin piles (equating to 360 hours) for DEP and a maximum of 92 pin piles (276 hours) for SEP (**Table 9-2**). OSP pin piling durations would be up to 24 hours per OSP.

195. Piling would not be constant during the piling phases and construction periods. There will be gaps between the installations of individual piles, and if installed in groups there could be time periods when piling is not taking place as piles are brought out to the site. There will also be potential delays for weather or other technical issues.

196. The duration of piling is based on a worst-case scenario and a very precautionary approach and, as has been shown by reference to data from other OWFs, the duration used in the impact assessment is conservative. An example of this conservatism in practice is available from the installation of monopile foundations at the Dudgeon OWF. In this case the impact assessment was based on an estimated time of up to 4.5 hours to install each monopile and the estimated duration of active piling was 301.5 hours (approximately 13 days). However, the actual total duration of active piling to install the 67 monopiles was 65 hours (approximately 3 days) with the average time for installation per monopile of 71 minutes; approximately 21% of the predicted maximum piling duration (DOWL, 2016).

Sequential piling

197. Further modelling covering the potential for multiple impact piling operations to occur at the same location in the same 24-hour period have been considered and the results are presented for a stationary receptor in **Table 9-22**.

198. **Figure 9.7** shows the contour plot for sequential piling based on the worst-case monopile for a stationary receptor and showing TTS (186dB) unweighted SEL_{cum}

(i.e. Popper *et al*. (2014)) criteria alongside the equivalent noise contours for a single piling scenario. As expected, there is an increase in the impact areas for a sequential piling scenario compared to a single piling scenario. The overall impact area (for TTS (186dB)) for the sequential piling scenario is greater than that for simultaneous piling. This is because, although both scenarios lead to the same number of pile strikes, the simultaneous piling noise sources are well separated and for most transects this means that only the closest will lead to a significant contribution to a receptor's overall noise exposure. Therefore, as a worst-case for TTS and all other SEL_{cum} criteria, a sequential piling scenario is assessed.

Table 9-22: Single Piling and Sequential Piling within a 24 Hour Period Underwater Noise Modelling Results for Both Monopile and Pin Pile Maximum Hammer Energies, for the Worst-Case Modelling Location Only (Using a Stationary Animal Model). For the Full Set of Modelling Results (Including for the Average Water Depth Modelling Location), See Appendix 10.2

Fish Group	Impact Criteria	Potential Impact	Location	Impact Areas and Ranges									
				Monopile (maximum hammer energy 5,500kJ)				Pin pile (4m diameter) (maximum hammer energy 3,000kJ)				Monopile (starting hammer energy 1,000kJ)[8]	
				Area	Max	Min	Mean	Area	Max	Min	Mean	Area	Max
Single Piling at the DEP SE or SEP E Worst-Case Modelling Locations													
Fish: no swim bladder (particle motion detection)	>213 dB unweighted SPL_{peak}	Mortality and potential mortal injury	DEP SE	**0.04km^2**	**110m**	110m	110m	**0.03km^2**	**100m**	90m	100m	**<0.01km^2**	**60m**
			SEP E	**0.03km^2**	**100m**	100m	100m	**0.03km^2**	**100m**	90m	100m	**<0.01km^2**	**<50m**
	>219 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	DEP SE	**1.4km^2**	**700m**	700m	700m	**0.5km^2**	**400 m**	380 m	390 m	**<0.01km^2**	**<50m**
			SEP E	**1.2km^2**	**700m**	600m	600m	**0.4km^2**	**350m**	330m	340m	**<0.01km^2**	**<50m**
	>216 dB unweighted SEL_{cum} [stationary]	Recoverable injury	DEP SE	**3.3km^2**	**1.1km**	1.0km	1.0km	**1.1km^2**	**600m**	580m	590m	**<0.01km^2**	**<50m**
			SEP E	**2.7km^2**	**1.0km**	900m	900m	**0.8km^2**	**530m**	500m	510m	**<0.01km^2**	**<50m**
	>186 dB unweighted SEL_{cum} [stationary]	TTS	DEP SE	**840km^2**	**19km**	13km	16km	**550 km^2**	**15km**	11km	13km	**<0.01km^2**	**190m**
			SEP E	**620km^2**	**16km**	12km	14km	**400km^2**	**12km**	10km	11km	**0.1km^2**	**180m**
Fish: swim bladder is not	>207 dB unweighted SPL_{peak}	Mortality and potential mortal injury	DEP SE	**0.23km^2**	**270m**	270m	270m	**0.17km^2**	**240m**	230m	240m	**0.06km^2**	**140m**
			SEP E	**0.19km^2**	**250m**	250m	250m	**0.14km^2**	**220m**	210m	220m	**0.05km^2**	**130m**

[8] *Note that the SEL_{ss} parameters presented for the starting hammer energy are not part of the Popper et al. (2014) criteria, but have been modelled to give an idea as to the levels of noise present for the first pile strike and at full energy at the end of the piling operations.*

Fish Group	Impact Criteria	Potential Impact	Location	Impact Areas and Ranges									
				Monopile (maximum hammer energy 5,500kJ)				Pin pile (4m diameter) (maximum hammer energy 3,000kJ)				Monopile (starting hammer energy 1,000kJ)[8]	
				Area	Max	Min	Mean	Area	Max	Min	Mean	Area	Max
involved in hearing (particle motion detection)	210 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	DEP SE	**15km^2**	**2.3km**	2.2km	2.2km	**5.6km^2**	**1.4km**	1.3km	1.3km	**<0.01km^2**	**<50m**
			SEP E	**12km^2**	**2.0km**	1.9km	2.0km	**4.2km^2**	**1.2km**	1.2km	1.2km	**<0.01km^2**	**<50m**
	203 dB unweighted SEL_{cum} [stationary]	Recoverable injury	DEP SE	**72km^2**	**5.0km**	4.7km	4.8km	**5.6km^2**	**1.4km**	1.3km	1.3km	**<0.01km^2**	**<50m**
			SEP E	**55km^2**	**4.4km**	4.1km	4.2km	**24km^2**	**2.8km**	2.7km	2.7km	**<0.01km^2**	**<50m**
	>186 dB unweighted SEL_{cum}	TTS	DEP SE	**840km^2**	**19km**	13km	16km	**550km^2**	**15km**	11km	13km	**0.12km^2**	**190m**
			SEP E	**620km^2**	**16km**	12km	14km	**400km^2**	**12km**	10km	11km	**0.1km^2**	**180m**
Fish: swim bladder involving in hearing (primarily pressure detection)	>207 dB unweighted SPL_{peak}	Mortality and potential mortal injury	DEP SE	**0.23km^2**	**270m**	270m	270m	**0.17km^2**	**240m**	230m	240m	**0.06km^2**	**140m**
			SEP E	**0.19km^2**	**250m**	250m	250m	**0.14km^2**	**220m**	210m	220m	**0.05km^2**	**130m**
	207 dB SEL_{cum} unweighted [stationary]	Mortality and potential mortal injury	DEP SE	**31km^2**	**3.3km**	3.1km	3.2km	**12km^2**	**2.0km**	2.0km	2.0km	**<0.01km^2**	**<50m**
			SEP E	**24km^2**	**2.8km**	2.7km	2.8km	**9.2km^2**	**1.7km**	1.7km	1.7km	**<0.01km^2**	**<50m**
	203 dB SEL_{cum} unweighted [stationary]	Recoverable injury	DEP SE	**72km^2**	**5.0km**	4.7km	4.8km	**32km^2**	**3.2km**	3.1km	3.2km	**<0.01km^2**	**<50m**
			SEP E	**55km^2**	**4.4km**	4.1km	4.2km	**24km^2**	**2.8km**	2.7km	2.7km	**<0.01km^2**	**<50m**
	>186 dB SEL_{cum} unweighted [stationary]	TTS	DEP SE	**840km^2**	**19km**	13km	16km	**550km^2**	**15km**	11km	13km	**0.12km^2**	**190m**
			SEP E	**620km^2**	**16km**	12km	14km	**400km^2**	**12km**	10km	11km	**0.1km^2**	**180m**

Fish Group	Impact Criteria	Potential Impact	Location	Impact Areas and Ranges									
				Monopile (maximum hammer energy 5,500kJ)				Pin pile (4m diameter) (maximum hammer energy 3,000kJ)				Monopile (starting hammer energy 1,000kJ)[8]	
				Area	Max	Min	Mean	Area	Max	Min	Mean	Area	Max
Based on data from Hawkins *et al.* (2014) relating to the levels of impulsive sound to which sprat and mackerel respond.	173 dB unweighted (SPL_{peak})	Behavioural disturbance	DEP SE	**390km^2**	**12km**	9.4km	11km	**330km^2**	**11km**	8.8km	10km	**220km^2**	**9.1km**
			SEP E	**290km^2**	**11km**	8.8km	9.6km	**250km^2**	**9.7km**	8.2km	8.9km	**160km^2**	**7.8km**
	168 (SPL_{peak})		DEP SE	**670km^2**	**17km**	12km	15km	**590km^2**	**16km**	11km	14km	**410km^2**	**13km**
			SEP E	**490km^2**	**14km**	11km	12km	**430km^2**	**13km**	11km	12km	**310km^2**	**11km**
	163 dB unweighted (SPLpeak-to-peak)		DEP SE	**1600km^2**	**29km**	18km	23km	**1500km^2**	**27km**	17km	22km	**1200km^2**	**23km**
			SEP E	**1200km^2**	**24km**	17km	19km	**1100km^2**	**23km**	16km	19km	**860km^2**	**20km**
	142 dB unweighted (SEL_{ss})		DEP SE	**1700 km^2**	**29 km**	19 km	23 km	**1500km^2**	**27km**	17km	22km	**1100km^2**	**23km**
			SEP E	**1200 km^2**	**25 km**	17 km	20 km	**1100km^2**	**23km**	16km	19km	**830km^2**	**19km**
	135 dB unweighted (SEL_{ss})		DEP SE	**2700 km^2**	**39 km**	24 km	29 km	**2400km^2**	**36km**	23km	28km	**2000km^2**	**32km**
			SEP E	**2000 km^2**	**34 km**	20 km	25 km	**1800km^2**	**31km**	19km	24km	**1500km^2**	**27km**
Sequential Piling within a 24 Hour Period													
Fish: no swim bladder (particle motion detection)	>219 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	DEP SE	**3.2km^2**	**1.0km**	1.0km	1.0km	**2.3km^2**	**880m**	850m	860m	**<0.01km^2**	**<50m**
			SEP E	**2.5km^2**	**900m**	880m	890m	**1.8km^2**	**780m**	750m	760m	**<0.01km^2**	**<50m**
	>216 dB unweighted SEL_{cum} [stationary]	Recoverable injury	DEP SE	**7.1km^2**	**1.5km**	1.5km	1.5km	**5.3 km^2**	**1.3 km**	1.3 km	1.3 km	**<0.01km^2**	**<50m**
			SEP E	**5.5km^2**	**1.4km**	1.3km	1.3km	**4.0 km^2**	**1.2 km**	1.1 km	1.1 km	**<0.01km^2**	**<50m**
	>186 dB unweighted	TTS	DEP SE	**1100km^2**	**23km**	15km	19km	**1000km^2**	**21km**	14km	18km	**<0.01km^2**	**190m**
			SEP E	**820km^2**	**19km**	14km	16km	**730km^2**	**18km**	13km	15km	**0.1km^2**	**180m**

Fish Group	Impact Criteria	Potential Impact	Location	Impact Areas and Ranges									
				Monopile (maximum hammer energy 5,500kJ)				Pin pile (4m diameter) (maximum hammer energy 3,000kJ)				Monopile (starting hammer energy 1,000kJ)[8]	
				Area	Max	Min	Mean	Area	Max	Min	Mean	Area	Max
	SEL_{cum} [stationary]												
Fish: swim bladder is not involved in hearing (particle motion detection)	210 dB unweighted SEL_{cum} [stationary]	Mortality and potential mortal injury	DEP SE	**31 km²**	**3.2km**	3.1km	3.2km	**24km²**	**2.8km**	2.7km	2.8km	**<0.01km²**	**<50m**
			SEP E	**24km²**	**2.8km**	2.7km	2.7km	**18km²**	**2.4km**	2.3km	2.4km	**<0.01km²**	**<50m**
	203 dB unweighted SEL_{cum} [stationary]	Recoverable injury	DEP SE	**130 km²**	**6.7km**	6.0km	6.3km	**100km²**	**6.0km**	5.5km	5.7km	**<0.01km²**	**<50m**
			SEP E	**95km²**	**5.9km**	5.3km	5.5km	**76km²**	**5.2km**	4.7km	4.9km	**<0.01km²**	**<50m**
	>186 dB unweighted SEL_{cum}	TTS	DEP SE	**1100km²**	**23km**	15km	19km	**1000km²**	**21km**	14km	18km	**0.12km²**	**190m**
			SEP E	**820km²**	**19km**	14km	16km	**730km²**	**18km**	13km	15km	**0.1km²**	**180m**
Fish: swim bladder involving in hearing (primarily pressure detection)	207 dB SEL_{cum} unweighted [stationary]	Mortality and potential mortal injury	DEP SE	**59km²**	**4.5km**	4.2km	4.3km	**47km²**	**4.0km**	3.8km	3.9km	**<0.01km²**	**<50m**
			SEP E	**45km²**	**4.0km**	3.7km	3.8km	**34km²**	**3.4km**	3.2km	3.3km	**<0.01km²**	**<50m**
	203 dB SEL_{cum} unweighted [stationary]	Recoverable injury	DEP SE	**130km²**	**6.7km**	6.0km	6.3km	**100km²**	**6.0km**	5.5km	5.7km	**<0.01km²**	**<50m**
			SEP E	**95km²**	**5.9km**	5.3km	5.5km	**76km²**	**5.2km**	4.7km	4.9km	**<0.01km²**	**<50m**
	>186 dB SEL_{cum} unweighted [stationary]	TTS	DEP SE	**1100km²**	**23km**	15km	19km	**1000km²**	**21km**	14km	18km	**0.12km²**	**190m**
			SEP E	**820km²**	**19km**	14km	16km	**730km²**	**18km**	13km	15km	**0.1km²**	**180m**

Simultaneous Piling

199. Simultaneous piling is possible should SEP and DEP be constructed concurrently. In this scenario, as a worst-case, one piling operation could occur in the SEP wind farm site at the same time (i.e. simultaneously) as a piling operation in the DEP wind farm site (one piling operation per project). The modelling assumed that the two piling operations start at the same time. Section 5.3 of **Appendix 10.2** provides detailed results for simultaneous piling noting that impact range distances have not been presented for simultaneous piling as there are two starting points for receptors.

200. **Figure 9.7** shows the contour plot for simultaneous piling based on the worst-case monopile for a stationary receptor and showing TTS (186dB) Unweighted SEL_{cum} (i.e. Popper *et al*. (2014)) criteria alongside the equivalent noise contours for a single piling scenario. As can be seen there is a convergence and slight increase in the overall impact area in a simultaneous piling scenario however as described above, the overall area impacted is smaller (for the TTS (186dB)) when compared to the sequential piling scenario. This is because, although both scenarios lead to the same number of pile strikes, the simultaneous piling noise sources are well separated and for most transects this means that only the closest will lead to a significant contribution to a receptor's overall noise exposure. Therefore, as a worst-case for TTS and all other SEL_{cum} criteria, a sequential piling scenario is assessed.

9.6.1.4.3 Magnitude of effect - SEP or DEP in Isolation

201. The worst-case scenario spatially considers the greatest area of impact from underwater noise during foundation piling. This would consist of using the maximum hammer energy of 5,500kJ installing 18+MW turbines using monopiles (1 monopile per wind turbine) at DEP and one OSP (8 pin piles), or 18+MW wind turbines at SEP and one OSP (8 pin piles) (**Table 9-2**).

202. Temporally, the worst-case scenario considers the longest duration for underwater noise during foundation piling. This would consist of 30 x 15MW wind turbines using pin piles (4 pin piles per wind turbine, 120 pin piles) installed at DEP or 23 x 15MW wind turbines (4 pin piles per wind turbine, 92 pin piles) at SEP (**Table 9-2**). Over the 2 years construction period, up to 15 days (384 hours) of total active piling would be required to install 128 pin piles (30 15MW wind turbines and one OSP) at DEP. Total active piling at SEP for 23 15MW wind turbines and one OSP (100 pin piles) would be up to 12.5 days (300 hours).

9.6.1.4.3.1 Mortality and recoverable injury

Fish with no swim bladder

203. From the installation of monopiles, at full hammer energy, there is potential for mortality and potential mortal injury / recoverable injury (>213 dB SPL_{peak}) to occur on fish with no swim bladder at ranges up to 100m for SEP and up to 110m for DEP based on a single pile scenario. The mortality and potential for mortal injury (>219 dB SEL_{cum}) would occur at a range of up to 700m for both projects for fish with no swim bladder. Recoverable injury (>216dB SEL_{cum}) would occur at a range of up to 1km for SEP and up to 1.1km for DEP (**Table 9-22**). For the starting hammer energy of a monopile (of 1,000kJ), there is the potential for mortality and potential mortal injury at a distance of 60m from the pile location, and for recoverable injury at up to 50m, from either SEP or DEP.

204. Considering the small areas potentially affected (minority of the receptor) and the temporary, short term and intermittent nature of piling activity, the magnitude of effect is considered to be low.

Fish with swim bladder not involved with hearing

205. There is potential for mortality / potential mortal injury and recoverable injury, for fish with swim bladders not involved in hearing, at ranges up to 250m for SEP and up to 270m for DEP (for >207dB SPL_{peak} criteria) from the installation of monopiles. There is the potential for the mortality / potential for mortal injury (>210 dB SEL_{cum}) at a range of up to 2km for SEP and up to 2.3km for DEP from the installation of monopiles based on a single pile scenario (**Table 9-22**). Taking the areas potentially affected along with the temporary, short term and intermittent nature of piling activity, the magnitude of effect is considered to be low.

206. There is, however, the potential for recoverable injury to occur on fish with swim bladders not involved in hearing at ranges up to 5km and 4.4km for SEP and DEP respectively (for 203dB SEL_{cum}) from the installation of monopiles (**Table 9-22**).

207. For the starting hammer energy of a monopile (of 1,000kJ), there is the potential for mortality and potential mortal injury at a distance of 140m (at DEP) and 130m (at SEP) from the pile location, and for recoverable injury at up to 50m, from either SEP or DEP.

208. Taking into account the spatial extent of the impact (minority of the receptor) and the temporary, short term and intermittent nature of piling activity, the magnitude of effect is considered to be low.

Fish with swim bladder involved in hearing

209. There is the potential for mortality / potential mortal injury (207dB SEL_{cum}) and recoverable injury (203dB SEL_{cum}) to occur on fish with swim bladders involved in hearing at ranges of up to 3.3km and 5km respectively from the installation of monopiles at DEP and ranges of up to 2.8km and 4.4km respectively for SEP (**Table 9-22**). For the starting hammer energy of a monopile (of 1,000kJ), there is the potential for mortality and potential mortal injury (207dB SPL_{peak}) at a distance of 140m (at DEP) and 130m (at SEP) from the pile location, and for recoverable injury at up to 50m, from either SEP or DEP.

210. **Figure 9.6** shows the herring spawning heat mapping combined with the modelled maximum range of mortality / potential mortal injury impacts, on stationary fish receptors with a swim bladder involved in hearing (which include herring), from SEP and DEP worst-case monopile based on a single pile installation. **Figure 9.6** also shows the impact ranges from the SEP N and DEP NE modelling locations. These impact ranges do not extend as far as those for the SEP E and DEP SE modelling locations (primarily due to the shallower conditions in these areas) and it can be seen that there is no overlap with the areas identified as being suitable herring spawning habitat to the northwest.

211. Taking into account the spatial extent of the impact (minority of the receptor) and the temporary, short term and intermittent nature of piling activity, the magnitude of effect is considered to be low.

Eggs and larvae

212. Popper *et al.* (2014) describes the impact criteria for potential mortality / potential mortal injury in eggs and larvae as >210 dB SEL_{cum} or >207 dB SPL_{peak}. These criteria are based on work by Bolle *et al.* (2012) who reported no damage to larval fish at SEL_{cum} as high as 210 dB re 1 μPa 2·s. On the basis of Bolle *et al.* (2012), the levels adopted in Popper *et al.* (2014) are likely to be conservative. As levels proposed in Popper *et al.* (2014) are similar to those described for fish species with a swim bladder not involved in hearing (210 dB SEL_{cum} or >207 dB SPL_{peak}) the modelled impact ranges for this category have been used to provide an indication of the potential impacts on fish eggs and larvae.

213. As outlined in **Table 9-22**, the ranges are as follows for monopiles at DEP: for mortality / potential mortal injury, 270m (>207dB SPL_{peak}) and 2.3km (210dB SEL_{cum}). For monopiles at SEP: for mortality / potential mortal injury, 250m (>207dB SPL_{peak}) and 2km (210dB SEL_{cum}). For the starting hammer energy of a monopile (of 1,000kJ), there is the potential for mortality and potential mortal injury at a distance of 140m (at DEP) and 130m (at SEP) from the pile location, and for recoverable injury at up to 50m, from either SEP or DEP.

214. In reference to herring eggs and larvae, **Figure 9.3** shows the herring spawning heat mapping, including IHLS herring larvae abundance. Heat mapping indicates that the confidence in herring spawning activity in the vicinity of SEP and DEP is low to medium. As discussed above, impact ranges on herring eggs and larvae would be smaller than those indicated in **Figure 9.6** which apply to adult herring.

215. Taking the small areas potentially affected, the temporary, short term and intermittent nature of piling activity, (and for herring the low to medium confidence in spawning activity in the vicinity (**Figure 9.3**)), the magnitude of effect is considered to be low.

Shellfish

216. There are no specific criteria currently published in respect of shellfish species due to insufficient data to establish them (Popper *et al.* 2014), however studies on lobsters have shown no effect on mortality, appendage loss or the ability of animals to regain normal posture after exposure to very high sound levels (>220 dB) (Payne *et al.* 2007).

217. The potential for piling noise to result in mortality / potential mortal injury or recoverable injury is therefore considered to be very low with the magnitude of effect expected to be negligible.

9.6.1.4.3.2 TTS and behavioural

All species

218. The outputs of the noise modelling for the spatial worst-case scenario indicate that TTS from the installation of monopiles may occur at distances of up to 19km for all the fish groups modelled for DEP, and 16km for all fish groups at SEP. The most pronounced behavioural responses are anticipated to occur within this range however would depend on the hearing ability of the species under consideration. For a starting hammer energy of 1,000kJ (for monopiles), there is the potential for TTS to occur at a distance of up to 190m for DEP and 180m for SEP.

219. More detailed consideration of potential behavioural responses in fish (particularly herring) has been provided in response to PEIR consultation (see **Table 9-1**). Behavioural response impact ranges based on observed levels from Hawkins *et al.* (2014) have been used to inform the single piling scenarios (**Table 9-22**). Whilst the authors note that the results of the study cannot yet be used to define sound exposure criteria for use in EIA, in the absence of reliable numerical criteria for behavioural disturbance in fish, it is considered that the values provide a useful metric to inform the assessment. It should be noted that the study was conducted under conditions in quiet inland waters which are unlikely to be equivalent to those around the SEP and DEP offshore sites.

220. The results indicate that behavioural responses in fish could occur at distances of up to 34km from the worst-case modelling location at SEP and 39km from DEP. Impact contours based on 135dB SELss scenario for the 1st strike and maximum hammer energies from the SEP North and DEP North modelling locations (i.e. not the worst-case modelling locations but those closest to the herring spawning ground to the north west) are shown on **Figure 9.8** in relation to herring spawning grounds. The impact contours do not extend into the IHLS survey areas to the north east where herring spawning activity is presumed to be concentrated.

221. The associated impacts of TTS could result in reduced fitness of some species. Behavioural responses to underwater noise can result in decreased feeding activity, lead to the potential avoidance of spawning grounds, or act as a potential barrier to, and result in subsequent alteration to migration patterns. Consequently, there is concern that behavioural responses could have an adverse impact on spawning behaviour and migration of certain species with potential population or sub-population level effects being of particular concern (Popper *et al.* (2014)). However, impacts on feeding activity are considered unlikely to cause long term, larger scale effects on fish populations given the wider availability of suitable feeding grounds in the region. Similarly, given that the Banks herring spawning ground is located to the north west outside of the maximum predicted underwater noise impact ranges for behavioural disturbance (see **Figure 9.8**), behavioural impacts on spawning herring are not anticipated.

222. As shown in **Table 9-2**, in terms of the temporal worst-case scenario, piling would be of a short-term duration at up to 12.5 days for SEP and 15 days for DEP installing pin piles. For monopiles (which result in the greatest impact ranges for underwater noise), the duration would be up to 4 days at SEP and up to 5 days at DEP with an additional day required to install pin piles for an OSP in each wind farm site resulting in a maximum temporal duration of 5 days at SEP and 6 days at DEP which is short term.

223. Taking account of the spatial extent of the impact with the overall short duration of piling and its intermittent nature, together with the fact that any effect associated with TTS and behavioural impacts would be temporary, the magnitude of effect for all species is considered to be low.

9.6.1.4.4 Sensitivity of effect - SEP or DEP in Isolation

224. In **Section 9.6.1.4.1**, four categories were identified that defined the sensitivity of fish to sound (see **Table 9-18**). In order to facilitate the assessment, fish receptors

have been grouped into these categories, with this being the basis for defining the sensitivity of the fish receptors (**Table 9-23** and **Table 9-24**).

225. Given the lack of specific impact criteria for shellfish, the assessment has been based on a review of literature on the current understanding of the potential effects of underwater noise on shellfish species.

Table 9-23: Hearing Categories of Fish Receptors and Respective Sensitivities for Mortality and Potential Mortal Injury

Category as defined by Popper *et al.* (2014)	Fish receptors relevant to SEP and DEP	Sensitivity
Fish with no swim bladder or other gas chamber	Dab Elasmobranchs River and sea lamprey Lesser weever Dragonet	Low
	Sandeels	Medium
Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume	Sea trout Smelt*	Low
	Gobies	Medium
Fish in which hearing involves a swim bladder or other gas volume	Herring Sprat Whiting European eel* Allis and Twaite Shad	Medium
Eggs and larvae	All fish and shellfish species	Medium
* denotes uncertainty or lack of current knowledge with regard to the potential role of the swim bladder in hearing		

226. The following section provides the rationale for these receptor sensitivities.

9.6.1.4.4.1 Mortality and recoverable injury

<u>Fish with no swim bladder</u>

227. The majority of fish receptors included within the group "fish with no swim bladder" (**Table 9-23**) are mobile and would be expected to vacate the area in which the impact could occur with the onset of ‘soft start’ piling. They are therefore considered receptors of low sensitivity.

228. Sandeels are an exception to this because, due to their burrowing behaviour and substrate dependence, they may have limited capacity to flee the area compared to other fish species. They are therefore considered, by exception for this group, to be of medium sensitivity.

<u>Fish with swim bladder not involved with hearing</u>

229. The majority of fish receptors included within the group "fish with swim bladders not involved in hearing" (**Table 9-23**) are mobile and would be expected to vacate the

area in which the impact could occur with the onset of 'soft start' piling. As such, they are considered receptors of low sensitivity.

230. An exception in this category are sand gobies, similarly to sandeel their mobility is limited due to their burrowing behaviour. They potentially have reduced capabilities to escape the areas affected by the greatest noise levels. However, gobies are abundant over wide areas of the North Sea and it is likely that any noise effects would impact only a small proportion of the population. As they have a relatively short life cycle of 2 years (Teal *et al.* 2009), the population would be expected to recover quickly if subject to localised impacts associated with piling. As such, they are considered to be receptors of medium sensitivity.

Fish with swim bladder involved in hearing

231. Species within the "fish with swim bladders involved in hearing" category (**Table 9-23**) are highly mobile and likely to depart the area from the onset of 'soft start' piling. These species are susceptible to barotrauma and detect sound pressure as well as particle motion. Therefore, they are regarded to be of medium sensitivity.

Eggs and larvae

232. Due to their lack of mobility, eggs and larvae are vulnerable to barotrauma and exposure may cause physiological abnormalities or defects. Bolle *et al.* (2014) exposed larvae of three species (herring, sole and bass) with different swim bladder development stages to pile driving noise reproduced to up to 210 dB SPL_{peak}. Survival was monitored for seven to ten days and none of the larvae showed significant difference in mortality compared to the control group.

233. Movement of eggs and larvae is determined by currents; they do not have the ability to flee the vicinity of piling activity. However, prolonged exposure could be reduced by any drift of eggs / larvae due to currents, which may reduce the risk of mortality.

234. The distribution of eggs and larvae for most species range over large areas, with the exception of herring eggs which are deposited in specific areas as described previously (**Section 9.5.2.3.1**). Injury or mortality of eggs and larvae in close proximity to piling is possible. However, it should be noted that any mortality associated with piling would be a small amount in comparison to the naturally high mortality rates during these life stages. Taking the above into account, egg and larval stages (all species) are considered to be of medium sensitivity.

Shellfish

235. Given the relatively low mobility of shellfish species in comparison to most fish species, and therefore their reduced ability to avoid areas in the proximity of piling, they are considered to be receptors of medium sensitivity.

9.6.1.4.4.2 TTS and behavioural

236. The assessment of the impact of TTS and behavioural impacts has been focused on key species as stated in **Table 9-16**, selected on the basis of the presence of known spawning and nursery grounds in the region, conservation status, commercial value and specific concerns raised during consultation.

Table 9-24: Hearing Categories of Fish Receptors and Respective Sensitivities for TTS and Behavioural

Category as defined by Popper *et al.* (2014)	Fish receptors relevant to the Projects	TTS and Behavioural	Sensitivity
Fish with no swim bladder or other gas chamber	Dab Elasmobranchs River and sea lamprey Lesser weever Dragonet Dover sole Plaice Mackerel Lemon sole	TTS – 186dB SEL_{cum} <u>Behavioural</u> (N) High (I) Moderate (F) Low	Low
	Sandeels		Medium
Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume	Sea trout Smelt*	TTS – 186dB SEL_{cum} <u>Behavioural</u> (N) High (I) Moderate (F) Low	Low
	Gobies		Medium
Fish in which hearing involves a swim bladder or other gas volume	Herring Sprat Whiting Cod European eel* Allis and Twaite Shad	TTS – 186dB SEL_{cum} <u>Behavioural</u> (N) High (I) High (F) Moderate	Medium
Eggs and larvae	All fish and shellfish species	TTS – 186dB SEL_{cum} <u>Behavioural</u> (N) Moderate (I) Low (F) Low	Medium

* denotes uncertainty or lack of current knowledge with regard to the potential role of the swim bladder in hearing

<u>Fish with no swim bladder</u>

237. SEP and DEP are located within a low intensity spawning ground for Dover sole, within a spawning ground[9] for lemon sole, and also low intensity nursery grounds for plaice, mackerel and thornback ray (**Appendix 9.1**). It should be noted that the degree of overlap between the spawning and nursery grounds of these species and the area with potential for TTS onset would be very small relative to the total area that the species could use for spawning. In addition, Dover sole, lemon sole and

[9] As identified by Coull *et al.* (1998), intensity not defined.

plaice are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

238. Elasmobranchs have no swim bladder or gas chamber, thus are incapable of detecting sound pressure and presumably sense particle motion (Casper *et al.* 2012). However, studies of their hearing have shown that they can detect sounds from below 50Hz to over 500Hz (Normandeau Associates Inc., 2012).

239. Under the spatial worst-case piling scenario, TTS may occur at ranges of up to 19km at DEP and up to 16km at SEP (**Table 9-22**). According to the Popper *et al.* (2014) criteria for behavioural impacts (or TTS, the species listed in **Table 9-24** (excluding sandeels) would be at high risk of TTS near the piling locations (tens of metres), they would be at moderate risk at intermediate distances (hundreds of metres) and at low risk when far (thousands of metres) from the piling location (**Table 9-24**). The potential area affected by TTS (and behavioural impacts) is small in the context of the wide distribution ranges of the species listed in **Table 9-24** (excluding sandeels), including those relating to spawning / nursery grounds for relevant species and therefore these species are considered to be of low sensitivity to underwater noise impacts associated with piling.

240. Studies monitoring lesser sandeel behavioural reactions to seismic surveys have shown behavioural reactions to noise source levels of 210 dB at 1 μPa (similar to piling see **Appendix 10.2**). The study indicates that seismic noise had a moderate effect on their behaviour, although no immediate lethal effect was observed (Hassel *et al.* 2004). Hassel *et al.* (2004) also review landings data from Norwegian sandeel trawlers which showed a temporary drop for a short period after the experiment. The results of this study indicate that the effects of such noise levels are likely to be short term, localised and constrained to behavioural level impacts only; with no long-term effects likely.

241. SEP and DEP are located within both the low intensity spawning and nursery grounds of sandeel (for greater, lesser, smooth and small sandeel species) (**Appendix 9.1**). As discussed in **Section 9.5.2.3.2**, sea bed habitat that has been classified as suitable for sandeel, particularly in and around the DEP wind farm site and in particular DEP North array area (**Figure 9.4**). Heat mapping identified medium confidence sandeel habitat in the SEP wind farm site, interlink cable corridors and the DEP wind farm site, with areas of high sandeel habitat confidence in parts of DEP South array area and very high confidence in parts of DEP North array area (**Figure 9.5**). It should be noted however that the degree of overlap between the spawning and nursery grounds of these species and the area with potential for TTS onset would be very small relative to the total area that the species could use for spawning, with extensive areas of high confidence sandeel habitat further to the north and west (**Figure 9.5**).

242. Sandeel species lack a swim bladder, and according to Popper *et al.* (2014), would therefore be at high risk of behavioural impact near (tens of metres) the piling locations, at moderate risk at intermediate distances (hundreds of metres) and at low risk when far (thousands of metres) from the piling location (**Table 9-24**). Taking this into account, together with their sea bed specific requirements, sandeels are considered to have medium sensitivity.

Fish with swim bladder not involved with hearing

243. As stated in **Table 9-24** diadromous species included in this category are smelt and sea trout. Studies on how underwater noise affects smelt are limited. Sea trout are only moderately sensitive to underwater sound (Nedwell *et al.* 2008). As a close relative of salmon (*Salmo salar*), sea trout were used as a model to determine the possible implications to salmon during piling operations at Southampton Water in 2003. Nedwell *et al*. (2008) presents the results from the study conducted simultaneously to the piling operations. Nedwell *et al*. (2008) found no obvious signs of trauma in any examined fish and no increase in activity or startled response was observed at any range from the piling.

244. TTS in fish species could occur at ranges up to 19km at DEP and 16km at SEP for monopiles. The species listed in **Table 9-24** (excluding gobies) would be at high risk of behavioural impact near the piling locations (tens of metres), they would be at moderate risk at intermediate distances (hundreds of metres) and at low risk when far (thousands of metres) from the piling location (**Table 9-24**). The potential area affected by TTS and behavioural impacts is very small in the context of the wide distribution ranges of the species listed in **Table 9-24** (excluding gobies), it should be noted, however, that diadromous species are only likely to occur very occasionally in the SEP and DEP offshore sites, and therefore the potential for these species to be subject to adverse piling noise impacts is very low. Furthermore, given the distance of SEP and DEP from The Wash and Humber, there is no potential for piling noise to affect these species during critical periods of their migration such as river entry and river exit. In light of the above, diadromous species are considered receptors of low sensitivity.

245. Sand gobies may be an exception as they have limited mobility and therefore potentially a reduced capacity to escape the areas affected by the greatest noise levels. A recent study found that continuous sound can impact gobies spawning as females are unable to hear sound produced by males (Blom *et al*. 2019). Gobies are, however, abundant over wide areas of the North Sea and therefore any noise effects would impact only a small proportion of the population. Further, given the relatively short life cycle of this species (Teal *et al.* 2009), the population would be expected to recover quickly if subject to localised impacts associated with piling. As such, they are considered to be receptors of medium sensitivity.

Fish with swim bladder involved in hearing

246. Blaxter and Hoss (1981) found that herring showed startle responses at received sound levels of 122 – 138dB re 1 µPa, and further observed that the response seen depended on the size of the fish. Various studies into the response of herring to underwater noise have found that during spawning and feeding seasons, there is little response to the noise, their urge to undertake these activities are of a higher priority than avoiding passing vessels or seismic surveys compared to reactions during wintering periods (Skaret *et al.* 2005; Peña *et al*. 2013; Misund 1994).

247. As previously stated, and shown in **Figure 9.3** and **Appendix 9.1 Figure 9.6**, SEP and DEP overlap with historic herring spawning grounds defined by Coull *et al.* (1998) however, from historic surveys, there was no significant spawning activity in and around the SEP and DEP offshore sites. Any herring spawning in and around the sites are part of the Banks sub population. The ORJIP 2018 study found that

Flamborough Head spawning ground was the current hotspot for the Banks component (Boyle and New, 2018).

248. Whilst the Coull *et al.* (1998) data suggests that the Projects overlap a portion of the Banks stock, data from the IHLS shows that the important area for herring spawning is located to the north around Flamborough Head as shown in **Figure 9.3** and **Appendix 9.1 Figure 9.9**, which also correlates with the ORJIP findings. The closest point of SEP is approximately 124km to Flamborough Head and DEP approximately 118km.

249. **Figure 9.6** and **9.7** show that the impact ranges associated with the potential for TTS onset overlap with areas of medium to low herring spawning confidence, including the area identified as the Banks sub-population spawning ground overlapping the wind farm sites. These figures are based on a stationary receptor which is considered precautionary since herring would be expected to flee during soft start piling from the areas where they are at risk of highest exposure (Dahl *et al*. 2015; Popper *et al*. 2014).

250. As with the construction of previous OWFs, it is unlikely that maximum hammer energies would reach 100% and therefore the area of potential TTS effects would be considerably smaller than indicated by **Figure 9.6** and **9.7**. There is no overlap of the TTS impact ranges of either SEP or DEP with the area of high larvae abundance revealed by the IHLS to the north around Flamborough Head (**Figures 9.3, 9.6** and **9.7**).

251. Herring have a swim bladder which is involved in hearing, and are therefore considered to have a high risk of behavioural impact when near (tens of metres) and in the intermediate vicinity (hundreds of metres) of the piling location, but at low risk when far (thousands of metres) from the piling location (**Table 9-18**). As SEP and DEP overlap with herring spawning grounds identified by Coull *et al.* (1998), piling would be expected to have a high behavioural effect. However, taking into account that there is no evidence of significant spawning in this area and the location of peak larval abundance is to the north of SEP and DEP beyond the maximum extent of noise impacts, it could be considered as 'far' from the piling location under Popper *et al.* (2014) risk level. Therefore, the potential impact area where TTS and behavioural impacts could occur (as shown in **Figure 9.6 and Figure 9.7**) and the potential for TTS is considered to be low. The substrate specific spawning behaviour of herring means that they are considered to be receptors of medium sensitivity.

252. SEP and DEP are located within the low intensity spawning for whiting and within the nursery grounds for cod. Although the projects do not overlap with any defined sprat spawning or nursery grounds, they were caught in abundance during the historic herring spawning surveys and have been included in the assessment. It should be noted however that the degree of overlap between the spawning and nursery grounds of these species and the area with potential for TTS onset would be very small relative to the total area that whiting could use for spawning (see **Appendix 9.1**). In addition, these species are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

253. These species have a swim bladder which is involved in hearing, and are therefore considered to have a high risk of behavioural impact when near (tens of metres) and in the intermediate (hundreds of metres) vicinity of the piling location, and at low risk

when far (thousands of metres) from the piling location (**Table 9-24**). Taking into account the wide distribution ranges of these species, including the areas used as spawning grounds, and the potential impact area where TTS and behavioural impacts could occur, and their low risk to behavioural reactions when ‘far field’ (thousands of metres) from the piling source, they are considered to be receptors of low sensitivity.

254. Diadromous species included in this category are allis shad and twaite shad, and European eel. As stated above, their behavioural impact is high for both near field and intermediate filed and moderate far field. It should be noted, however, that diadromous species are only likely to occur occasionally in the area of SEP and DEP, and therefore the potential for these species to be subject to piling noise is very low. Furthermore, given the distance of SEP and DEP from The Wash and Humber 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. In light of the above, diadromous species are considered receptors of low sensitivity.

9.6.1.4.4.3 Changes to Prey Species or Feeding Behaviour

255. Sandeels and clupeids (herring and sprat) play an important role in the North Sea’s food web as prey for birds, marine mammals and piscivorous fish. There is the potential for changes in the behaviour of these prey species associated with piling noise that may result in indirect impacts on the species that feed on them. The potential impact of their availability as a result of piling for piscivorous fish is given below. The potential impacts on other receptor groups such as marine mammals and seabirds are assessed in **Chapter 10 Marine Mammal Ecology** and **Chapter 11 Offshore Ornithology** and are therefore not discussed here.

256. The outputs of the noise modelling for the spatial worst-case scenario indicate that TTS may occur at distances of up to 19km from DEP and up to 16km from SEP for all the fish groups modelled, depending on the hearing ability of the species. The most pronounced behavioural responses are expected to occur within this range, however, based on criteria from Hawkins *et al.* (2014) behavioural impacts could potentially extend to wider areas of up to 34km for SEP and 39km for DEP (see **Table 9-22**).

257. As shown in **Table 9-2**, under the temporal worst-case scenario (maximum number of piles) for DEP with 30 four-legged jacket foundations and one OSP, piling would take up to 408 384 (15 days) and 23 four-legged jacket foundations and one OSP and would take up to 300 hours (12.5 days) for SEP.

258. Although potentially causing changes in the movements of key prey species, TTS and behavioural impacts on herring, sandeels and sprat has not been identified. In addition, where avoidance or behavioural reactions take place, these would occur on both prey species and the fish species that they feed on. Taking this into account, together with the wide distribution ranges of both prey and piscivorous fish, the sensitivity is considered to be low.

<u>Eggs and larvae</u>

259. Studies on TTS or behavioural effect on eggs and larvae are limited and have differing results. Nedelec *et al.* (2015) found that cod larvae exposed to regular and random noise grew less between days 1 and 2 days post hatch (dph), but growth

caught up by day 16 dph. Cod larvae exposed to regular noise used their yolk sacs faster after 2 days of exposure and resulted in lower body width-length ratio after 16 dph (Nedelec *et al.* 2015). Other studies have found that larvae exposed to higher noise levels grew less 12 days dph (Banner and Hyatt, 1978, as cited in Nedelec *et al.* 2015), while another found that noise had no impact on larval length or weight (Bruintjes and Radford, 2014). From the limited information available, these short term impacts are likely to be localised and recoverable.

260. As with fish species, TTS in eggs and larvae could occur at ranges up to 19km at DEP and 16km at SEP for monopiles. **Table 9-24** states that eggs and larvae would be at moderate risk of behavioural impact near the piling locations (tens of metres), they would be at low risk at intermediate distances (hundreds of metres) and at low risk when far (thousands of metres) from the piling location (**Table 9-24**). The potential area affected by TTS and behavioural impacts is very small in the context of the wide distribution of various species' eggs and larvae and the potential for these species to be subject to piling noise is low. Therefore, eggs and larvae are considered to be of low sensitivity.

<u>Shellfish</u>

261. Studies of marine bivalves (e.g. mussels *Mytilus edulis*) exposed to pile driving for 50 minutes at a distance of 15m have shown that mussels have high clearance rates[10] during the pile driving compared to ambient noise (Spiga *et al.* 2016). Spiga *et al.* (2016) suggest that during periods of pile driving, mussels move from a physiologically maintenance state to active metabolism to compensate for the stress caused by pile driving. Similar studies exposing crabs to other anthropogenic noise have also resulted in increased metabolic rate measured by high cardiovascular activity induced by stress (Weilgart, 2018). From such studies, it is clear that noise triggers a stress response and given their low mobility and therefore reduced ability to vacate the area, they are considered to be of medium sensitivity.

9.6.1.4.5 Impact Significance - SEP or DEP in Isolation

262. The following sections describe the significance of impact for each category as defined by Popper *et al.* (2014), based on the negligible to low magnitude of effect defined above and the sensitivity of effect as described in **Table 9-23** and **Table 9-24**.

9.6.1.4.5.1 Mortality and recoverable injury

<u>Fish with no swim bladder</u>

263. The majority of fish species within the group "fish with no swim bladder" (**Table 9-23**) are mobile and would be expected to vacate the area in which the impact could occur within the onset of 'soft start' piling. With low magnitude and sensitivity of effect, the impact is therefore assessed to be of **minor adverse** significance.

264. As sandeels burrow, are substrate dependent and potentially have limited capacity to flee, they are considered to be of medium sensitivity. With a low magnitude, the impact is therefore assessed to be of **minor adverse** significance.

---

[10] Clearance rate is the rate that filter-feeders remove suspended particles from water (Spiga *et al.* 2016).

Fish with swim bladder not involved with hearing

265. The majority of fish receptors included within the group "fish with swim bladders not involved in hearing" (**Table 9-23**) are considered to be of low sensitivity with the exception of gobies, that are deemed to be of a medium sensitivity. These sensitivities in combination with low magnitude are all assessed to result in impacts of **minor adverse** significance.

Fish with swim bladder involved in hearing

266. All the fish receptors within the group "fish with swim bladders involved in hearing" (**Table 9-23**) are considered to be of medium sensitivity. This, in combination with the low magnitude of effect, would result in an impact of **minor adverse** significance.

Eggs and larvae

267. With their limited mobility, eggs and larvae are considered to be of medium sensitivity. This, in combination with the low magnitude of effect, results in an impact of **minor adverse** significance.

Shellfish

268. As shellfish have limited ability to avoid areas in the proximity of piling, they are considered to be receptors of medium sensitivity. This, in combination with the negligible magnitude of effect results in an impact of **minor adverse** significance.

9.6.1.4.5.2 TTS and behavioural

Fish with no swim bladder

269. Most of the receptors listed in **Table 9-24** are considered to be of low sensitivity, with the exception of sandeel, which are deemed to be of medium sensitivity. In combination with a low magnitude of effect, this results in an impact significance of **minor adverse** for all of these species.

Fish with swim bladder not involved in hearing

270. With the exception of gobies, which have been considered to be of medium sensitivity, the remainder of the species in this category are deemed to be of low sensitivity. Combined with a low magnitude of effect, the impact significance has been assessed to be **minor adverse** for all species including gobies.

Fish with swim bladder involved in hearing

271. All fish species listed in **Table 9-24** under this category are considered to be of medium sensitivity and with a low magnitude of effect, the impact significance has been assessed to be **minor adverse**.

Eggs and larvae

272. Eggs and larvae are considered to be of medium sensitivity. This, in combination with the low magnitude of effect, results in an impact of **minor adverse** significance.

Shellfish

273. Shellfish have been assessed to be receptors of medium sensitivity. This, in combination with the low magnitude of effect results in an impact of **minor adverse** significance.

9.6.1.4.6 Magnitude of effect - SEP and DEP

274. The worst-case scenario spatially considers the greatest area of effect from underwater noise during foundation piling. This would consist of using the maximum hammer energy of 5,500kJ for installing 53 x 15MW turbines using monopiles (1 monopile per wind turbine) and two OSPs (16 pin piles in total) (**Table 9-2**).

275. Temporally, the worst-case scenario considers the longest duration for underwater noise during foundation piling. This would consist of 53 x 15MW turbines using pin piles (4 pin piles per wind turbine, 212 pin piles) and two OSPs (16 pin piles) (**Table 9-2**). Over the 4 years construction period up to 28.5 days (684 hours) of total active piling would be required to install 228 pin piles.

276. There is approximately 10km between the SEP and DEP wind farm sites and the maximum impact range for mortality / potential mortal injury and recoverable injury is up to 270m (>207dB SEL_{peak}) and up to 4.5km (207dB SEL_{cum}) based on a sequential piling scenario with a monopile maximum hammer energy of 5,500kJ. As shown in **Table 9-22,** the maximum impact range is up to 1.2km greater (for both SEP and DEP) for mortality / potential mortal injury impacts (207dB SEL_{cum}) under the sequential piling scenario, however this increase is not at a level which is considered to increase the magnitude of impact from that based on a single piling scenario. There will be no overlap between two projects and their assessments in isolation (provided above) and the magnitude of effect for mortality / potential mortal injury and recoverable injury is low for all receptors.

277. The maximum impact range from TTS and behavioural response is up to 23km (DEP SE modelling location) for a sequential piling scenario using the maximum hammer energy (5,500kJ) during the installation of monopiles for all receptors. There is a possibility of overlap between the maximum impact ranges if SEP and DEP are constructed concurrently (see **Figure 9.7**). However, taking into account the temporary, short term and intermittent nature of piling activity, and that any impact to fish and shellfish receptors would be temporary, the magnitude of effect is considered to remain low.

Sensitivity of effect - SEP and DEP

278. As stated above for SEP or DEP in isolation, the sensitivity of effect would be the same as listed in **Table 9-23** for mortality and potential mortal injury / recoverable injury and **Table 9-24** for TTS and behavioural risks for SEP and DEP, as the same level of impact would occur, regardless of when piling was undertaken.

Impact Significance - SEP and DEP

279. The magnitude and sensitivity of effect for SEP and DEP is the same as SEP or DEP in isolation, therefore the impact of underwater noise on fish and shellfish receptors is considered to be of **minor adverse** significance.

9.6.1.5 Impact 5: Underwater noise from other activities

280. Piling is not the only source of noise that may impact fish and shellfish receptors during construction. For example, other potential sources of underwater noise include cable laying, trenching, rock placement, drilling, suction dredging and vessels.

9.6.1.5.1 Magnitude of effect - SEP or DEP in Isolation

281. The noise generated from these activities have the potential to disturb fish and shellfish species in and around the offshore sites by causing avoidance, changes in swimming speed and direction and by altering schooling behaviour (Popper *et al.* 2014).

282. The duration of the cable installation process is highly variable depending on sea bed composition (**Chapter 6 Marine Geology, Oceanography and Physical Processes**) and the methods used. The cable installation methods that are currently being considered are:

- Ploughing;
- Jetting;
- Trenching;
- Vertical injector; and
- Surface laid with cable protection where burial is not possible;

283. There are no clear indications that underwater noise caused by the installation of subsea cables poses a significant risk to marine fauna. However, it is considered that there is a potential for disturbance to fish species to occur associated with this (OSPAR, 2012).

284. In addition to potential noise impacts from cable installation activity, there will also be an increase in the number of vessels associated with construction transiting the offshore sites. This could also result in increased underwater noise levels and disturbance to fish species.

285. In the context of this assessment, it should be noted that the absolute maximum number of vessels on site at any one-time during construction is 16, however due to construction sequencing not all types of vessel will in reality be on site at the same time.

286. Considering the limited areas as stated in **Table 9-2** that are potentially affected and the temporary nature of the construction phase, the magnitude of effect is considered to be low.

9.6.1.5.2 Sensitivity of effect - SEP or DEP in Isolation

287. Taormina *et al.* (2018) reviewed various underwater noise studies specific to cable trenching and installation that suggest behavioural impacts on fish species would be expected to occur in localised areas in the immediate proximity of the activities/vessels (i.e. from metres to few hundred metres) at noise levels around 186 dB re 1 μPa.

288. The underwater noise generated by other construction activities, including vessel noise, was modelled to determine the potential impact ranges on fish species. The

modelling found that for all fish species, the impact range for recoverable injury (using threshold of 170 dB SPL_{RMS}) would occur within 50m of all other activities, and the potential for TTS onset in all fish species (using the shipping and other continuous noise TTS threshold of 158 dB SPL_{RMS}) would occur within 50m of all other activities (see **Appendix 10.2** for more information).

289. Murchy *et al.* (2019) focused on the impacts of shipping noise and seismic surveys on marine invertebrates and found that shipping noise induced physiological responses such as increased respiration rate and heat shock proteins, all indicators of stress. Wale *et al.* (2013a) found that shore crabs exposed to repeated ship noise consumed more oxygen, indicating higher metabolic rate and potentially greater stress. This study also found that after the first exposure to the ship noise, the crabs became habituated to it (Wale *et al.* 2013a). Not only are they affected physiologically, behaviour such as feeding and anti-predator adaptation are also altered (Wale *et al.* 2013b).

290. Fish and shellfish species can be expected to adapt and to be habituated to increased levels of such noise to some extent given the existing levels of shipping activity in the SEP and DEP offshore sites (**Chapter 13 Shipping and Navigation**). As the effects of these noise sources are temporary and recoverable, the sensitivity of effect for fish and shellfish are considered to be low.

9.6.1.5.3 Impact Significance - SEP or DEP in Isolation

291. Taking account of the comparatively wide distribution ranges of fish and shellfish species in the context of the small areas potentially affected, the magnitude and sensitivity of effect are considered to be low, resulting in an impact of **minor adverse** significance.

9.6.1.5.4 Magnitude of effect - SEP and DEP

292. The maximum duration for the offshore construction period, including piling and export cable installation, is up to four years for SEP and DEP. Although, construction activities would not be constant throughout this period, particularly if there is a phased approach to construction, the areas in and around the offshore sites are likely to be busier with vessels associated with construction. This could result in increased underwater noise levels and disturbance to fish species.

293. In the context of this assessment, the absolute maximum number of vessels on site at any one-time during construction is 25 vessels, for both SEP and DEP (although as above, not all types of vessel will in reality be on site at the same time).

294. Considering the limited areas as stated in **Table 9-2** that are potentially affected and the temporary nature of the construction phase, the magnitude of effect is considered to be low.

9.6.1.5.5 Sensitivity of effect - SEP and DEP

295. As with SEP or DEP in isolation, the sensitivity of effect for SEP and DEP is also be considered as low.

9.6.1.5.6 Impact Significance - SEP and DEP

296. The effects of underwater noise on fish and shellfish from other activities from SEP and DEP are the same as for SEP or DEP in isolation. With low magnitude and sensitivity of effect the impact is considered to be of **minor adverse** significance.

9.6.1.6 Impact 6: Underwater noise during UXO clearance

297. As agreed at the marine mammals ETG meeting on the 20th July 2020, UXO clearance requirements will be addressed through a separate Marine Licence application post consent. This assessment has been provided for information purposes only. A MMMP for UXO clearance in accordance with the **Draft MMMP** (document reference 9.4) will be developed post consent.

298. The southern North Sea still has large quantities of UXO remaining on the sea bed as a result from both world wars and sea dumping of expired munitions. There is the potential that controlled UXO clearance may be required prior to construction. Whilst the Applicant would make reasonable endeavours to avoid any underwater UXO that are identified in preference to clearance, it is necessary to consider the potential for underwater UXO detonation where avoidance is not possible.

<u>Magnitude of effect - SEP or DEP in Isolation</u>

299. Prior to construction, a detailed UXO survey would be undertaken. As such, the exact numbers or types of UXO are currently unknown. A worst-case scenario has been assumed that the maximum duration of UXO clearances could be up to 25 days (per project), based on one detonation per 24 hour period. A range of charge sizes have also been assessed, with a maximum charge weight of 525kg.

300. During the construction of the operational Sheringham Shoal OWF, only one UXO was found, out of a potential of 52 targets investigated (Scira Offshore Energy, 2010). A total of 243 targets were investigated for Dudgeon OWF, with 20 of those identified as UXO requiring clearance, in addition to three partial UXO that also required clearance (Statoil, 2015).

301. Should detonation of UXO be required in the SEP or DEP offshore sites, there is potential to result in injury and disturbance to fish species in the vicinity of the detonation. Depending on the size of the charge, physical injury / trauma would occur within close range to the detonation (**Table 9-26**), and TTS and behavioural effects occurring at greater distance (beyond 810m). Given the short and intermittent nature of this activity (limited to instances when detonation of UXO is required) and the fact that for the most part any effects would be limited to the vicinity of the area where the detonation takes place, the magnitude of effect is considered to be low.

<u>Sensitivity of effect - SEP or DEP in Isolation</u>

302. The full understanding of the acoustic waves generated from UXO detonation that propagate on and through sea bed is lacking. The waves propagating along the surface of the sea bed will not re-radiate into the water column but have the potential to harm benthic species including shellfish, although this is also poorly understood (Cheong *et al.* 2020).

303. Currently there are no specific data published with respect to shellfish species, however as previously stated under Impact 4, studies on lobsters have shown no

effect on mortality, appendage loss or the ability of animals to regain normal posture after exposure to very high sound levels (>220 dB) (Payne *et al.* 2007). Therefore, they are not assessed any further with regard to underwater noise impacts due to UXO clearance.

304. Whilst it is clear that explosions will result in potential mortality or injury to fish species at close range, there are no data currently available on the effects of explosions on fish hearing (e.g. TTS) or behaviour. Existing information suggests that there may be temporary or partial loss of hearing at high sound levels, especially in fish where the swim bladder enhances sound pressure detection. In the case of behavioural impacts, it is considered that startle responses are likely to occur if the received signal is of sufficient magnitude. Such responses last less than a second and do not necessarily result in significant changes in subsequent behaviour (Popper *et al.* 2014).

305. Popper *et al.* (2014) states that there is evidence (e.g. Goertner *et al.* 1994; Stephenson *et al.* 2010; Halvorsen *et al.* 2012) that little or no damage occurs to fishes without a swim bladder except at very short ranges from an in-water explosive event. Popper *et al.* (2014) also states that Goertner (1978) showed that the range from an explosive event over which damage may occur to a non-swim bladder fish is in the order of 100 times less than that for swim bladder fish.

306. The modelling undertaken to inform this assessment, estimated ranges of impact associated with UXO detonations for different charge weights to provide an indication of the ranges at which mortality / potential injury may occur to fish species (**Appendix 10.2**). As outlined in Popper *et al.* (2014) fish species are considered to be at risk of mortality or potential mortal injury at a peak SPL of between 229dB and 234dB re 1μPa as shown in **Table 9-25**. The ranges at which this noise level could occur are provided in **Table 9-26**.

Table 9-25: Criteria for Explosions Used in the Assessment (Source Popper et al. (2014))

Category	Mortality	Recoverable Injury		TTS		Masking	Behaviour
Fish: no swim bladder (particle motion detection)	229 - 234 dB peak	> 216 dB SEL$_{cum}$ Or > 213 dB peak	(N) High (I) Low (F) Low	>> 186 dB SEL$_{cum}$	(N) High (I) Moderate (F) Low	N/A	(N) High (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (particle motion detection)		203 dB SEL$_{cum}$ Or > 207 dB peak	(N) High (I) High (F) Low	> 186 dB SEL$_{cum}$	(N) High (I) Moderate (F) Low	N/A	(N) High (I) High (F) Low
Fish: swim bladder involving in hearing (primarily		203 dB SEL$_{cum}$ Or > 207 dB peak	(N) High (I) High (F) Low	186 dB SEL$_{cum}$	(N) High (I) High (F) Low	N/A	(N) High (I) High (F) Low

Category	Mortality	Recoverable Injury	TTS	Masking	Behaviour
pressure detection)					
Eggs and larvae	> 13mm/s peak velocity	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	N/A	(N) High (I) Low (F) Low
(N = Near-field; I = Intermediate-field; F = Far-field)					

Table 9-26: Calculated Mortal and Potential Injury Impact Ranges (M) for any Fish Species

Popper *et al.* (2014) Unweighted SPL_{peak}	Charge Weight (kg)				
	25	55	120	240	525
234 dB (Mortality and potential mortal injury)	170m	230m	290m	370m	490m
229 dB (Mortality and potential mortal injury)	290m	380m	490m	620m	810m

307. The risk of recoverable injury (including PTS), TTS and behavioural impacts are presented qualitatively in line with the Popper *et al.* (2014) approach in **Table 9-18**. It should be noted that the risks outlined in **Table 9-25** are based on small charges, such as those used to dismantle in-water structures. A greater risk should therefore be assumed for larger charges (**Appendix 10.2**). As detailed in **Section 10.3.3** of **Chapter 10 Marine Mammal Ecology**, a MMMP for UXO clearance will be developed in the pre-construction period (in consultation with the relevant Statutory Nature Conservation Bodies (SNCBs) and the MMO), detailing the required mitigation measures to minimise the potential risk of physical and auditory injury (PTS) to marine mammals as a result of underwater noise during UXO clearance. This would potentially also reduce the risk to fish and shellfish species. A **Draft MMMP** (document reference 9.4) is provided as part of the DCO application.

308. Taking account of the severity of the impact particularly at close range, but acknowledging that impacts would occur at individual rather than at population levels, all fish species, as well as eggs and larvae, are considered to be receptors of medium sensitivity.

9.6.1.6.1 Impact Significance - SEP or DEP in Isolation

309. The combination of medium sensitivity with the low magnitude of effect results in an impact of **minor adverse** significance for SEP or DEP in isolation.

9.6.1.6.2 Magnitude of effect - SEP and DEP

310. Depending on the outcome from the UXO survey, there is likely to be more possible UXO targets in a SEP and DEP scenario. However, as with SEP or DEP in isolation the potential to result in injury and disturbance to fish species in the surrounding area will depend on the size of the charge. These will be of a short and intermittent nature (limited to instances when detonation of UXO is required) and for the most

part, any effects would be limited to the vicinity of the area where the detonation takes place, therefore the magnitude of effect is considered to be low.

9.6.1.6.3 Sensitivity of effect - SEP and DEP

311. As with SEP or DEP in isolation, the sensitivity of effect for SEP and DEP is considered to be medium.

9.6.1.6.4 Impact Significance - SEP and DEP

312. The receptor sensitivity and magnitude of effect for SEP and DEP is the same as SEP or DEP in isolation, therefore the impact of underwater noise during UXO clearance on fish and shellfish receptors is considered to be of **minor adverse** significance.

9.6.1.7 Impact 7: Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works

313. There is the potential for changes to fishing activity within the study area and surrounding areas during the construction of offshore infrastructure. This is due to the potential displacement of fishing activity in to other areas and may result in changes to commercially exploited species within the study area.

Magnitude of effect - SEP or DEP in Isolation

314. The principal commercial species targeted in the study area include whelk, brown crab, lobster and herring (**Section 9.5.2.1**). Other species caught commercially within the study area include Dover sole, plaice, whiting, mackerel, dab, bass, sprat, brill and cod. These species are some of the most economically important species in UK waters and are targeted across wide areas in the southern North Sea. The offshore sites account for a small extent in the context of the overall fishing grounds for these species (see **Chapter 12 Commercial Fisheries**). As construction activities are temporary and short term, along with the small spatial extent of effect, the overall magnitude of effect is deemed to be low.

Sensitivity of effect - SEP or DEP in Isolation

315. DEP overlaps historic whelk, crab and lobster fishing grounds whereas SEP primarily overlaps with crab and lobster fishing grounds depicted in 2010 and shown in **Figure 4-5** of **Appendix 12.1 Commercial Fisheries Technical Report**.

316. Closure during construction may act as de-facto no take zones (NTZ), offering respite for adult lobsters (Roach and Cohen*,* 2020; Roach *et al.* 2018). It has been demonstrated that where fishing exploitation is absent, the biomass and abundance of lobsters increase (Roach and Cohen*,* 2020; Roach *et al.* 2018). However, it should also be noted that this reduction in fishing pressure within the SEP and DEP offshore sites may increase fishing pressure in adjacent areas.

317. Temporary restrictions of fishing activity can allow uninterrupted contribution to the spawning stocks; for example Stelzenmüller *et al.* (2020) observed that creating de-facto marine protected areas (MPA) with the construction and operation phases of OWFs, might have a beneficial impact on the reproductive output of fish spawning in the area. In addition to this, lower trophic level species like infauna benefit from the absence of disturbance due to mobile fishing gear as well as an increase in macrofaunal diversity (Roach and Cohen, 2020).

318. In Roach *et al.* (2018), the fishery was able to recuperate some of the economic loss during the closure of the area, by landing larger and better quality lobsters once the area was opened again in 2015.

319. Fishing activity for finfish species are primarily regulated through the setting of annual 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 SEP or DEP, as fishing will continue until TACs or set limitations in effort are reached (i.e. through vessels fishing in the wider grounds available in the southern North Sea).

320. Furthermore, as described in **Chapter 12 Commercial Fisheries**, significant impacts (i.e. exceeding minor adverse 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 study area. Therefore, the sensitivity of commercially exploited species in respect of potential changes in fishing activity as a result of the project is considered to be low.

Impact Significance - SEP or DEP in Isolation

321. Taking the low receptor sensitivity and magnitude of effect, the resulting impact arising from changes in commercially exploited species is considered to be of **minor beneficial** significance.

Magnitude of effect - SEP and DEP

322. The magnitude of effect on commercially exploited species from SEP and DEP remains the same as for a SEP or DEP in isolation scenario i.e. low.

Sensitivity of effect - SEP and DEP

323. The sensitivity of the commercially exploited species from SEP and DEP remains the same as for a SEP or DEP in isolation scenario i.e. low.

Impact Significance - SEP and DEP

324. As with SEP or DEP in isolation, with the low receptor sensitivity and magnitude of effect, the resulting impact from changes in commercially exploited species is considered to be of **minor beneficial** significance.

9.6.2 Potential Impacts during Operation

9.6.2.1 Impact 1: Temporary habitat loss / disturbance

325. Certain activities during operation will result in the temporary disturbance of the sea bed and consequent impacts on fish and shellfish receptors. This includes any requirement for use of jack-up vessels or anchoring, as well as cable reburial and/or repairs.

Magnitude of effect - SEP or DEP in Isolation

326. Effects will be on a considerably smaller scale and at a much lower frequency than those assessed in relation to construction (**Section 9.6.1.1**), where the potential for negligible to minor adverse impacts has been identified, depending on the species in question.

327. Considering the availability of similar suitable habitat both in the offshore development areas and in the wider context of the southern North Sea, together with the intermittent and reversible nature of the effect, the magnitude of physical disturbance during operation for either SEP or DEP is considered to be negligible for all species.

Sensitivity of effect - SEP or DEP in Isolation

328. Fish and shellfish receptors are considered to have a low sensitivity to temporary disturbance during operation. Many species will be able to move away from the areas of disturbance and in all cases the effects will be highly localised and small in extent relative to changes resulting from natural conditions (e.g. storm events), as described in **Section 9.6.1.1**.

Impact Significance - SEP or DEP in Isolation

329. With a negligible magnitude of effect and low sensitivity, the resulting impact for all species is considered to be of **negligible adverse** significance.

Magnitude of effect - SEP and DEP

330. The number of relevant O&M activities that might occur in relation to SEP and DEP will be approximately double that considered with respect to each project in isolation. However, activities will still be undertaken at a relatively low frequency during the anticipated 40 year design life of SEP and DEP, and the range of effects from temporary disturbance will not interact between the two projects, as described in **Chapter 6 Marine Geology, Oceanography and Physical Processes**. The magnitude of physical disturbance during operation for SEP and DEP is therefore considered to remain as negligible for all species.

Sensitivity of effect - SEP and DEP

331. Fish and shellfish receptors are considered to have a low sensitivity to temporary disturbance during operation.

Impact Significance - SEP and DEP

332. With a negligible magnitude of effect and low sensitivity, the resulting impact for all species is considered to remain as **negligible adverse** significance for SEP and DEP.

9.6.2.2 Impact 2: Permanent habitat loss

333. Habitat loss will occur during the lifetime of SEP and DEP as a result of structures, scour and external cable protection installed on the sea bed. It is currently unknown which structures will be removed or remain *in situ* at the point of decommissioning. Removal of accessible installed components such as the wind turbine components and foundations (above the sea bed level) is expected, however, there is potential for some structures to be left *in situ* such as external cable protection or scour protection.

334. A Decommissioning Programme will be agreed with the relevant authorities at the point of decommissioning. Therefore, it is currently unknown if habitat loss during the operational phase will be lasting/long term or permanent. As a precautionary approach, habitat loss has been considered as permanent with the exception of

where the Applicant has made a commitment to removal on decommissioning, which is addressed by Impact 3 (long term habitat loss) below.

Magnitude of effect - SEP or DEP in Isolation

335. The worst-case footprint of permanent infrastructure (which may not be decommissioned) includes scour protection around (18MW) GBS foundations and up to one OSP with suction bucket foundations, unburied cable protection and cable crossings (**Table 9-2**). For context, the maximum area of permanent habitat loss within the SEP or DEP offshore sites is 0.50km^2 and 0.67km^2 respectively (**Table 9-2**), which is not considered significant in the context of the amount of similar available habitat in the wider area.

336. The fish and shellfish receptors present in the offshore sites have comparatively large areas which are identified as being potentially suitable spawning grounds, nursery grounds (as described in **Section 9.5.2.3**) and foraging grounds, and many have wide distribution ranges; all of which may be spatially and temporally variable. However, species such as herring and sandeel are highly dependent on specific sea bed substrates (**Section 9.5.2.3**).

337. In summary, potentially suitable herring spawning habitat areas have been identified within the SEP and DEP boundaries and are likely present in surrounding areas, although mapping based on BGS base maps and heat mapping is likely to overestimate the extent of this habitat (**Figures 9.2** and **9.3**). The SEP wind farm site in particular has been identified as having preferred herring spawning habitat due to its higher gravel content. There is, however, an absence of evidence that herring spawn in the vicinity of SEP and DEP. Indeed, herring spawning surveys undertaken for the existing SOW and DOW concluded that herring spawning did not occur within the study areas (Brown and May Marine, 2009; Brown and May Marine, 2010). Based on the available evidence outlined above, the area is considered to be unlikely to be a hotspot for herring spawning and if spawning does occur it is likely to be at low levels. (**Figure 9.3**; **Appendix 9.1 Section 9.3.3.1.1** and **Figure 9.10**).

338. With regard to sandeel, IBTS data indicate that high abundances of greater sandeel and Raitt's sandeel are present to the north and north west of SEP and DEP (see **Section 9.1.3.3.9** of **Appendix 9.1**). In terms of habitat suitable for sandeel spawning, Ellis *et al.* (2012) shows the highest intensity spawning grounds to be located to the north of SEP and DEP, with SEP and DEP being within a low intensity spawning area (**Figure 9.30 of Appendix 9.1**). It is recognised that a relatively large proportion of the DEP wind farm site is identified as being Preferred sandeel habitat (see **Figure 9.4**) however when considering the potential for a permanent loss of up to 0.67km^2 of habitat within the DEP wind farm site (i.e. less than 1%) within a localised area of the North Sea, vast swathes of which are identified as being potentially suitable sandeel nursery and spawning habitat (Ellis *et al.* 2012), the magnitude of impact is considered to be low.

339. Overall, due to the presence of comparable habitats identified throughout the SEP and DEP offshore sites and the wider region, as demonstrated by survey data from SOW and DOW, as well as Hornsea 3 OWF (RPS, 2018), and the localised spatial extent of impacts, the magnitude of effect of permanent habitat loss is considered to be low.

Sensitivity of effect - SEP or DEP in Isolation

340. As the species within the offshore sites have moderately large areas for spawning, nursery and foraging, and are widely distributed, they are deemed to be of low sensitivity to permanent habitat loss.

Impact Significance - SEP or DEP in Isolation

341. Based on the low sensitivity of fish and shellfish and a low magnitude of effect in relation to permanent habitat loss during the operational phase in either the SEP or DEP offshore area, the impact significance is assessed as **minor adverse**.

Magnitude of effect - SEP and DEP

342. The maximum footprint of hard substrate on the sea bed causing permanent habitat loss is larger for the SEP and DEP scenario (1.159km^2) (**Table 9-2**). However, the expected loss remains a small proportion of the total available habitats, therefore the magnitude of effect is considered to remain as low.

Sensitivity of effect - SEP and DEP

343. The sensitivity to permanent habitat loss for a SEP and DEP scenario would be the same as SEP or DEP in isolation, with fish and shellfish species considered to be of a low sensitivity.

Impact Significance - SEP and DEP

344. With a low magnitude and sensitivity of effect in relation to permanent habitat loss during the operation of SEP and DEP, the impact is assessed as **minor adverse** significance.

9.6.2.3 Impact 3: Long term habitat loss

345. As described above in relation to Impact 2, a distinction is made between permanent habitat loss where infrastructure is expected or assumed to be decommissioned *in situ* (assessed in **Section 9.6.2.2**) and long term habitat loss that will result from the installation of infrastructure where the Applicant has made a commitment to removal on decommissioning (this section).

346. Since the extent of long term habitat loss is very small with respect to both the in isolation and SEP and DEP scenarios (see below), one assessment is provided that addresses all potential scenarios.

Magnitude of effect - SEP or DEP in Isolation or SEP and DEP

347. As described in **Table 9-2**, external cable protection inside the Cromer Shoal Chalk Beds MCZ, may be installed, where necessary, for unburied cables along the offshore export cable route through the MCZ. The Applicant has committed to installing removable external cable protection systems within the MCZ at the decommissioning stage to avoid permanent impact to MCZ benthic habitats.

348. The worst-case footprint of cable protection and HDD exit transition zone in the MCZ, and therefore the maximum area of long term habitat loss, is 900m^2 for SEP or DEP in isolation, or 1,800m^2 for both Projects. With the commitment to remove this infrastructure at decommissioning it is expected that habitat loss will last for the duration of the DEP and/or SEP operational phase (40 years). Therefore, the impact

will be temporary (throughout the project duration), but will be very limited in extent, therefore the magnitude of effect is assessed as low.

Sensitivity of effect - SEP or DEP in Isolation or SEP and DEP

349. The sensitivity to long term habitat loss for the purpose of the assessment is assumed to be the same as assessed for permanent habitat loss, with fish and shellfish species considered to be of a low sensitivity to such small scale and localised effects.

Impact Significance - SEP or DEP in Isolation or SEP and DEP

350. Based on the low sensitivity of fish and shellfish and a low magnitude of effect in relation to long term habitat loss during the operational phase in the offshore sites, the impact significance is assessed as **minor adverse**.

9.6.2.4 Impact 4: Introduction of wind turbine foundations, scour protection and hard substrate

351. The introduction of various man-made structures such as foundations and scour protection in soft sediment areas increases and changes habitat availability and type, resulting in locally altered biodiversity as species are able to establish and thrive in previously hostile environments (Birchenough and Degraer, 2020; Coolen *et al.* 2020). The colonisation of such species may cause indirect effects on fish and shellfish populations if the structures act as artificial reefs, as well as direct impacts due to the potential of foundations acting as fish aggregation devices.

Magnitude of effect - SEP or DEP in Isolation

352. The area of hard substrate within DEP from GBS foundations, associated scour and cable protection that have the potential to be colonised is 0.48km^2 in total and 0.35km^2 within SEP (**Table 9-2**). Although, due to the three dimensional nature of foundation design, the actual area, including that available for colonisation, is likely to be greater.

353. During the lifetime of the project, the associated hard substrate will be of local spatial extent. The magnitude of effect is considered to be low with respect to both indirect and direct potential effects.

Sensitivity of effect - SEP or DEP in Isolation

354. The introduction of new hard substrate in areas that are predominately sandy or soft sediments may cause positive effects through potential habitat enhancement (Roach and Cohen, 2020). Initially structures are colonised with suspension feeders such as mussels, anemones and amphipods in high densities (Birchenough and Degraer, 2020), as described in **Section 8.6.2.4** in **Chapter 8 Benthic Ecology**. Attracted by feeding opportunities, various species of shellfish such as edible crab and European lobster, and fish such as cod and mackerel may aggregate around the structures, resulting in species of higher trophic levels also being drawn to the rich environment with various seabirds and marine mammals being found in higher densities than those in the open sea (Birchenough and Degraer, 2020).

355. As stated previously, the sea bed sediments in and around the SEP and DEP offshore sites are predominantly soft sediments. New species that are drawn to the area are likely to be those normally associated with rocky or hard substrate,

providing ideal conditions for certain benthic and fish species, therefore the structures are likely to increase the overall diversity and biomass. In addition to this, the artificial hard substrates have been shown to attract different life stages of fish for foraging, shelter and reproduction, suggesting that they can provide high-quality spawning, nursery and feeding grounds, attributing to indirect evidence of productivity (Stelzenmüller *et al.* 2020; Fowler *et al.* 2020; Todd *et al.* 2018).

356. Studies have concluded that the effect of a Fish Aggregation Device (FAD) result in an increase of the biomass of fish species around foundations compared to areas where there was no FAD present. Fish are attracted and aggregate from the surrounding areas as they are attracted to the new habitat by increased feeding opportunities (Wilhelmsson *et al.* 2006; Andersson and Ohman, 2010; Bohnsack ,1989). Inger *et al.* (2009) studied the bases of the foundations at Swedish OWFs finding that they acted as a FAD for both demersal and pelagic species. The study concluded that the presence of the structures have the capacity to act both as artificial reef and FAD which have been used previously to facilitate restoration of damaged ecosystems, and de facto marine-protected areas, which have proven successful in enhancing both biodiversity and fisheries (Inger *et al.* 2009).

357. Modelling of offshore wind ecosystems have shown that they provide protection and feeding grounds, demonstrating the positive responses for upper trophic level species. In addition to lower level species like infauna benefitting from the absence disturbance due to mobile fishing gear (van Hal *et al.* 2017; Roach and Cohen, 2020). Reubens *et al.* (2014) observed significant cod and pouting numbers were attracted to the artificial reef created by the turbine foundations.

358. The species assemblage and their dynamics such as changes in dominant species, will vary over the lifetime of the project, as Lindeboom *et al.* (2011) found during a review of short term ecological effects of the OWEZ in the Netherlands, based on two years of post-construction monitoring. The study found that within the first year the dominant pelagic species switched from herring to sandeel and species richness of demersal fish increased after the first year of construction (Lindeboom *et al.* 2011). The Lillgrund OWF undertook the longest monitoring programme to date, that showed no overall increase in total abundance, although there was an increase in abundance associated with the base of the foundations for some species (Andersson, 2011). These studies correlate with MMO (2014), where there were minor changes in fish communities reported due to the addition of hard substrate at sites including North Hoyle and Kentish Flats.

359. Scour protection and foundation bases provide similar habitats to those found naturally (e.g. with various crevices and holes) for crustaceans (Linley *et al.* 2007). Horns Rev 1 OWF post-construction monitoring surveys noted that the hard substrates were used as a hatchery or nursery grounds for several species, which was particularly successful for edible crab. BioConsult (2006) concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas. Studies in the UK have identified increases of benthic species including crabs and lobsters from colonisation of sub-surface structures by subtidal sessile species on which they can feed (Linley *et al.* 2007).

360. Based on the results of the post monitoring surveys cited above, any changes in the community structure and abundance of fish and shellfish species within the offshore development area are likely to be small. Therefore, the sensitivity of fish receptors

in general are deemed to be low, and shellfish, herring and sandeels are considered to be medium.

Impact Significance - SEP or DEP in Isolation

361. With the magnitude of effect being low in relation to the introduction of hard substrate, in addition to a sensitivity of medium (shellfish) to low (elasmobranch and fin fish species), the impact of the introduction of hard substrate is therefore assessed as **minor adverse** significance for all species. It should be noted that this impact may be considered to be a beneficial one rather than adverse, however to reflect the fact that any impact represents a change from what might be considered natural or baseline conditions, a precautionary approach is to assume that the impact may be adverse.

Magnitude of effect - SEP and DEP

362. The area of hard substrate within SEP and DEP from GBS foundations, associated scour and cable protection that have the potential to be colonised is 1.159km^2 in total (**Table 9-2**). Although the total footprint is greater than a SEP or DEP in isolation scenario, the magnitude of effect is considered to be the same for SEP and DEP, therefore the magnitude is deemed as low.

Sensitivity of effect - SEP and DEP

363. The sensitivity of effect for the introduction of hard substrate for a SEP and DEP scenario would be the same as SEP or DEP in isolation: shellfish, herring and sandeels are deemed to be of a medium sensitivity with other finfish species considered to be of a low sensitivity.

Impact Significance - SEP and DEP

364. As with SEP or DEP in isolation, the impact of the introduction of hard substrate is assessed as **minor adverse** significance for all species.

9.6.2.5 Impact 5: Increased suspended sediments and sediment re-deposition

365. Disturbance caused by jack up vessel legs or anchors, as well as cable reburial and/or repair may result in small volumes of sediment being re-suspended. However, the volumes of sediment disturbed from such activities, as well as the overall duration of the disturbance, would be significantly reduced relative to construction (**Section 9.6.1.2**).

Magnitude of effect - SEP or DEP in Isolation

366. Increases in SSCs are expected to cause localised and short-term increases at the point of discharge. Released sediment may then be transported in suspension in the water column by tidal currents. As outlined in **Table 9-2**, it is assumed that there could be up to 10 jack-up movements per year for each of SEP and DEP (i.e. 20 in total). Cable repairs or replacements will only be carried infrequently – for example one export and interlink cable repair every 10 years and two infield cable repairs every 10 years. Similarly, for reburial, there may be up to 0.2km per export cable affected every 10 years, and 1% of each of the total interlink and infield cabling every 10 years.

367. As described in relation to construction (**Section 9.6.1.2**), increased SSCs and levels of sediment re-deposition will be localised and short lived. Therefore, the

magnitude of effect of SSC and re-deposition during the operational phase is considered to be negligible.

Sensitivity of effect - SEP or DEP in Isolation

368. The sensitivity of fish and shellfish receptors to temporary increases in SSC and sediment deposition is provided in **Section 9.6.1.2**. A worst-case scenario of low sensitivity has been assigned in relation to increased SSC and re-deposition for all fish and shellfish species.

Impact Significance - SEP or DEP in Isolation

369. With a negligible magnitude of effect and low sensitivity, the impact significance is deemed to be **negligible adverse**.

Magnitude of effect - SEP and DEP

370. Although there will be approximately double the amount of operational activity when considering both projects being built, the magnitude of effect is expected to be the same as for SEP or DEP in isolation. As above, any increases in SSC are anticipated to be localised and short-term, therefore the magnitude of effect of SSC and re-deposition during the operational phase is considered to be negligible.

Sensitivity of effect - SEP and DEP

371. As with SEP or DEP in isolation, a worst-case scenario of low sensitivity has been assigned in relation to increased SSC and re-deposition for all fish and shellfish species.

Impact Significance - SEP and DEP

372. With a negligible magnitude and low sensitivity of effect in relation to increased SSC and re-deposition during the operational phase of SEP and DEP, the impact is considered to be of **negligible adverse** significance.

9.6.2.6 Impact 6: Re-mobilisation of contaminated sediments

373. As discussed in **Section 9.6.1.3** and in **Chapter 7 Marine Water and Sediment Quality**, contaminants in the study area have not been reported at significantly elevated levels that would be a cause for concern. Any effects from the remobilisation of contaminated sediments and sediment redeposition are likely to be less than during the construction of SEP and DEP, either in isolation or if both projects are built.

374. Taking into account a negligible magnitude of effect and negligible sensitivity, the resulting impact arising from remobilisation of contaminated sediments and sediment re-deposition is considered to be of **negligible adverse** significance for both the SEP or DEP in isolation and SEP and DEP scenarios.

9.6.2.7 Impact 7: Underwater noise

375. Operational noise sources may include wind turbine vibration, maintenance activities, and vessels. It is therefore likely that these noise sources would increase the existing baseline noise levels in the offshore sites.

9.6.2.7.1 Magnitude of effect - SEP or DEP in Isolation

376. Noise from the operating wind turbines will be present for the lifetime of the wind farm/s, however levels are expected to be only slightly elevated above background ambient noise levels (see below). Vessels servicing SEP or DEP during operation would also generate noise, with a maximum of approximately 700 vessel round trips (per project) expected to occur each year to carry out required maintenance. The vast majority of these will be by small O&M vessels, such as the crew transfer vessel (CTV). Overall, levels of activity will be low in the context of the current levels of vessel traffic in the area (see **Chapter 13 Shipping and Navigation**). As described in relation to Impact 5 (**Section 9.6.2.5**), other O&M activities that may generate noise including the use of jack up vessels for major component replacement, cable repairs/replacements and reburial will only be carried out infrequently.

377. As such, during operation it is expected that there will be only a slight and localised increase above background noise levels, therefore the magnitude of effect for either SEP or DEP is considered to be low.

9.6.2.7.2 Sensitivity of effect - SEP or DEP in Isolation

378. Median noise levels of noise in the North Sea were 90.5 dB re 1 µPa in the 63-Hz band, and 93.6 dB re 1 µPa in the 125-Hz band from data obtained in 2013 and 2014 (Merchant*,* 2018). Recent noise monitoring studies have found that noise radiated from individual turbines are low compared to noise radiated from cargo ships, this also includes larger turbines (Tougaard *et al*. 2020). Further studies of operational wind farms such as North Hoyle, Scroby Sands, Kentish Flats and Barrow found the noise generated to be only marginally above ambient noise levels (Cefas 2010, Nedwell *et al*. 2007 and Edwards *et al*. 2007).

379. 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 10.2**. As suggested above, however, this has been shown to be low and only slightly elevated above background ambient noise levels.

380. The underwater noise modelling undertaken for the impact of operational wind turbine noise on fish shows that for all fish species, the impact of recoverable injury (using the shipping and other continuous noise threshold of 170 dB SPL_{RMS}) would occur within 50m of the wind turbine, as would the potential for TTS onset in all fish species (using the shipping and other continuous noise TTS threshold of 158 dB SPL_{RMS}) (see **Appendix 10.2** for more information).

381. The Cefas (2009) review of monitoring data from operational UK OWFs indicated that there was no evidence from post-construction fish surveys that operational noise had resulted in significant impacts on fish populations, either in terms of changes to species composition or reductions in abundance. In addition to this, there is little to no evidence of avoidance by mobile species during the operational period (Leonhard *et al*. 2011; Walls *et al*. 2013), however some species have increased in abundance compared to pre-construction, baseline levels (Leonhard *et al.* 2011).

382. Horns Rev 1 OWF monitoring during the operational phase (Leonhard *et al.* 2006) revealed that colonisation of scour protection at the base of wind turbine foundations by edible crab had been rapid with up to 1,900 individuals recorded per m^2. As

colonisation was rapid and prolific, these results were interpreted to indicate that operational noise had no impact on shellfish populations (Leonhard *et al.* 2006).

383. In view of the above, the sensitivity of fish and shellfish species to operational noise and activities is considered to be low.

9.6.2.7.3 Impact Significance - SEP or DEP in Isolation

384. The low sensitivity of effect combined with the low magnitude of effect, results in an impact of **minor adverse** significance.

9.6.2.7.4 Magnitude of effect - SEP and DEP

385. The magnitude of effect of SEP and DEP is the same as SEP or DEP in isolation. There may be more vessels servicing SEP and DEP during operation, although the increase is small since the majority of vessels and vessel trips would be shared.

386. During operation it is expected that there will be a slight increase above background noise levels that will be localised, therefore the magnitude of effect for SEP and DEP is considered to remain as low.

9.6.2.7.5 Sensitivity of effect - SEP and DEP

387. Operational underwater noise for a SEP and DEP scenario would be the same as SEP or DEP in isolation with fish and shellfish species considered to be of low sensitivity.

9.6.2.7.6 Impact Significance - SEP and DEP

388. With a low magnitude and sensitivity of effect in relation to underwater noise during the operational phase of SEP and DEP, the impact is assessed as being of **minor adverse** significance.

9.6.2.8 Impact 8: Electromagnetic fields (EMF)

389. OWFs transmit the energy produced along a network of cables. As energy is transmitted, the cables emit low-energy EMF. The electrical (E) and magnetic (B) fields generated increase proportionally to the amount of electricity transmitted. The primary consideration for EMFs emitted by subsea cables is the B-field since a number of marine organisms have the ability to detect and respond to these (Gill and Dessender, 2020).

390. SEP and DEP will involve installing offshore (and onshore) export cable circuits using HVAC technology. Fish and shellfish species are less likely to exhibit responses to HVAC cables when compared to High Voltage Direct Current (HVDC) transmission cables due to the higher strength EMF emitted by HVDC (Normandeau, Tricas and Gill, 2011).

391. Based on the project specific EMF assessment undertaken in Tripp (2021), the following results, shown in **Table 9-27** and **Table 9-28**, were predicted for the offshore magnetic and induced electrical fields for three scenarios.

392. All calculations were performed assuming maximum load, minimum circuit separation and assume export cables (i.e. cables likely to emit greater EMF compared to infield and interlink cables) buried at 1m below the sea bed (Tripp, 2021).

Table 9-27: Calculated Maximum Magnetic Fields for SEP and DEP Offshore Export Cable Circuit Scenarios (Calculations Assume a Cable Burial Depth of 1m)

Scenario	Magnetic field (µT)						
	Cable surface (i.e. surface laid cable)	Distance above sea bed (m)					
		0m	1m	2m	5m	10m	20m
Scenario 1 **SEP and DEP equally rated**	1421	20.93	5.45	2.43	0.59	0.17	0.06
Scenario 2 **SEP and DEP unequally rated**	1653	26.49	6.97	3.13	0.77	0.23	0.07
Scenario 3A **SEP circuit only**	1217	17.97	4.71	2.13	0.54	0.16	0.05
Scenario 3B **DEP circuit only**	1653	26.54	7.02	3.18	0.81	0.24	0.07

Table 9-28: Modelled Maximum Induced Electric Field (mV/m) in Small Shark at Various Distances Above SEP and DEP Export Cable Circuits

Scenario	Electric field (mV/m)						
	Distance above sea bed (m)						
	0m	0.3m	1m	2m	5m	10m	20m
Scenario 1 **SEP and DEP equally rated**	17.00	10.27	4.42	1.98	0.48	0.14	0.05
Scenario 2 **SEP and DEP unequally rated**	21.53	13.02	5.66	2.55	0.63	0.18	0.06
Scenario 3A **SEP circuit only**	14.60	8.82	3.83	1.73	0.44	0.13	0.04
Scenario 3B **DEP circuit only**	21.56	13.12	5.70	2.58	0.66	0.20	0.05

393. Overall, the predicted magnetic fields for SEP and DEP OWFs based on Tripp (2021) are greatest on the sea bed and reduce rapidly with vertical and horizontal distance from the circuits. The highest magnetic fields were observed for Scenarios 2 and 3B, due to these options carrying a greater current, but in all cases the maximum magnetic fields were below 27µT at the sea bed for a cable buried at 1m. The magnetic field at the cable surface had the highest possible exposures and ranged between 1217 and 1653µT. Where loose rock dump burial occurs, there is a possibility that small fish or shellfish could be exposed to higher levels, if small enough to penetrate the loose rock. However, it should be noted that the Applicant

has committed to installing removable external cable protection systems within the MCZ and so no loose rock dump would be used in this area. This would prevent or limit the ability of small fish and shellfish to penetrate the cable protection within the MCZ and be subject to the highest possible exposures.

394. The magnetic fields from all scenarios reduced to very low levels within a few metres from the circuits and it is important to note that these levels do not take account of shielding factors of the cable sheath which would further reduce the fields.

395. For the electrical fields, the maximum induced electric field in a small shark was 21.7mV/m at the sea bed (assuming a cable burial depth at 1m), but this reduced to below 1 mV/m, 5m from the cable circuits for each option considered. These levels significantly decreased in a smaller fish which was also considered. The induced electric field was more than 4.5 times lower than that in the shark due to its smaller size.

396. The main concern with EMF associated with the operation of OWFs, in particular E and B fields emitted by export cables (which tend to emit stronger EMF than infield and interlink cables (Normandeau, Tricas and Gill, 2011)), is that they will interfere with the navigation of sensitive migratory species by affecting the speed and/or the course of their migration, causing subsequent potential impacts if they do not reach essential feeding, spawning and nursery grounds. Specifically, interaction may occur if the fish or shellfish migration route coincides with the cables, particularly in shallow waters (<20m) (Gill, Bartlett and Thomsen, 2012). where there is greater probability of encountering the high voltage cables coming to shore. On a more local scale, species like the elasmobranchs (i.e. sharks, rays and skates) that use EMF to detect food may become confused and spend additional time hunting prey as a result of anthropogenic EMF thereby reducing their daily food intake and overall fitness. Likewise, fish and shellfish species that use EMF to detect predators or kin, may alter their behaviour as a result of anthropogenic EMF. If sufficient numbers of individuals are affected this could have consequences at the population and community scale. However, as noted above, offshore export cables in the MCZ (i.e. the nearshore area where species are likely to be most sensitive and potentially be subject to the highest strength EMF) would be buried or, where burial is not possible, protected with external cable protection and therefore EMF would largely be attenuated in these areas.

397. The principal fish species groups potentially affected by EMF emitted by the interlink, infield and export cables during the operational phase of SEP and DEP which are assessed in this section are as follows:

- Elasmobranchs;
- Diadromous migratory species: European eel, river and sea lamprey, sea trout and shad (twaite & allis);
- Other fish species: cod and plaice; and
- Shellfish species.

398. As described in **Section 9.5**, elasmobranchs were recorded in relatively few number in the historic otter trawl and beam trawl surveys of SOW and DOW, as well as the 2010 elasmobranch survey of SOW (see **Appendix 9.1**). River and sea lamprey are present in some East Anglian rivers and sea lamprey however records of river and

sea lamprey in rivers in Norfolk (and East Anglia as a whole) are relatively scarce compared with other areas of the UK (Kelly and King, 2001).

399. European eel is widely distributed throughout the Anglian region, including Norfolk, although those found off the East Anglian coast, including off Norfolk, are generally thought to originate from the rivers in northeast England and southeast Scotland such as the Esk, Wear, Coquet, Tyne and Tweed (Pawson, 2013).

9.6.2.8.1 Magnitude of effect - SEP or DEP in Isolation

400. Because of the physical properties of EMF, specifically that they are what is known as "vectors" not "scalars" (i.e. have direction as well as magnitude), the magnitudes of the EMF from two different sources do not simply add together. The addition of EMF from different sources is complex, but has the general effect that, when the field from one source is larger than the other, the larger field dominates, with the smaller field making only a small difference to the resulting field. Based on Tripp (2021), the maximum magnetic fields produced by the worst-case scenario, which was for the DEP in isolation (3B) scenario, was 26.5μT at the sea bed assuming a cable buried at 1m depth, reducing to 1μT at 4.4m vertically above the cables (see **Table 9-27**). Background measurements of the magnetic field are approximately 50μT in the southern North Sea (Tasker *et al*. 2010). There is potential that, where areas of rough terrain are encountered, burial depths shallower than 1m would be achieved which could result in EMF levels higher than 26.5μT however levels would still be below those expected to result in significant physiological or behavioural impacts on fish and shellfish ecology receptors and along the majority of the cable routes EMF would be below ambient/background measurements. Therefore, the overall magnitude of effect of EMF for either SEP or DEP on fish and shellfish receptors is considered to be low.

9.6.2.8.2 Sensitivity of effect - SEP or DEP in Isolation

401. With regard to receptor sensitivity, a number of organisms in the marine environment are known either to be sensitive to electromagnetic fields or have the potential to detect them (Gill *et al*. 2005), including elasmobranchs; diadromous migratory species, such as European eel, river and sea lamprey, sea trout and shad; other fish species, such as cod and plaice; and shellfish (Scott *et al.* 2021).

<u>Elasmobranchs</u>

402. Elasmobranchs are the major group of organisms known to be electrosensitive. They possess specialised electroreceptors called Ampullae of Lorenzini and naturally detect bioelectric emissions from prey, conspecifics and potential predators / competitors (Gill *et al*. 2005). They are also known to detect magnetic fields.

403. Few sharks and rays have been recorded within the SEP and DEP offshore sites, with only one starry smoothhound recorded in the export cable corridor just south of SEP (Brown & May Marine, 2013). However, starry smooth-hounds represented the greatest numbers caught in the pre-construction cable installation elasmobranch survey (Brown & May Marine, 2010), while 23 different elasmobranch species have been recorded in the North Sea (Daan, 2005), with elasmobranchs typically having wide distribution range and defined nursery grounds.

404. Bird *et al.* (2020) indicates that thornback ray is the most likely skate species to be present within the SEP and DEP offshore sites and McCully *et al.* (2013) identified Thornback ray within the vicinity of SEP and DEP (see **Section 9.5.1**). Literature on elasmobranch spawning is limited and elasmobranch abundance is overall low within the area of the SEP and DEP offshore sites.

405. Hutchison *et al.* (2018) conducted a field experiment in Long Island Sound, Connecticut (U.S.) and showed that little skates (*Leucoraja erinacea*) crossed over a 300 kV HVDC transmission cable. However, the skates showed a strong distributional response associated with the higher EMF zone, moved significantly greater distances along the cable route, and displayed increased turning activity. However, as noted above fish and shellfish species are less likely to exhibit responses to HVAC cables when compared to High Voltage Direct Current (HVDC) transmission cables due to the higher strength EMF emitted by HVDC (Normandeau, Tricas and Gill, 2011).

406. Brown and May Marine (2013) concluded, from the studies and the MMO's 2014 review of environmental data associated with post consent monitoring, that the EMF produced by offshore electricity cables may cause behavioural effects, but that these are not significant enough to alter feeding or migratory behaviour. However, it was also noted that biological and / or environmental factors are likely to determine the abundance of elasmobranchs (Brown and May Marine, 2013).

407. EMF emitted by interlink, infield and export cables during operation could potentially result in temporary behavioural reactions however, long term impacts on feeding, migration or confusion in elasmobranch species are not anticipated. A worst-case medium level of interaction between elasmobranchs and EMF is therefore predicted. Elasmobranch species are considered to be of medium vulnerability, medium recoverability and local value; therefore, they are receptors of medium sensitivity.

<u>Diadromous migratory species</u>

408. European eel possess magnetic material of biogenic origin of a size suitable for magnetoreception and are thought to use the geomagnetic field for orientation (Moore and Riley, 2009). In addition, their lateral line has been found to be slightly sensitive to electric current (Vriens and Bretschneider 1979). Research carried out on sea trout also indicates that these species are able to respond to magnetic fields (Formicki and Winnicki 2009). The presence of magnetic material suitable for magnetoreception has been found in salmonids (Moore *et al*. 1990), as has the ability of this species to respond to electric fields (Rommel and McLeave 1973).

409. Lampreys possess ampullary electroreceptors that are sensitive to weak, low frequency electric fields (Bodznick and Preston 1983); however, information on the use that they make of the electric sense 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 (Normandeau, Tricas and Gill, 2011).

410. The SEP and DEP wind farm sites are located 15.8 and 26.5km respectively from shore and therefore it is expected that diadromous migratory species will not be subject to EMF associated with interlink, infield and export cables prior to river entry or immediately after leaving The Wash and River Humber. They may, however, occasionally transit the area of the SEP and DEP offshore sites (particularly the export cable corridor closer to shore), and there is, therefore, potential for EMF

associated to affect these species during migration and/or feeding activity (further detailed below).

411. Various studies have been carried out in relation to the migration of eels and the potential effect of EMF derived from OWF cables. For example, experiments undertaken at the operational wind farm of Nysted detected barrier effects, however correlation analysis between catch data and data on power production showed no indication that the observed effects were attributable to EMF. Furthermore, mark and recapture experiments showed that eels did cross the offshore export cable (Hvidt *et al*. 2005). Similarly, a recent 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 associated with the magnetic fields. Öhman *et al*. (2007) suggested that even if an effect on migration was demonstrated, the effect was small, and on average the delay caused by the passage was approximately 30 minutes. Based on the above, a medium degree of interaction between EMF and European eel is expected to occur. European eel are therefore considered to be of medium vulnerability, medium recoverability and national importance; therefore they are deemed to be of medium sensitivity.

412. Any potential impacts on movement and behaviour in sea trout would be closely linked to the proximity of the fish to the EMF source. Gill and Bartlett (2010) suggest that any impact associated with EMF on the migration of salmonids, including sea trout (with Shad having similar migratory behaviour) would be dependent on the depth of water and the proximity of home rivers to development sites. During the later stages of marine migration, 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. The level of effect-receptor interaction between EMF associated with the interlink, infield and export cables and sea trout (along with Shad) is considered to be small. These species are considered to be of medium vulnerability, medium recoverability and regional to national importance therefore they are deemed to be of medium sensitivity.

413. Lampreys, like elasmobranchs, possess electroreceptors that are sensitive to weak, low-frequency electric fields (Bodznick and Preston 1983). Whilst responses to electric fields have been reported in these species, information on the use that they make of the electric sense 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 (Normandeau*,* Tricas and Gill, 2011). 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, with the overall degree of interaction between lampreys and EMF is anticipated to be very small. Lampreys are considered to be of low vulnerability, medium recoverability and international importance; therefore, they are deemed to be of low sensitivity.

<u>Other fish species</u>

414. Further to the species described above, there is some evidence of a response to EMF in other fish species, such as cod and plaice (Gill *et al*. 2005). The results of post-construction monitoring carried out in operational wind farms do not suggest that EMF have resulted in significant detrimental impacts on these species. Lindeboom *et al*. (2011) suggest that the presence of the foundations and scour

protection and potential changes in the fisheries related to OWF development would have the most impact upon fish species. Similarly, Leonhard and Pedersen (2006) indicate that noise from the wind turbines and EMF from cabling do not seem to have a major impact on fish and other mobile organisms attracted to the hard bottom substrates for foraging, shelter and protection. In line with this, research carried out at the Nysted OWF (Denmark), focused on detecting and assessing possible effects of EMF on fish during power transmission, and found no differences in the fish community composition after the wind farm was operational (Hvidt *et al*. 2005). Whilst effects on the distribution and migration of four species were observed (European eel, flounder, cod and Baltic herring), it was recognised that the results were likely to be valid on a very local scale, and only on the individual level, and that an impact on a population or community level was likely to be very limited.

Shellfish

415. Research on the ability of marine invertebrates to detect EMF has been limited. The ability to detect magnetic fields has been studied for some shellfish species and there is evidence in some of a response to magnetic fields, including molluscs and crustaceans (Normandeau, Tricas and Gill (2011); Scott, Harsanyi and Lyndon (2018); Scott *et al.* (2021).

416. Crustacea, including lobster and crabs, have been shown to demonstrate a response to B fields, with the spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (Boles and Lohmann; 2003). Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau, Tricas and Gill, 2011). Indirect evidence from post construction monitoring programmes undertaken in operational wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence of submarine power cables and associated magnetic fields.

417. Gill and Dessender (2020), note that most field and semi-natural studies conducted have focused on behavioural effects and none have shown any demonstrable significant impacts of EMF on sensitive species (for example see Gill et al. 2014) . However, a controlled laboratory experiment showed some adverse effects of prolonged exposure to high-intensity EMF (in the millitesla [mT] range) on the physiology, development, and growth of several species of demersal fish and crustaceans (Woodruff et al. 2012).

418. This is supported by Scott, Harsanyi and Lyndon (2018) which studied the effects in a laboratory setting of simulated EMF on brown crab and found that the circadian rhythm of stress related parameters haemolymph L-Lactate and D-Glucose were affected. Behavioural and response parameters (antennular flicking, activity level, attraction/avoidance, shelter preference and time spent resting/roaming) during 24-hour periods were also measured. EMF was found to have no effect on respiration rate, activity level or antennular flicking rate. However, brown crabs showed a clear attraction to EMF exposed shelter (69%) compared to control shelter (9%) and significantly reduced their time spent roaming by 21%.

419. The EMF was created using four electric solenoid magnets (24 V) connected to variable power supplies on ceramic tiles underneath the tanks. A high strength EMF

scenario, with the magnets being run at full power, created a peak EMF of 40 millitesla (mT) and a low strength scenario at 2.8mT was also measured (note these are far above the EMF levels predicted at the surface of the SEP and DEP export cables (see **Table 9-27**)). The different EMF strengths had a significant effect on L-Lactate level. After 4 hours of exposure, crabs exposed to the high strength EMF had significantly lower concentrations of L-Lactate compared to those in low strength EMF indicating increased levels of stress.

420. In addition, a recent study by Scott *et al.* (2021) investigated the effects of different strength EMF exposure (250µT, 500µT, 1000µT) on brown crab and again measured stress related and behavioural and response parameters. EMF strengths of 250µT were found to have limited physiological and behavioural impacts. Exposure to 500µT and 1000µT were found to disrupt the L-Lactate and D-Glucose circadian rhythm and alter Total Haemocyte Count (THC). Crabs showed a clear attraction to EMF exposed (500µT and 1000µT) shelters with a significant reduction in time spent roaming.

421. It is important to note that, to date, EMF levels similar to these experimental conditions have not been observed around deployed marine renewable energy devices. These effects would be more likely observed for sessile species that stay near undersea cables when compared with mobile species (Gill and Dessender, 2020).

422. Taormina et al. (2020) exposed juvenile European lobsters (Homarus gammarus) in a laboratory setting to a DC or AC B-field (maximum up to 200 µT) and found no statistically significant effect on their exploratory and sheltering behaviours. The authors suggested that a behavioural response to B-fields, up to 200 µT, does not appear to be a factor influencing the European lobster's juvenile life stage.

423. Based on the research available, shellfish are considered to be of low vulnerability, medium recoverability and local regional importance; and therefore, they are deemed to be of low sensitivity.

9.6.2.8.3 Impact Significance - SEP or DEP in Isolation

424. With regard to elasmobranchs; diadromous migratory species, such as European eel, river and sea lamprey, sea trout and shad; other fish species such as cod and plaice; and shellfish, as previously stated, the overall magnitude of effect regarding EMF is considered to be low. Therefore, EMF effects on elasmobranchs; diadromous migratory; other fish species and shellfish, taking into consideration their sensitivities, are assessed to result in an overall impact of **minor adverse** significance during the operation of SEP or DEP in isolation.

9.6.2.8.4 Magnitude of effect - SEP and DEP

425. As stated for SEP or DEP in isolation, because of the physical properties of EMF, specifically that they are what is known as "vectors" not "scalars" (i.e. have direction as well as magnitude), the magnitudes of the EMF from two different sources do not simply add together. The potential magnitude of effect on fish and shellfish receptors will not increase above the predicted EMF value of 26.5µT (assuming a cable buried at 1m depth) at the sea bed (which is under background measurements of 50µT in the southern North Sea), therefore the overall magnitude of effect of EMF for SEP and DEP on fish and shellfish receptors is considered to remain as low.

9.6.2.8.5 Sensitivity of effect - SEP and DEP

426. Operational EMF associated with the interlink, infield and export cables for the SEP and DEP would result in the same sensitivity as SEP or DEP in isolation, with fish and shellfish species considered to be of low to medium sensitivity.

9.6.2.8.6 Impact Significance - SEP and DEP

427. With a low magnitude and low to medium sensitivity of effect in EMF associated with the interlink, infield and export cables for SEP and DEP , the impact is assessed to remain as **minor adverse** significance.

9.6.2.9 Impact 9: Impacts on commercially exploited species associated with the displacement of fishing from the area of activity / works

428. As a result of the presence of SEP or DEP infrastructure during operation, fishing activity may be reduced within the wind farm sites, this may cause changes in commercially exploited species within the area due to the displacement of fishing activity elsewhere.

Magnitude of effect - SEP or DEP in Isolation

429. Changes in fishing activity during operation are expected to be similar, if not less, than during the construction of either SEP or DEP, as discussed in construction Impact 7 above and in **Section 12.6.2.5** in **Chapter 12 Commercial Fisheries**.

Sensitivity of effect - SEP or DEP in Isolation

430. The sensitivity of effect on commercially exploited species associated with their displacement from the area of activity / works are provided in **Section 9.6.1.7** in relation to construction Impact 7.

431. A worst-case scenario of low sensitivity has been determined in relation to impacts on commercially exploited species associated with their displacement from the area of activity / works.

Impact Significance - SEP or DEP in Isolation

432. Taking the low receptor sensitivity and magnitude of effect the resulting impact arising from changes in fishing activity is considered to be of **minor beneficial** significance.

Magnitude of effect - SEP and DEP

433. Although the total area would be greater than either SEP or DEP, the magnitude of effect is expected to be same and is considered to be low.

Sensitivity of effect - SEP and DEP

434. The sensitivity of SEP and DEP would be the same as SEP or DEP in isolation, therefore the sensitivity is deemed to be low.

Impact Significance - SEP and DEP

435. Taking the low receptor sensitivity and magnitude of effect the resulting impact arising from changes in fishing activity is considered to be of **minor beneficial** significance.

9.6.3 Potential Impacts during Decommissioning

436. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in **Chapter 4 Project Description** and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all the turbine elements, part of the foundations (those above sea bed level), removal of some or all of the infield cables, interlink cables, and export cables. Scour and cable protection would likely be left *in situ*, other than in the MCZ where it may be removed (as assessed above in **Section 9.6.2.3**).

437. During the decommissioning phase, there is potential for wind turbine foundation and cable removal activities to cause changes in suspended sediment concentrations because of sediment disturbance effects.

438. The types of effect would be comparable to those identified for the construction phase, with the key impacts including:

- Impact 1: Temporary habitat loss / disturbance;
- Impact 2: Increased suspended sediments and sediment re-deposition; and
- Impact 5: Underwater noise.

439. The sensitivity of receptors during the decommissioning is assumed to be the same as described for the construction phase. The magnitude of effect is considered to be no greater and, in all probability, less than that considered for the construction phase. Accordingly, given the construction phase assessments concluded no significant impacts (i.e. minor impact or lower) for fish and shellfish receptors, it is anticipated that the same would be valid for the decommissioning phase regardless of the final decommissioning methodologies for either the SEP or DEP in isolation or SEP and DEP scenarios.

9.7 Cumulative Impacts

9.7.1 Identification of Potential Cumulative Impacts

440. The initial step in the cumulative assessment is the identification of which residual impacts assessed for DEP and/or SEP on their own have the potential for a cumulative impact with other plans, projects and activities (described as 'impact screening'). This information is set out in **Table 9-29** below, together with a consideration of the confidence in the data that is available to inform a detailed assessment and the associated rationale. Only potential impacts assessed in **Section 9.6** as negligible or above are included in the CIA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact).

441. **Table 9-29** concludes that in relation to fish and shellfish there is the potential for cumulative effects with other plans or projects arising from: underwater noise impacts (all phases); habitat loss; introduction of foundations, scour protection and hard substrate; and impacts from EMF (during operation).

Table 9-29: Potential Cumulative Impacts (Impact Screening)

Impact	Potential for Cumulative Impact	Data Confidence	Rationale
Construction			
Impact 1: Temporary habitat loss / disturbance	No	High	Impacts are time-limited in duration and local in nature with a low magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Impact 2: Increased suspended sediments and re-deposition	No	High	
Impact 3: Re-mobilisation of contaminants	No	High	Management measures in place for SEP and DEP will also be in place on other projects reducing their risk of occurring.
Impact 4: Underwater noise during foundation piling	Yes	High	Other developments within the southern North Sea have the potential to also have a noise impact on fish and shellfish sensitive receptors. Therefore, in the context of noise impacts, there could be cumulative effects.
Impact 5: Underwater noise from other activities	Yes	High	
Impact 6: Underwater noise during UXO clearance	Yes	High	
Impact 7: Impacts on commercially exploited species from displacement of fishing activity	No	High	Chapter 12 Commercial Fisheries has concluded that this impact pathway does not lead to cumulative impacts with other plans or projects.
Operation			
Impact 1: Temporary habitat loss / disturbance	No	High	Impacts are time-limited in duration and local in nature with a low magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Impact 2: Permanent habitat loss	Yes	High	Additive habitat loss across the region can have cumulative impacts.
Impact 3: Long term habitat loss	Yes	High	As above
Impact 4: Introduction of foundations, scour protection and hard substrate	Yes	High	Additive introduction of other hard substrates from foundations and scour protection throughout the region may have a cumulative effect.
Impact 5: Increased suspended sediments and re-deposition	No	High	Impacts are time-limited in duration and local in nature with a low magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Impact 6: Re-mobilisation of contaminants	No	High	Management measures in place for SEP and DEP will

Impact	Potential for Cumulative Impact	Data Confidence	Rationale
			also be in place on other projects reducing their risk of occurring.
Impact 7: Underwater noise	Yes	High	Other developments within the southern North Sea have the potential to also have a noise impact on fish and shellfish sensitive receptors. Therefore, in the context of noise impacts, there could be cumulative effects.
Impact 8: EMF	Yes	Medium	Other plans or projects with EMF impacts may have cumulative effects with SEP and DEP. Medium confidence reflects some gaps in the understanding of effects of EMF on some receptors.
Impact 9: Impacts on commercially exploited species from displacement of fishing activity	No	High	Chapter 12 Commercial Fisheries has concluded that this impact pathway does not lead to cumulative impacts with other plans or projects.
Decommissioning			
Impact 1: Temporary habitat loss / disturbance	No	High	Impacts are time-limited in duration and local in nature with a low magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Impact 2: Increased suspended sediments and re-deposition	No	High	
Impact 5: Underwater noise	Yes	High	Other developments within the southern North Sea have the potential to also have a noise impact on fish and shellfish sensitive receptors. Therefore, in the context of noise impacts, there could be cumulative effects.

9.7.2 Other Plans, Projects and Activities

442. Following impact screening, the next step in the cumulative assessment is the identification of the other plans, projects and activities that may result in cumulative impacts for inclusion in the CIA (described as 'project screening'). This information is set out in **Table 9-30** below, together with a consideration of the relevant details of each, including current status (e.g. under construction), planned construction period, closest distance to SEP and DEP, status of available data and rationale for including or excluding from the assessment.

443. The project screening has been informed by the development of a CIA Project List which forms an exhaustive list of plans, projects and activities in a very large study

area relevant to SEP and DEP. 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.

444. In addition to the CIA method outlined in **Section 6.8** in **Chapter 5 EIA Methodology**, the following considerations were also used to determine which plans and projects are screened into the CIA for potential impacts to fish and shellfish:

- those that overlap with the same spawning and/or nursery grounds for fish and shellfish species as the proposed Projects; and
- are located in the same regional study area and, therefore, are likely to impact the same fish and shellfish receptors.

445. Note that projects in Tier 1 are already operational and, therefore, are considered as part of the baseline and are not included in the CIA. The exception is where there is detailed information available in relation to operation and maintenance activities of operational wind farms (i.e. marine licences or applications), which will be carried out over the lifetime of those projects.

Table 9-30: Summary of Projects Considered for the CIA in Relation to SEP and DEP (Project Screening)

Project	Status	Construction Period	Closest Distance from Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
OWFs						
Dudgeon	In operation	n/a	0 (cable corridor) 0 (array area)	High	Y	The operational phase of the OWF will overlap with SEP and DEP.
Sheringham Shoal	In operation	n/a	0 (cable corridor) 0 (array area)	High	Y	The operational phase of the OWF will overlap with SEP and DEP.
Race Bank	In operation	n/a	9 (array area) 15 (cable corridor)	High	Y	The operational phase of the OWF will overlap with SEP and DEP.
Triton Knoll	In operation	Complete in 2022	13 (array area) 19 (cable corridor)	High	Y	The operational phase of the OWF will overlap with SEP and DEP.
Hornsea Project Two	In construction	2020-2022 (offshore construction)	34 (cable corridor) 52 (array area)	High	Y	The operational phase of the OWF will overlap with SEP and DEP.
Hornsea Project One	In operation	N/A	32 (cable corridor) 54 (array area)	High	Y	The operational phase of the OWF will overlap with SEP and DEP.

Project	Status	Construction Period	Closest Distance from Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
Norfolk Vanguard	Consented	2025-2027 (offshore construction)	28 (cable corridor) 58 (array area)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
Norfolk Boreas	Consented	2025-2029	22 (cable corridor) 82 (array area)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
Hornsea Project Three	Consented	2023-2031 (offshore export cable construction 2026-2027, possibly also 2030-2031)	0 (cable corridor) 83 (array area)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
East Anglia THREE	Consented	2023-2026	94 (cable corridor) 95 (array area)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
East Anglia ONE North	Consented	2023-2026	97 (cable corridor) 98 (array area)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.

Project	Status	Construction Period	Closest Distance from Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
East Anglia TWO	Consented	2023-2026	98 (cable corridor) 103 (array area)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
Hornsea Project Four	Application submitted	2024-2029	52 (array area) 70 (cable route)	Medium	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
Dogger Bank A and B	In construction	2022-2024 (offshore)	110 (cable corridor) Dogger Bank A 148 (array area) Dogger Bank B 167 (array area)	High	N	There will be no spatial overlap of effects given the distance between the OWF and SEP and DEP.
Dogger Bank C and Sofia	In construction	2024-2025 (offshore)	166 (cable corridor) 172 (array area)	High	N	There will be no spatial overlap of effects given the distance between the OWF and SEP and DEP.
North Falls	Pre-PEIR	Late 2020's	120 (cable corridor) 128 (array area)	Low	N	The projects are over 100km away and are not defined in sufficient detail within the public domain to enable a meaningful assessment.
Five Estuaries	Pre-PEIR	Late 2020's	127 (cable corridor)	Low	N	

Project	Status	Construction Period	Closest Distance from Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
			135 (array area)			
Outer Dowsing	Pre-PEIR	Unknown	13 (array area) 16 (cable corridor)	High	Y	There is the potential for overlap in the construction and operational phases of the OWF and SEP and DEP.
Dogger Bank South East	Pre-PEIR	Unknown	115 (array area) 121 (cable corridor)	High	N	The projects are over 100km away and are not defined in sufficient detail within the public domain to enable a meaningful assessment.
Dogger Bank South West	Pre-PEIR	Unknown	129 (array area) 134 (cable corridor)	High	N	The projects are over 100km away and are not defined in sufficient detail within the public domain to enable a meaningful assessment.
Aggregate Extraction						
Area 254 Marcon - aggregate dredging (Tarmac Marine Dredging Ltd).	Marine licence (MLA/2018/00349/1) granted. Variation requested (on hold)	1992-present	61 (cable corridor) 67 (array area)	High	N	Aggregate extraction at Area 254 has been ongoing since 1992, with the latest marine licence a continuation of existing activities. Therefore, effects from the aggregate dredging form part of the baseline.
Oil and Gas						
Independent Oil and Gas / Blythe Hub	Installed	Approved in 2020 (subject to subsequent permit	1 (array area), (4 cable corridor	High	N	First gas is expected in 2022, therefore the project will be operational before SEP and DEP construction begins in 2025 at the earliest. Given all impacts were considered not significant and

Project	Status	Construction Period	Closest Distance from Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
Development. Elgood well tied back via production pipeline to a new production platform (Blythe)		applications) and first gas is expected in 2022.				are local in nature, it is considered there is no impact pathway for interaction between the two projects.
Other						
EIFCA Byelaw 12 Inshore trawling restriction and Byelaw 15 Towed gear restriction for bivalve molluscs	Active	N/A	0 (cable corridor) 9 (array area)	High	N	The restrictions on the use of bottom towed gear will be beneficial to fish and shellfish ecology receptors that may be impacted by SEP and DEP. Therefore, there is no potential for cumulative adverse impacts.
EIFCA Restricted area 35 (closed to bottom towed gear)	Active	N/A	0 (cable corridor) 6 (array area)	High	N	
Viking Link interconnector project	Planned	2022 - 2023	43 (to SEP array)	High	N	The project is over 40km away from SEP and DEP and there is therefore no potential for cumulative impact on the identified receptors.
Sustainable Seaweed Ltd Seaweed Farm	Application submitted	N/A	1.5 (array area) 8 (cable corridor)	Low	N	Not defined in sufficient detail within the public domain to enable a meaningful assessment.

Project	Status	Construction Period	Closest Distance from Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
Norfolk Seaweed Ltd	Application submitted	Unknown	12 (cable corridor) 17 (array area)	High	Y	The assessment provided as part of MMO Case reference: MLA/2020/00475 states that during construction, no underwater noise other than that of the work boat engine holding station as concrete block anchors are lowered to the sea bed would occur. No seismic surveys will be undertaken Therefore, there is no pathway for cumulative underwater noise impacts. There is potential for additive habitat loss and introduction of hard substrate impacts from anchor installation by Norfolk Seaweed Ltd and so it has been included in the assessment however impact contribution would be negligible due to small footprint of anchors and the site.

9.7.3 Assessment of Cumulative Impacts

446. Having established the residual impacts from SEP and/or DEP with the potential for a cumulative impact (**Section 9.7.1**), along with the other relevant plans, projects and activities, the following sections provide an assessment of the level of impact that may arise.

9.7.3.1 Cumulative Impact 1: Underwater Noise

Underwater Noise from Piling

447. There is the potential for piling at SEP and DEP and other wind farm projects to result in cumulative impacts from noise on fish and shellfish species. Cumulative impacts from piling noise may arise from either a spatial or temporal overlap with SEP and DEP resulting from either simultaneous or sequential piling, or both.

448. Of particular concern is the potential for cumulative impacts to occur on species that use the overlapping area for spawning, although consideration for other species has also been given. Species with potential spawning grounds that overlap with SEP and DEP include the following:

- Herring;
- Dover sole;
- Whiting;
- Sandeel;
- Lemon sole; and
- Mackerel.

449. Herring, sandeel, and whiting have been assessed as having medium sensitivity to underwater noise with Dover sole, mackerel and lemon sole having low sensitivity to underwater noise (**Table 9-24**).

450. It should be noted that in the case of mackerel, SEP and DEP do not overlap spawning grounds; however, the closest spawning grounds are located approximately 15km to the north and north east and are, therefore, close enough to be potentially affected by cumulative piling noise impacts (see **Appendix 9.1 Figure 9.20**).

451. With regard to sandeels, SEP and DEP overlap with low intensity spawning grounds, with high intensity spawning grounds located to the north over the Dogger Bank area, approximately 70km away. Sandeel habitat assessments identify suitable sandeel habitat in the offshore sites and indicate that the DEP wind farm site is located in an area with a higher confidence for sandeel presence based on heat mapping (**Figure 9.4**). Being substrate dependent, sandeels have limited capacity to flee underwater noise. The range at which TTS could occur from the construction of SEP and DEP is a maximum of 19km and 23km respectively (**Figure 9.40**). Similarly, in the case of mackerel, the maximum range at which TTS could occur is also 19km and 23km for SEP and DEP respectively. At these ranges, only one other project, the Round 4 project Outer Dowsing, is within the range where noise effects may overlap with those from SEP/DEP. However, as Outer Dowsing is still within the relatively early stages of planning it is unlikely that there will be a temporal overlap in piling noise effects between the projects.

452. Both SEP and DEP are found within identified herring spawning grounds, with further spawning grounds approximately 13km to the north west. However, as discussed in **Section 9.5.2.3.1** and **Figure 9.3** the confidence in herring spawning activity in the vicinity is low to medium and the area is considered to be unlikely to be a hotspot for herring spawning. SEP and DEP are also found within low intensity spawning grounds for whiting. Both herring and whiting have medium sensitivity to underwater noise and the range of TTS has been modelled as having a maximum range of 19km and 23km from SEP and DEP respectively (**Table 9-22**; fish whose swim bladders are involved in hearing) (**Figure 9.6**). Within this maximum TTS range, only Outer Dowsing OWF is within the spatial range of potential underwater noise cumulative impacts. However, as indicated above, temporal overlap of construction phases between the projects is not anticipated.

453. SEP and DEP are also found within Dover sole and lemon sole spawning grounds, with the latter being of low intensity. Similar to mackerel, both Dover and lemon sole are considered to have low sensitivity to underwater noise with the maximum range for TTS at 19km and 23km for SEP and DEP respectively. As already discussed, the only other project with potential underwater noise cumulative effects is Triton Knoll OWF which, whilst there is spatial overlap there is no temporal overlap.

454. The remaining species with known spawning grounds in the vicinity of SEP and DEP have very wide spawning grounds in the context of the relatively small spatial extent over which piling may have an effect.

455. In view of the above, the cumulative impact of construction noise from piling at SEP and DEP on fish species is considered to be **negligible** and, therefore, not significant.

<u>Underwater Noise from Other Construction Activities</u>

456. In addition to piling noise there may be other activities during construction and decommissioning at other projects that could result in potential disturbance to fish and shellfish, such as transiting vessels, cable laying, rock placement and dredging. As described in **Section 9.6.1.5**, potential impacts on fish and shellfish would occur over very small areas, i.e. within the immediate proximity of the construction activity/vessel.

457. The magnitude of underwater noise effects from other construction activities is much lower than from piling. As such, there is unlikely to be an interaction with other project activities. Therefore, the magnitude of the cumulative impact is considered to be negligible.

458. The fish species that may potentially be affected by cumulative underwater construction and decommissioning noise are the same as for the cumulative piling noise assessment. Taking this and the above into account, the cumulative impact is considered to be **negligible** and, therefore, not significant.

<u>Underwater Noise from UXO clearance during Construction</u>

459. The detonation of UXO associated with other OWF projects could result in adverse effects on fish species in the vicinity of the detonation. Physical injury could occur in close proximity to the detonation, with TTS/behavioural effects occurring at greater distances.

460. Whilst it is recognised that there is the potential for an increase in the number of UXO detonations from other projects, UXO clearance is a short term activity that is intermittent in nature. Considering this together with the fact 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, the magnitude of effect is considered to be low.

461. Taking into account the severity of the impact at close range, which would occur at an individual level, rather than population level, fish and shellfish receptors are considered to be of medium sensitivity. This combined with a low magnitude results in a cumulative impact of **minor adverse** significance.

Underwater Noise from Operational Activities

462. The operational underwater noise source with the potential for cumulative effects is vessel noise. Underwater noise generated from the operational wind turbines is not considered further as the TTS impact range has been modelled as being <50m (**Section 9.6.2.7**, with further details in **Appendix 9.2**) and, therefore, does not have the potential for cumulative effects with other projects.

463. Operational noise assessed for SEP and DEP alone has determined that the increase in noise levels above background would be very small and localised in nature. With this in mind and the distance between SEP and DEP and other projects (**Table 9-30**), the magnitude of effect is considered to be low.

464. Monitoring data from other operational wind farms suggest that operational noise does not have the potential to result in any discernible effect on fish and shellfish species. Therefore, fish and shellfish receptors are considered to have low sensitivity. This combined with a low magnitude of effect, results in a cumulative impact of **minor adverse** significance.

9.7.3.2 Cumulative Impact 2: Habitat Loss

465. There will be a loss of habitat supporting fish and shellfish receptors due to the presence of the project infrastructure, such as the turbine and OSP foundations and associated scour protection. It is expected that during the decommissioning stage, project infrastructure will be removed and the site returned to its natural state, as much as is feasibly possible. It is recognised that some infrastructure cannot be decommissioned and, therefore, will remain in place causing permanent habitat loss. Project infrastructure that is expected to remain in place includes cable and scour protection and piles. With regard to piles, however, they will be cut below the sea bed; therefore, the sea bed surface is expected to return to its natural state.

466. Given that it is currently unknown which structures will be removed or remain *in situ* at the point of decommissioning, permanent habitat loss has been assumed in the majority of cases. The only exception being where the Applicant has made the commitment to removal on decommissioning (namely any external cable protection that is used in the MCZ – see **Section 9.6.2.3**). In this instance, the loss is assessed as long term i.e. for the lifetime of the projects only.

467. For SEP and DEP, 1.159km^2 of permanent habitat loss from the foundations and associated scour protection and external cable protection is expected (**Section 9.6.2.2**) from SEP and DEP. There would be up to 1,800m^2 of long term habitat loss from external cable protection in the MCZ, which will be removed on decommissioning. Habitat loss will be widely dispersed throughout the SEP and

DEP wind farm sites and the cable corridors. The area of habitat loss is small compared to some other recent OWFs in the southern North Sea. Hornsea Project Three, for example, will result in a permanent loss of up to 4.2km^2 of habitat.

468. It is not possible to say with certainty what percentage of the cumulative habitat loss across different projects will affect particular fish and shellfish ecology receptors, such as a spawning ground or nursery area. For example, it is highly unlikely that the 1.159km^2 of permanent habitat loss from SEP and DEP will all be in sandeel habitat or herring spawning grounds.

469. The fish and shellfish species in the region use comparatively large areas for spawning and nursery grounds, and for foraging. Whilst it is recognised that across the southern North Sea there will be additive effects with respect to loss of spawning grounds or other important fish and shellfish habitat, the overall combined magnitude of these will be negligible relative to the scale of the fish and shellfish receptors potentially affected. Therefore, impacts as a result of habitat loss are expected to be minimal, and the fish and shellfish species receptors are considered to be of low sensitivity to this pathway of effect. With regard to sandeel and herring, given their dependence on specific substrates and, therefore, more limited habitat availability, they are considered to be of medium sensitivity.

470. With the above in mind, the cumulative impact of habitat loss of SEP and DEP is considered to be of **minor adverse** significance.

9.7.3.3 Cumulative Impact 3: Introduction of Foundations, Scour Protection and Hard Substrate

471. The introduction of hard substrate from SEP and DEP, together with other offshore projects could result in cumulative impacts on fish and shellfish species in terms of changes to the species assemblage.

472. As with the loss of habitat, the introduction of hard substrate would occur in a dispersed manner throughout the SEP and DEP wind farm sites and cable corridors, rather than being concentrated in one main area. Taking this into account, together with the distance to other projects as identified in **Table 9-30**, the magnitude of effect is considered to be low.

473. As described in **Section 9.6.2.4,** post-construction monitoring surveys undertaken at operational wind farms suggest that changes in fish and shellfish community structures associated with the introduction of hard substrate would be highly localised and limited to the immediate vicinity of the foundations. With this in mind, the sensitivity of the fish and shellfish species is considered to be low, resulting in a cumulative impact of **minor adverse** significance.

9.7.3.4 Cumulative Impact 4: EMF

474. As outlined for SEP or DEP in isolation, both elasmobranch and migratory species are considered to be receptors of medium sensitivity to EMF. Based on the anticipated low magnitude of effect, this was assessed as resulting in a minor adverse impact for these species. However, both elasmobranchs and migratory fish have a wide distribution range in the North Sea and, given the overall wide ranging and/or migratory behaviour of both elasmobranch and migratory fish species, the cumulative impacts of EMF from SEP and DEP with other relevant projects is overall considered to be **negligible** and therefore not significant for these species. No

cumulative impacts are predicted for other fish species and shellfish as a result of the localised nature of the predicted impacts and their low sensitivity.

9.7.3.5 Cumulative Impact 5: Decommissioning Impacts

475. As outlined for the project alone (**Section 9.6.3**), it is anticipated that the effects on fish and shellfish receptors during the decommissioning phase in a cumulative context would be comparable to those identified for construction.

476. The sensitivity of receptors during decommissioning is assumed to be the same as for the construction phase. The magnitude of effect is considered to be no greater than for construction. Therefore, it is anticipated that any cumulative impacts during the decommissioning phase would be no greater than those assessed for the construction phase.

9.8 Transboundary Impacts

477. The distribution of the populations of fish and shellfish species assessed are independent of national geographical boundaries. The alone assessment for SEP and DEP has been undertaken taking into account the distribution of fish stocks and populations irrespective of national jurisdictions. In addition, the alone assessments for SEP and DEP have demonstrated that the spatial extent of impacts from the construction, operation and decommissioning of SEP and DEP do not stretch beyond UK waters and have been assessed as not significant in all cases.

478. It should also be noted that the anticipated impacts on fish and shellfish ecology are generally localised in nature, being restricted to the project boundaries and surrounding area. SEP and DEP are a minimum of 187km from any international territory boundary.

9.9 Inter-relationships

479. The construction, operation and decommissioning phases of SEP and DEP could cause a range of effects on fish and shellfish ecology. The magnitude of these effects has been assessed using expert assessment, drawing from a wide science base.

480. These effects not only have the potential to directly affect the identified fish and shellfish receptors but may also manifest as impacts upon receptors other than those considered within the context of fish and shellfish ecology. All of the identified inter-relationships have been considered in the relevant chapters, as indicated in **Table 9-31**.

Table 9-31: Chapter Topic Inter-Relationships

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Construction			
Increased suspended sediments and sediment re-deposition	**Chapter 6 Marine Geology, Oceanography and Physical Processes**	**Section 9.6.1.2**	Changes in SSCs and associated sediment re-deposition, described in Chapter 6, could have potential

Topic and description	Related chapter	Where addressed in this chapter	Rationale
			impacts on fish and shellfish ecology.
Re-mobilisation of contaminated sediment	Chapter 7 Marine Water and Sediment Quality	Section 9.6.1.3	Re-mobilisation of contaminated sediment, described in Chapter 7, could have potential impacts on fish and shellfish ecology.
Benthic ecology	Chapter 8 Benthic Ecology	Section 9.6.1.1	The benthic environment provides habitat and prey species for fish and shellfish receptors. Therefore, impacts on benthic ecology can have subsequent impacts on fish and shellfish.
Prey species	Chapter 10 Marine Mammal Ecology Chapter 11 Offshore Ornithology	Throughout Section 9.6	Potential impacts on fish and shellfish could affect the prey resource for marine mammals and birds.
Commercially exploited species	Chapter 12 Commercial Fisheries	Section 9.6.1.7	Changes to the fish and shellfish resource could affect commercial fisheries. Changes to fishing activity could affect fish and shellfish ecology.
Operation			
Increased suspended sediments and sediment re-deposition	As above	Section 9.6.2.5	As above
Re-mobilisation of contaminated sediment	As above	Section 9.6.2.6	As above
Benthic ecology	As above	Sections 9.6.2.1 to 9.6.2.3	As above
Prey species	As above	Throughout Section 9.6.2	As above
Commercially exploited species	As above	Section 9.6.2.9 and throughout Section 9.6.2	As above
Decommissioning			
As for construction			

9.10 Interactions

481. 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 9-32**. This provides a screening tool for which impacts have the potential to interact. **Table 9-33** then provides an assessment for each receptor (or receptor group) as related to these impacts.

482. The impacts are first 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.

483. None of the potential interactions identified with respect to fish and shellfish ecology are expected to result in a synergistic or greater impact than those assessed in **Section 9.6**.

Table 9-32: Interactions Between Impacts – Screening

Potential Interaction between Impacts									
Construction									
	Impact 1 Temporary habitat loss / disturbance	Impact 2 Increased suspended sediments and sediment re-deposition	Impact 3 Re-mobilisation of contaminated sediments	Impact 4 Underwater noise during foundation piling	Impact 5 Underwater noise from other activities	Impact 6 Underwater noise during UXO clearance	Impact 7 Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works	-	-
Impact 1 Temporary habitat loss / disturbance	-	Yes	No	No	No	No	No	-	-
Impact 2 Increased suspended sediments and sediment re-deposition	Yes	-	No	No	No	No	No	-	-
Impact 3 Re-mobilisation of contaminated sediments	No	No	-	No	No	No	No	-	-
Impact 4 Underwater noise	No	No	No	-	Yes	Yes	No	-	-

Potential Interaction between Impacts									
during foundation piling									
Impact 5 Underwater noise from other activities	No	No	No	Yes	-	Yes	No	-	-
Impact 6 Underwater noise during UXO clearance	No	No	No	Yes	Yes	-	No	-	-
Impact 7 Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works	No	No	No	No	No	No	-	-	-
Operation									
	Impact 1 Temporary habitat loss / disturbance	Impact 2 Permanent habitat loss	Impact 3 Long term habitat loss	Impact 4 Introduction of wind turbine foundations, scour protection and hard substrate	Impact 5 Increased suspended sediments and sediment re-deposition	Impact 6 Re-mobilisation of contaminated sediments	Impact 7 Underwater noise	Impact 8 EMF	Impact 9 Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works
Impact 1 Temporary habitat loss / disturbance	-	Yes	Yes	Yes	Yes	No	No	No	No

Potential Interaction between Impacts									
Impact 2 Permanent habitat loss	Yes	-	Yes	Yes	Yes	No	No	No	Yes
Impact 3 Long term habitat loss	Yes	Yes	-	Yes	Yes	No	No	No	Yes
Impact 4 Introduction of wind turbine foundations, scour protection and hard substrate	Yes	Yes	Yes	-	No	No	No	No	No
Impact 5 Increased suspended sediments and sediment re-deposition	Yes	Yes	Yes	No	-	No	No	No	No
Impact 6 Re-mobilisation of contaminated sediments	No	No	No	No	No	-	No	No	No
Impact 7 Underwater noise	No	No	No	No	No	No	-	No	No
Impact 8 EMF	No	No	No	No	No	No	No	-	No
Impact 9 Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works	No	Yes	Yes	No	No	No	No	No	-
Decommissioning									

Potential Interaction between Impacts									
It is anticipated that the decommissioning impacts will be similar in nature to those of construction, with the key impacts including: • Impact 1: Temporary habitat loss / disturbance; • Impact 2: Increased suspended sediments and sediment re-deposition; and • Impact 5: Underwater noise.									
	Impact 1 Temporary habitat loss / disturbance	Impact 2 Increased suspended sediments and sediment re-deposition	Impact 5 Underwater noise	-	-	-	-	-	-
Impact 1 Temporary habitat loss / disturbance	-	Yes	No	-	-	-	-	-	-
Impact 2 Increased suspended sediments and sediment re-deposition	Yes	-	No	-	-	-	-	-	-
Impact 5 Underwater noise	No	No	-	-	-	-	-	-	-

Table 9-33: Interactions Between Impacts – Phase and Lifetime Assessment

	Highest significance level				
Receptor	**Construction**	**Operation**	**Decommissioning**	**Phase assessment**	**Lifetime assessment**
Fish and shellfish species	Minor adverse	Minor adverse	Minor adverse	No greater than individually assessed impact *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, therefore there is limited potential for interaction with habitat disturbance from sea bed preparation, installation of cables etc. and associated effects (increased SSC). The effects resulting from habitat disturbance will be localised, temporary and episodic with limited potential for interaction. Any reduction in fishing effort would be beneficial, although likely to be of low magnitude. It is therefore considered that these impacts would not interact to change the significance level overall. *Operation* Disturbance to or loss of habitat will be confined to the immediate footprint of the infrastructure/activities. The magnitude of effect is, in all cases,	No greater than individually assessed impact The greatest magnitude of effect will be the spatial footprint of construction noise (i.e. UXO clearance and piling) and the habitat disturbance from sea bed preparation, installation of cables etc. Once this disturbance impact has ceased all further impacts during construction, operation and decommissioning will be small scale, 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 interact to change the significance level overall.

	Highest significance level				
Receptor	**Construction**	**Operation**	**Decommissioning**	**Phase assessment**	**Lifetime assessment**
				low to negligible. EMF and noise effects will also be locally confined and again the magnitude of effect is low to negligible and relates to largely the same spatial footprint. It is therefore considered that none of these impacts would interact to increase the significance level overall. *Decommissioning* It is anticipated that the decommissioning impacts will be similar in nature to those of construction.	

9.11 Potential Monitoring Requirements

484. As described in this chapter, a large amount of geophysical, benthic and fish ecology monitoring data is available from the existing SOW and DOW, much of which will be highly relevant to SEP and DEP given their close proximity and the similarity of the developments. The **Offshore IPMP** (document reference 9.5) includes provision for monitoring of potential changes in sandeel habitat suitability.

485. Monitoring requirements are described in the **Offshore IPMP** (document reference 9.5) submitted alongside the DCO application, which will be further developed and agreed with stakeholders prior to construction, taking account of the final detailed design of SEP and DEP.

9.12 Assessment Summary

486. Numerous literature and data sources have been used to determine and characterise the fish and shellfish species and populations that may be impacted by SEP and DEP. This has included extensive site specific geophysical and benthic surveys and an associated habitat mapping process, as well as historical surveys of the operational SOW and DOW.

487. The fish and shellfish ecology receptors identified include a number of species of interest due to their ecological, commercial and/or conservation value, for example sandeel, herring, edible crab, lobster and European eel.

488. The magnitude of effects identified and the sensitivity of the receptors to each effect has been assessed drawing from a wide science base, including project-specific surveys, underwater noise modelling and other assessments from the inter-related chapters of the ES.

489. The majority of the DEP wind farm site (particularly the DEP North array area) were identified as being preferred sandeel habitat as assessed through comparison of sediment fractional composition. Whilst the majority of SEP wind farm site were assessed as 'Marginal' or 'Unsuitable' for sandeel (**Figure 9.4**). The assessment of potential temporary habitat loss / disturbance impacts on sandeel have been assessed in **Section 9.6.1.1** and conclude that the residual impact would be of **minor adverse** significance

490. With regards to herring, the higher gravel content (with very little mud) of the SEP wind farm site and areas of the export cable corridor indicate that these areas are potentially suitable for herring spawning. However, the existence of potentially suitable spawning ground does not necessarily mean it is used as a spawning ground which is supported by the historic site surveys at the existing wind farms which concluded that herring spawning did not occur. Within the DEP wind farm site, most stations are classified as being 'Unsuitable' for herring spawning. The assessment of potential temporary habitat loss / disturbance impacts concluded that the residual impact would be of **minor adverse** significance.

491. Herring are also sensitive to underwater noise impacts of which the key source is piling. Potential impacts were assessed based on a worst-case sequential piling scenario for SEP and DEP which generally resulted in small scale increases in impact ranges for the criteria considered in the assessment. For example, an

increase in the impact range of up to 1.2km (from 3.3 to 4.5km for fish with a swim bladder used in hearing - i.e. herring) for mortality / potential mortal injury impacts (207dB SEL_{cum}) compared to a single piling scenario (i.e. SEP or DEP in isolation) was determined from the underwater noise modelling. However, since SEP and DEP are approximately 10km away there would be no overlap in these areas. Potential TTS and behavioural impacts have also been considered in the underwater noise modelling and assessment. Overall, the impact assessment concluded that impacts would be of **minor adverse** significance.

492. The assessment has established that there will be some **minor adverse** residual impacts during the construction, operation and decommissioning phases of SEP and DEP. Impacts are generally localised in nature, being restricted to the project boundaries and surrounding area.

493. A summary of the impact assessment for fish and shellfish ecology is provided in **Table 9-34**.

Table 9-34: Summary of Potential Impacts on Fish and Shellfish Ecology

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation[11]	Residual impact	Cumulative residual impact
Construction							
Impact 1 Temporary habitat loss / disturbance	Herring and sandeel	Medium	Negligible	Minor adverse	n/a	Minor adverse	n/a
	Shellfish	Medium					
	Elasmobranchs	Low		Negligible adverse		Negligible adverse	
	Other finfish species	Low					
Impact 2 Increased suspended sediments and sediment re-deposition	Herring and sandeel	Medium	Low	Minor adverse	n/a	Minor adverse	
	Other fin fish species	Low					
Impact 3 Re-mobilisation of contaminated sediments	All fish and shellfish species	Low	Negligible	Negligible adverse	n/a	Negligible adverse	
Impact 4A Underwater noise during foundation piling – Mortality and recoverable injury	Fish with no swim bladder or other gas chamber						
	Dab Elasmobranchs River and sea lamprey Lesser weever Dragonet	Low	Low	Minor adverse	n/a	Minor adverse	Negligible

[11] Note that embedded mitigation (as described in **Section 9.3.3**) is already incorporated into this assessment.

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation[11]	Residual impact	Cumulative residual impact
	Sandeels	Medium					
	Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume						
	Sea trout Smelt	Medium	Low	Minor adverse	n/a	Minor adverse	Negligible
	Gobies	Low					
	Fish in which hearing involves a swim bladder or other gas volume						
	Herring Sprat Whiting European eel Allis and twaite shad	Medium	Low	Minor adverse	n/a	Minor adverse	Negligible
	Eggs and larvae All fish and shellfish	Medium	Low	Minor adverse	n/a	Minor adverse	Negligible
Impact 4B Underwater noise during foundation piling – TTS and behavioural	Fish with no swim bladder or other gas chamber						
	Elasmobranchs	Low	Low	Minor adverse	n/a	Minor adverse	Negligible
	Sandeels	Medium					Negligible
	Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume						
	Sea trout Smelt	Low	Low	Minor adverse	n/a	Minor adverse	Negligible
	Gobies	Medium					Negligible
	Fish in which hearing involves a swim bladder or other gas volume						

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation[11]	Residual impact	Cumulative residual impact
	Herring Sprat Whiting Cod European eel Allis and twaite shad	Medium	Low	Minor adverse	n/a	Minor adverse	Negligible
	Eggs and larvae	Medium	Low	Minor adverse	n/a	Minor adverse	Negligible
	Shellfish	Medium	Low	Minor adverse	n/a	Minor adverse	Negligible
Impact 5 Underwater noise from other activities	All fish and shellfish	Low	Low	Minor adverse	n/a	Minor adverse	Minor adverse
Impact 6 Underwater noise during UXO clearance	All fish and shellfish	Medium	Low	Minor adverse	n/a	Minor adverse	Minor adverse
Impact 7 Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works	Commercial exploited fish species	Low	Low	Minor beneficial significance	n/a	Minor beneficial significance	n/a
Operation							
Impact 1 Temporary habitat loss	Fish and shellfish receptors	Low	Negligible	Negligible adverse	n/a	Negligible adverse	n/a
Impact 2 Permanent habitat loss	Fish and shellfish receptors	Low	Low	Minor adverse	n/a	Minor adverse	
Impact 3 Long term habitat loss	Fish and shellfish receptors	Low	Low	Minor adverse	n/a	Minor adverse	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation[11]	Residual impact	Cumulative residual impact
Impact 4 Introduction of wind turbine foundations, scour protection and hard substrate	Other finfish species	Low	Low	Minor adverse	n/a	Minor adverse	Minor adverse
	Shellfish, herring and sandeels	Medium					
Impact 5 Increased suspended sediments and sediment re-deposition	All fish and shellfish species	Low	Negligible	Negligible adverse	n/a	Negligible adverse	n/a
Impact 6 Re-mobilisation of contaminated sediments	All fish and shellfish species	Negligible	Negligible	Negligible adverse	n/a	Negligible adverse	n/a
Impact 7 Underwater noise	All fish and shellfish species	Low	Low	Minor adverse	n/a	Minor adverse	Minor adverse
Impact 8 EMF	All fish and shellfish species	Low	Low	Minor adverse	n/a	Minor adverse	Negligible
Impact 9 Impacts on commercially exploited species associated with displacement of fishing from the area of activity / works	Commercial exploited fish species	Low	Low	Minor beneficial significance	n/a	Minor beneficial significance	n/a
Decommissioning							
It is anticipated that the decommissioning impacts will be similar in nature to those of construction, with the key impacts including: • Impact 1: Temporary habitat loss / disturbance; • Impact 2: Increased suspended sediments and sediment re-deposition; and • Impact 5: Underwater noise from other activities.							

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Additional mitigation[11]	Residual impact	Cumulative residual impact
Impact 1 Temporary habitat loss / disturbance	All fish and shellfish species	Equal to construction phase	No greater and, in all probability less than construction phase	No significant impacts (minor adverse or lower)	n/a	Not significant impacts (minor adverse or lower)	Not significant impacts (minor adverse or lower)
Impact 2 Increased suspended sediments and sediment re-deposition	All fish and shellfish species	Equal to construction phase	No greater and, in all probability less than construction phase	No significant impacts (minor adverse or lower)	n/a	Not significant impacts (minor adverse or lower)	Not significant impacts (minor adverse or lower)
Impact 5 Underwater noise from other activities	All fish and shellfish species	Equal to construction phase	No greater and, in all probability less than construction phase	No significant impacts (minor adverse or lower)	n/a	Not significant impacts (minor adverse or lower)	Not significant impacts (minor adverse or lower)

9.13 References

ABPmer (2012). East Anglia Offshore Wind Zonal Environmental Appraisal Report. Appendix G – Physical Processes Baseline and References.
AQUIND Limited (2019) AQUIND Interconnector Environmental Statement
Aires, C., González-Irusta, J.M., Watret, R. (2014). Updating Fisheries Sensitivity Maps in British Waters. Scottish Marine and Freshwater Science Vol 5 No 10. Edinburgh: Scottish Government, 88pp. DOI: 10.7489/1555-1.
Aitken, A. (2018). North Western Inshore Fisheries Conservation Authority. Brown Crab and European Lobster Fisheries in the NWIFCA District. The Use of Returns Data to Inform Management. Available online at: https://www.nw-ifca.gov.uk/app/uploads/Agenda-Item-10-Annex-A-TSB-Annex-A-Crab-and-Lobster-Report-Use-of-Landings-Data-08-01-18.pdf (accessed on 15/01/21).
Andersson, M. (2011). OWFs. Ecological Effects of Noise and Habitat Alteration on Fish. PhD Thesis, Department of Zoology, Stockholm University.
Beatrice OWF Ltd (2018). Beatrice OWF Piling Strategy Implementation Report. Available online at: http://marine.gov.scot/sites/default/files/lf000005-rep-2397_bowlpilingstrategyimplementationreport_rev1_redacted.pdf (accessed 07/02/21).
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
BioConsult (2006). Hydroacoustic Monitoring of Fish Communities at OWFs, Horns Rev OWF, Annual Report 2005.
Birchenough, Silvana & Degraer, Steven. (2020). Introduction Science in support of ecologically sound decommissioning strategies for offshore man-made structures: taking stock of current knowledge and considering future challenges.
Bird, C., Burt, G. J., Hampton, N., McCully Phillips, S. R., and Ellis, J. R. 2020. Fifty years of tagging skates (Rajidae): using mark-recapture data to evaluate stock units. Journal of the Marine Biological Association of the United Kingdom, 100: 121–131. Cambridge University Press. [redacted]
Birklund, J. and Wijsman, J. W. M. (2005). Aggregate Extraction: A Review on the Effects on Ecological Functions. Report Z3297/10 SAWDPIT Fifth Framework Project no EVK3-CT-2001-00056. Available online at [redacted] (accessed on 25/01/21).
Boles, L.C. and Lohmann, K.J. (2003). True navigation and magnetic maps in spiny lobsters. Nature 421, pp. 60-63.

Bolle LJ, de Jong CAF, Bierman SM, van Beek PJG, van Keeken OA, Wessels PW, van Damme CJG, Winter HV, de Haan D, Dekeling RPA (2012). Common sole larvae survive high levels of pile-driving sound in controlled exposure experiments. PLoS ONE 7: e33052.
Boyle, G and New, P. (2018). ORJIP Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options. Final report – June 2018. The Carbon Trust. United Kingdom. 247 pp.
Blom, E., Kvarnemo, C., Dekhla, I., Schöld, S., Andersson, M., Svensson, O. and Amorim, M. (2019). Continuous but not intermittent noise has a negative impact on mating success in a marine fish with paternal care. Scientific Reports, 9(1).
Blyth-Skyrme, R. (2010). Options and opportunities for marine fisheries mitigation associated with wind farms. Final report for Collaborative Offshore Wind Research into the Environment contract FISHMITIG09. COWRIE Ltd, London.
Bodznick, D. and Preston, D.G.1983. Physiological characterization of electroreceptors in the lampreys Ichthyomyzon uniscuspis and Petromyzon marinus. Journal of Comparative Physiology 152, pp. 209-217.
Brown and May Marine (2009). Sheringham Shoal OWF. Pre-Construction Herring Spawning Survey 21st September to 8th December 2009. Final Report.
Brown and May Marine (2010). Sheringham Shoal OWF. Post-Construction Herring Spawning Survey 26th September to 23rd November 2010. Final Report.
Brown and May Marine (2013) Sheringham Shoal OWF. Post-Cable Installation Elasmobranch Survey. August 2013. Interim Report
Bruintjes R, Radford AN. (2014). Chronic playback of boat noise does not impact hatching success or post-hatching larval growth and survival in a cichlid fish. PeerJ 2:e594 [redacted].
Casper, B.M., M.B. Halvorsen, and A.N. Popper. (2012). Are sharks even bothered by a noisy environment? In: Popper, A.N. and A.D. Hawkins, eds. The effects of noise on aquatic life. New York: Springer Science + Business Media, LLC. Pp. 93-98.
Cefas (2019). Salmon Stocks and Fisheries in England and Wales, 2019. Preliminary assessment prepared for ICES, March 2020. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/907284/SalmonReport-2019-summary.pdf
Cefas, Department of Environment and Regulatory Affairs, Department of Trade and Industry, and Marine Consents and Environment Unit (2004). OWFs: Guidance note for environmental impact assessment in respect of FEPA and CPA requirements Version 2, Marine Consents Environment Unit, pp. 48.
Cefas (2009). Strategic review of OWF monitoring data associated with FEPA Licence Conditions. Fish. Contract: ME1117, Version 1.5.Available online at: https://tethys.pnnl.gov/sites/default/files/publications/Walker-2009-Fish.pdf
Cefas (2010). Strategic review of OWF monitoring data associated with FEPA Licence Conditions. Fish. Contract: ME1117, Version 1.5.

Cefas (2011). Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Contract report: ME5403, September 2011.
Chapman, C.J., (2004). Northern North Sea Shellfish and Fisheries. Strategic Environmental Assessment – SEA5. Technical Report for Department of Trade & Industry. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/197384/SEA5_TR_Fish_Chapman.pdf (accessed on 15/01/21).
Cheong, S.H., Wang, L., Lepper, P., and Robinson, S. (2020). FINAL REPORT: Characterisation of Acoustic Fields Generated by UXO Removal Phase 2. BEIS Offshore Energy SEA Sub-Contract OESEA-19-107
CIEEM (2018). Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine. Chartered Institute of Ecology and Environmental Management, Winchester.
Coolen, Joop & Boon, Arjen & Crooijmans, Richard & Pelt, Hilde & Kleissen, Frank & Gerla, Daan & Beermann, Jan & Birchenough, Silvana & Becking, L. & Luttikhuizen, Pieternella. (2020). Marine stepping-stones: Connectivity of Mytilus edulis populations between offshore energy installations. Molecular Ecology. 29. 686 - 703. 10.1111/mec.15364.
Coull, K.A., Johnstone, R., and S.I. Rogers. (1998). Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd., v + 58 pp.
Dahl, P. H., De Jong, C., & Popper, A. N. (2015). The underwater sound field from impact pile driving and its potential effects on marine life. Acoustics Today, 11, 18–25.
De Gieter, M., Leermakers, M., Van Ryssen, R., Noyen, J., Goeyens, L. and Baeyens, W., (2002). Total and Toxic Arsenic Levels in North Sea Fish. Archives of Environmental Contamination and Toxicology, 43(4), pp.406-417.
Dekeling, R.P.A., Tasker, M.L., Van der Graaf, A.J., Ainslie, M.A, Andersson, M.H., André, M., Borsani, J.F., Brensing, K., Castellote, M., Cronin, D., Dalen, J., Folegot, T., Leaper, R., Pajala, J., Redman, P., Robinson, S.P., Sigray, P., Sutton, G., Thomsen, F., Werner, S., Wittekind, D., Young, J.V., (2014). Monitoring Guidance for Underwater Noise in European Seas, Part II: Monitoring Guidance Specifications, JRC Scientific and Policy Report EUR 26555 EN, Publications Office of the European Union, Luxembourg, 2014, doi: 10.2788/27158.
Department for Environment, Food and Rural Affairs (DEFRA) (2010). Eel management plans for the United Kingdom. Overview for England and Wales, pp. 38.
Dudgeon Offshore Wind Limited (2009). Dudgeon OWF Environmental Statement.
DOWL (2016). Dudgeon OWF - Piling Summary and Lessons Learned. August 2016.
Edwards, B., Brooker, A., Workman, R., Parvin, S. and Nedwell, J. (2007). Subsea operational noise assessment at the Barrow OWF site. Subacoustech Report.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M. (2012). Spawning and nursery grounds of selected fish species in UK waters. Science Series Technical Report. Cefas, Lowestoft, 147, pp. 56.

Engel-Sørensen, K., and Skyt, P. (2001). Evaluation of the Effect of Sediment Spill from OWF Construction on Marine Fish. Report to SEAS, Denmark, pp. 18.

Envision (2021). Benthic Habitat Mapping for Dudgeon and Sheringham Extension Projects Geophysical Data Interpretation & Habitat Mapping.

European Commission (2018). Guidance on Energy Transmission Infrastructure and EU nature legislation.

European Commission (2020). Guidance document on wind energy developments and EU nature legislation.

Folk, R. L., (1954). The distinction between grain size and mineral composition in sedimentary rock nomenclature, Jour. Geology 62, 344–359.

Formicki, K. Sadowski, M. Tanski, A. Korzelecka-Orkisz, A. and Winnicki, A. 2004. Behaviour of trout (Salmo trutta L.) larvae and fry in a constant magnetic field. Journal of Applied Ichthyology 20, pp. 290-294.

Fowler, A. M., Jørgensen, A.-M., Coolen, J. W. P., Jones, D. O. B., Svendsen, J. C., Brabant, R., Rumes, B., and Degraer, S. (2020). The ecology of infrastructure decommissioning in the North Sea: what we need to know and how to achieve it. – ICES Journal of Marine Science, 77: 1109–1126.

Fugro (2020a). Sheringham Shoal Extension Habitat Report. Dudgeon Extension Project. Offshore Norfolk. Volume 2 Habitat Assessment Report. Survey Period: 10 to 19 August 2020. 200270 R 002 01 15 October 2020. Draft.

Fugro (2020b). Dudgeon Extension Habitat Report. Sheringham Extension Project. Offshore Norfolk. Volume 3 Habitat Assessment Report. Survey Period: 10 to 19 August 2020. 200270 R 003 01 15 October 2020. Draft.

Furness, R. W. (1990). A preliminary assessment of the quantities of Shetland sandeels taken by seabirds, seals, predatory fish and the industrial fishery in 1981–83. Ibis, 132: 205-217.

Gibson-Hall, E., Jackson, A. & Marshall, C. (2020). Palinurus elephas European spiny lobster. 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. [cited 26-01-2021]. Available online at: [redacted]

Gill, A. B., Gloyne-Philips, I., Kimber, J., and Sigray, P. 2014. Marine Renewable Energy, Electromagnetic (EM) Fields and EM-Sensitive Animals. In M. A. Shields and A. I. L. Payne (Eds.), Marine Renewable Energy Technology and Environmental Interactions (pp. 61-79). Dordrecht: Springer Netherlands. https://tethys.pnnl.gov/publications /marine-renewable-energy-electromagnetic-em-fields -em-sensitive-animals

Gill, A.B., Bartlett, M. and Thomsen, F., 2012. Potential interactions between diadromous fishes of UK conservation importance and the electromagnetic fields and subsea noise from marine renewable energy developments. Journal of Fish Biology, 81(2), pp.664-695.
Gill, Andrew B. and Desender, Marieke. 2020 State of the Science Report, Chapter 5: Risk to Animals from Electromagnetic Fields Emitted by Electric Cables and Marine Renewable Energy Devices. United States: N. p., 2020. Web. doi:10.2172/1633088.
Green, B., Gardner, C., Hochmuth, J. and Linnane, A. (2014). Environmental effects on fished lobsters and crabs. Reviews in Fish Biology and Fisheries, 24(2), pp.613-638.
Gill, A.B. Gloyne-Phillips, I. Neal, K.J. and Kimber, J.A. (2005). The Potential Effects of Electromagnetic Fields generated by Sub-Sea Power Cables associated with OWF Development on Electrically and Magnetically Sensitive Marine Organism- a Review. COWRI.E. 1.5 Electromagnetic Fields Review. Final Report. COWRIE-EM FIELD 2-06-2004
Greenstreet, S. P. R., Holland,G. J.,Guirey,E.J. Armstrong, E., Fraser,H.M. and Gibb, I. M. (2010). Combining hydroacoustic sea bed survey and grab sampling techniques to assess “local” sandeel population abundance ICES J. Mar. Sci. (2010) 67(5): 971-984.
Greenstreet, S. P. R., McMillan, J. A., and Armstrong, F. (1998). Seasonal variation in the importance of pelagic fish in the diet of piscivorous fish in the Moray Firth, NE Scotland: a response to variation in prey abundance? ICES Journal of Marine Science, 55.
Haig, J.A., Rayner, G., Akritopoulou, E., & Kaiser, M.J. (2015). Fecundity of Cancer pagurus in Welsh waters, a comparison with published literature. Fisheries & Conservation Science report No 49, Bangor University. Pp.24.
Hammond, P. S., Hall, A. J., and Prime, J. H. (1994). The diet of grey seals around Orkney and other island and mainland sites in northeastern Scotland. Journal of Applied Ecology, 31
Halvorsen, M., Zeddies, D., Ellison, W., Chicoine, D., Popper, A. (2012). Effects of mid-frequency active sonar on hearing in fish. The Journal of the Acoustical Society of America, vol. 131, pp 599.
Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Østensen, Ø., Haugland, E.K., Fonn, M., Høines, Å., & Misund, O.A. (2003). Reaction of sandeel to seismic shooting: a field experiment and fishery statistics study.
Hawkins A D, Roberts L, Cheesman S (2014). Responses of free-living coastal pelagic fish to impulsive sounds. J. Acoust. Soc. Am. 135: 3101-3116.
Hawkins, A.D. and Popper, A.N. (2016). A sound approach to assessing the impact of underwater noise on fish and invertebrates. ICES Journal of Marine Science, doi:10.1093/icesjms/fsw205.
Hawkins, A., Johnson, C. and Popper, A., (2020). How to set sound exposure criteria for fishes. The Journal of the Acoustical Society of America, 147(3), pp.1762-1777.

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.
HM Government (2011). UK Marine Policy Statement. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69322/pb3654-marine-policy-statement-110316.pdf
HM Government (2014). East Inshore and East Offshore Marine Plans. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/312496/east-plan.pdf
HOW03 (2018). Hornsea Three OWF Environmental Statement
Hutchison, Z., Sigray, P., He, H., Gill, A., 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 (OCS Study BOEM 2018-003). Report by University of Rhode Island for Bureau of Ocean Energy Management, U.S. Department of Interior, Sterling, VA
Hutchison, Z. L., Gill, A. B., Sigray, P., He, H., and King, J. W. 2020. Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species. Scientific Reports, 10: 1–15. Nature Research. [redacted]
Hvidt, C.B. Kaustrup, M. Leonhard, S.B. and Pedersen, J. (2005). Fish along the cable trace. Nysted OWF. Final Report 2004.
Jensen, Henrik; Anna Rindorf, Peter J. Wright, Henrik Mosegaard (2011). Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery, ICES Journal of Marine Science, Volume 68, Issue 1, January 2011, Pages 43–51, [redacted]
Joint Nature Conservation Committee (JNCC) (2020). Atlantic salmon Salmo salar. Special Areas of Conservation Species List. Available at: https://sac.jncc.gov.uk/species/S1106/.
Kastelein, R.A., Jennings, N., Kommeren, A., Helder-Hoek, L. and Schop, J (2017). Acoustic dose-behavioral response relationship in sea bass (Dicentrarchus labrax) exposed to playbacks of pile driving sounds. Marine Environmental Research 130, 315-324. [DOI: [redacted]
Kelly, F. and King, J. (2001). A review of the ecology and distribution of three lamprey species, Lampetra fluviatilis (L.), Lampetra planeri (Bloch) and Petromyzon marinus (L.): a context for conservation and biodiversity considerations in Ireland. In Biology and Environment: Proceedings of the Royal Irish Academy, pp. 165-185.
Kerby, T., Cheung, W.W.L., William, van Oosterhout, C. and Engelhard, G. (2013). Wondering about wandering whiting: Distribution of North Sea whiting between the 1920s and 2000s. Fisheries Research. 145. 54–65. 10.
Leonhard, S. and Pedersen, J. (2006). Benthic Communities at Horns Rev Before, During and After Construction of Horns Rev OWF.

Latto, P. L. Reach, I.S. Alexander, D. Armstrong, S. Backstrom, J. Beagley E. Murphy,K. Piper, R. and Seiderer, L.J. (2013) Screening spatial interactions between marine aggregate application areas and sandeel habitat. A Method Statement produced for BMAPA
Leonhard, S., Stenberg, C., Stottrup, J. Eds: (2011). Effect of the Horns Rev 1 OWF on Fish Communities. Follow-up Seven Years after Construction. DTU Aqua, Orbicon, DHI, NaturFocus. Report commissioned by The Environmental Group through contract with Vattenfall Vindkraft A/S.
Lindeboom, H.J. Kouwenhoven, H.J. Bergman, M.J.N. Bouma, S. Brasseur, S. Daan, R.Fijn, R.C. de Haan, D. Dirksen, S. van Hal, R. Lambers, R.H.R. ter Hofsted, R. Krijgsveld, K.L. Leopold, M. and Scheidat, M. (2011). Short-term ecological effects of an OWF in the Dutch coastal zone: a compilation. Environ. Res. Lett. 6.
Linley, E.A.S., Wilding, T.A., Black, K., Hawkins, A.J.S. and Mangi S. (2007). Review of the Reef Effects of OWF 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.
Marine Management Organisation (2014). Review of post-consent OWF monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, pp 194. MMO Project No: 1031. ISBN: 978-1-909452-24-4. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/317787/1031.pdf
Marine Management Organisation (2020). Landings data, 2009- 2019 within ICES rectangles 34F0, 34F1, 35F0 and 35F1.
MarineSpace Ltd, ABPmer Ltd, ERM Ltd, Fugro EMU Ltd and Marine Ecological Surveys Ltd, (2013). Environmental Effect Pathways between Marine Aggregate Application Areas and Atlantic Herring Potential Spawning Habitat: Regional Cumulative Impact Assessments. Version 1.0. A report for the British Marine Aggregates Producers Association.
McCully, S. R., Burt, G. J., Silva, J. F. and Ellis, J. R. (2013). Monitoring thornback ray movements and assessing stock levels. Centre for Environment, Fisheries and Aquaculture Science (Lowestoft), Fishery Science Partnership, Programme 35, 33 pp.
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.
Merchant, N. (2018). Continuous low frequency sound (ambient noise) in UK seas. UK Marine Online Assessment Tool, available at: [redacted]
Mesquita, C., Dobby, H., Graham,P. J., Jones, C.S., Fernandes, P.G. (2020). Abundance and spatial distribution of brown crab (Cancer pagurus) from fishery-independent dredge and trawl surveys in the North Sea, ICES Journal of Marine Science, fsaa105, [redacted]

Misund, O. (1994). "Swimming behaviour of fish schools in connection with capture by purse seine and pelagic trawl." Marine Fish Behaviour in Capture and, Abundance Estimation. Pp. 84-106.
Moore, A. and Riley, W.D. 2009. Magnetic particles associated with the lateral line of the European eel Anguilla anguilla. Journal of Fish Biology 74(7), pp. 1629-1634.
Moore, A. Freake, S.M. and Thomas, I.M. 1990. Magnetic particles in the lateral line of the Atlantic Salmon (Salmo salar L.). Philosophical Transactions: Biological Sciences 329(1252), pp. 11-15.
Mueller-Blenkle, C., McGregor, P., Gill, A., Anderson, M., Metcalfe, J., Bendall, V., Sigray, P., Wood, D., Thomsen, F. (2010). Effects of Pile-driving Noise on the Behaviour of Marine Fish. COWRIE Ref: Fish 06-08, Technical Report 31st March 2010.
Murchy, K. A., Davies, H., Shafer, H., Cox, K., Nikolich, K., Juanes, F., (2019). Impacts of noise on the behavior and physiology of marine invertebrates: A meta-analysis. Proceedings of Meetings on Acoustics 5ENAL 37 (1), 040002.
NBL (2019) Norfolk Boreas Limited Environmental Statement.
Neal, K.J. & Wilson, E. (2008). Cancer pagurus Edible crab. 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 online at: [redacted] accessed 25/01/21.
Nedelec S.L., Simpson S.D., Morley E.L., Nedelec B, Radford AN. (2015). Impacts of regular and random noise on the behaviour, growth and development of larval Atlantic cod (Gadus morhua). Proc. R. Soc. B 282: 20151943. [redacted].
Nedwell, J.R., Turnpenny, A.W.H., Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L., and Howell, D. (2007). A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise. Subacoustech Report No. 534R1231.
Nedwell, J. R., Parvin, S. J., Brooker, A, G., and Lambert, D. R., (2008). Modelling and measurement of underwater noise associated with the proposed Port of Southampton capital dredge and redevelopment of berths 201/202 and assessment of the disturbance to salmon. Subacoustech Report No. 805R0444 to Associated British Ports.
Normandeau Associates, Inc. (2012). Effects of Noise on Fish, Fisheries, and Invertebrates in the U.S. Atlantic and Arctic from Energy Industry Sound-Generating Activities. A Workshop Report for the U.S. Dept. of the Interior, Bureau of Ocean Energy Management. Contract # M11PC00031. 72 pp. plus Appendices.
Normandeau, E., Tricas, T. and Gill, A. (2011). Effects of EMF from undersea power cables on elasmobranchs and other marine species. U.S. Depart. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

National Marine Fisheries Service (NMFS) (2016). Technical guidance for assessing the effects of anthropogenic sound on marine mammals hearing: Underwater acoustic thresholds for onset of permanent and temporary threshold shifts. US Dep. Of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55.
Öhman, C. Sigray, P. and Westerberg, H. 2007. Offshore windmills and the effects of electromagnetic fields on fish Royal Swedish Academy of Science. Ambio 36(8), pp. 630-633.
OPSAR.(2012). Guidelines on Best Environmental Practice (BEP) in Cable Laying and Operation. OSPAR 12/22/1, Annex 14, EIHA 17/9/1, Annex 8. Revised in 2017.
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.
Pace Geotechnics (2020). UK Extension Project Cable Burial Risk Assessment Report No: PACE-EQU-C1105/RPT01.
Pawson, M. (1995) Biogeographical identification of English Channel fish and shellfish stocks. Fisheries Research Technical Report. MAFF Direct. Fisheries Research, Lowestoft, vol. 99, pp. 72.
Pawson, M.G. (2013). Anglian Rivers Sea Trout project. Phase 1 Report. Report by the Anglian Sea Trout Project partnership, Environment Agency. Available at: [redacted] Accessed 09/10/2020.
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.
Pėrez-Domínguez R., and Vogel, M. R. (2010). Baseline larval fish assemblages along the Dutch coast, Southern North Sea. Report to Port Rotterdam. Project Organisation Maasvlakte 2 (PMV2). Institute of Estuarine and Coastal Studies University of Hull, UK. Report ZBB727-F-2001.
Peritus International Ltd. 2022. Scour and Cable Protection Decommissioning Study. NECR403. Natural England.
Popper AN, Hawkins AD, Fay RR, Mann D, Bartol S, Carlson T, Coombs S, Ellison WT, Gentry R, Halvorsen MB, Løkkeborg S, Rogers P, Southall BL, Zeddies D and Tavolga WN (2014). Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report, ASA S3/SC1.4 TR-2014 prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer and ASA Press, Cham, Switzerland.
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.
Popper, A. and Hawkins, A., (2018). The importance of particle motion to fishes and invertebrates. The Journal of the Acoustical Society of America, 143(1), pp.470-488.

Popper, A. and Hawkins, A., (2019). An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. Journal of Fish Biology, 94(5), pp.692-713.
Popper, A., Hawkins, A., Sand, O. and Sisneros, J., (2019). Examining the hearing abilities of fishes. The Journal of the Acoustical Society of America, 146(2), pp.948-955.
Planning Inspectorate (2019). Proposed Dudgeon and Sheringham Shoal OWF Extensions Scoping Opinion.
Renewable UK (2013). Cumulative impact assessment guidelines, guiding principles for cumulative impacts assessments in OWFs; Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010056/EN010056-000427-6.1.11%20Volume%201%20Chapter%2011%20Fish%20and%20Shellfish%20Ecology.pdf.
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.
Roach, M. and Cohen, M. (2020). Westermost Rough OWF Shellfish Survey 2017. A study commissioned by the holderness fishing industry group.
Rommel, S.A. and McCleave, J.D.1973. Prediction of Oceanic Electric Fields in relation to fish migration. ICES Journal of Marine Science. 35(1), pp. 27-31.
RPS (2018). Hornsea Project Three Offshore Wind Farm Environmental Statement.
Scira Offshore Energy Ltd. (2006). Sheringham Shoal OWF Environmental Statement.
Scira Offshore Energy (2010). Sheringham Shoal Offshore Wind Farm Project Sea bed Intervention UXO Clearance.
Scott, K.; Harsanyi, P.; Easton, B.A.A.; Piper, A.J.R.; Rochas, C.M.V.; Lyndon, A.R. (2021). Exposure to Electromagnetic Fields (EMF) from Submarine Power Cables Can Trigger Strength-Dependent Behavioural and Physiological Responses in Edible Crab, Cancer pagurus (L.). J. Mar. Sci.Eng. 2021, 9, 776. [redacted]
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, 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), pp. 2729-2743.
Skaret, G., Axelsen, B.E., Nottestad, L., Ferno, A., and Johannessen, A. (2005). The behaviour of spawning herring in relation to a survey vessel. ICES Journal of Marine Science, vol. 62, pp. 1061-1064.

Spiga, I., Spiga, I., Caldwell, G.S., Bruintjes, R., (2016). Influence of Pile Driving on the Clearance Rate of the Blue Mussel, Mytilus edulis (L.) P. Meet. Acoust. 27, 040005.

Statoil (2015). Dudgeon UXO Verification and Clearance Survey.

Stelzenmüller, V. et al., (2020), Research for PECH Committee – Impact of the use of offshore wind and other marine renewables on European fisheries. European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.

Taormina, B., Bald, J., Want, A., Thouzeau, G., Lejart, M., Desroy, N. and Carlier, A. (2018). A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. Renewable and Sustainable Energy Reviews.

Taormina, B., Di Poi, C., Agnalt, A.-L., Carlier, A., Desroy, N., Escobar-Lux, R. H., D'eu, J.-F., Freytet, F., and Durif, C. M. F. 2020. Impact of magnetic fields generated by AC/ DC submarine power cables on the behavior of juvenile European lobster (Homarus gammarus). Aquatic Toxicology, 220, 105401. doi:10.1016/j.aquatox.2019.105401

Tasker, M. L., Amundin, M., Andre, M., Hawkins, A., Lang, W., Merck, T., Scholik-Schlomer, A., Teilmann, J., Thomsen, F., Werner, S. and Zakharia, M. (2010). Underwater noise and other forms of energy. Marine Strategy Framework Directive Task Group 11 Report

Todd, V., Lavallin, E., and Macreadie, P. (2018). Quantitative analysis of fish and invertebrate assemblage dynamics in association with a North Sea oil and gas installation complex. Marine Environmental Research. 142. 10.1016/j.marenvres.2018.09.018.

Tougaard, J., Hermannsen, L. and Madsen, P.T. (2020). How loud is the underwater noise from operating offshore wind turbines? The Journal of the Acoustical Society of America, 148(5), pp.2885–2893.

Tripp, H. (2021). Sheringham Shoal and Dudgeon OWF Extension Projects EMF assessment

Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F., Stamp, T. (2018). Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth, pp. 91. Available online at: [redacted]

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

Teal, L. (2011). 'The North Sea fish community: past, present and future : background document for the 2011 National Nature Outlook', Journal of Photochemistry and Photobiology B-biology - J PHOTOCHEM PHOTOBIOL B-BIOL.

Tollit, D. J., and Thompson, P. M. (1996). Seasonal and between year variations in the diet of harbour seals in the Moray Firth, Scotland. Canadian Journal of Zoology, 74: 1110e1121.
Tonk, L. and Rozemeijer, M.J.C. (2019). Ecology of the brown crab (Cancer pagurus) and production potential for passive fisheries in Dutch OWFs. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report number C064/19A, 49 pp.; 3 tab.; 86 ref.
Tyler-Walters, H., Tillin, H.M., d'Avack, E.A.S., Perry, F., Stamp, T., (2018). Marine Evidence-based Sensitivity Assessment (MarESA) – A Guide. Marine Life Information Network (MarLIN). Marine Biological Association of the UK, Plymouth, pp. 91. Available online at: [redacted]
Walker, P. A., Howlett, G., and Millner, R. (1997). Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. – ICES Journal of Marine Science, 54: 797–808.
Wale, M.A., Simpson, S.D., and Radford, A.N. (2013a). Noise negatively affects foraging and antipredator behaviour in shore crabs Anim. Behav., 86 (2013), pp. 111-118.
Wale, M.A., Simpson, S.D., and Radford, A.N. (2013b). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise Biol. Lett., 9 (2013), p. 20121194.
Walls, R. Canning, S., Lye G., Givens L., Garrett C. and Lancaster J (2013). Analysis of marine environmental monitoring plan data from the Robin Rigg OWF, Scotland (operational year 3) technical report. Report produced by Natural Power on behalf of E.ON Climate & Renewables.
Weilgart, L (2018). The Impact of Ocean Noise Pollution on Fish and Invertebrates. Report by OceanCare.
Whalley, C., Rowlatt, S., Bennett, M. and Lovell, D., (1999). Total Arsenic in Sediments from the Western North Sea and the Humber Estuary. Marine Pollution Bulletin, 38(5), pp.394-400.
Winslade, P. (1971). Behavioural and embryological studies on the lesser sandeel Ammodytes marinus (Raitt). PhD thesis, Univ. East Anglia. pp. 174.
Woodruff, D., Schultz, I., Marshall, K., Ward, J., and Cullinan, V. 2012. Effects of Electromagnetic Fields on Fish and Invertebrates Task 2.1.3: Effects on Aquatic Organisms Fiscal Year 2011 Progress Report. Report No. PNNL-20813. Report by Pacific Northwest National Laboratory for U.S. Department of Energy, Washington DC.
Wright, P. J., and Tasker, M. L. (1996). Analysis of fish consumption by seabirds by age class of prey fish. In Hunt, G.L., and Furness, R.W. (Eds.), Seabird/Fish Interactions, with Particular Reference to Seabirds in the North Sea. ICES Cooperative Research Report, 216: 2e5.