East Anglia TWO Offshore Windfarm

Chapter 10

Fish and Shellfish Ecology

Environmental Statement
Volume 1

Applicant: East Anglia TWO Limited
Document Reference: 6.1.10
SPR Reference: EA2-DWF-ENV-REP-IBR-000902 Rev 01
Pursuant to APFP Regulation: 5(2)(a)

Author: Royal HaskoningDHV
Date: October 2019
Revision: Version 1

Prepared by:	Checked by:	Approved by:
Paolo Pizzolla Digitally signed by Paolo Pizzolla Date: 2019.10.07 11:11:51 +01'00'	Julia Bolton Digitally signed by: Julia Bolton Date: 2019.10.08 10:30:30 Z	Helen Walker Digitally signed by: Helen Walker Date: 2019.10.08 11:32:24 Z

Revision Summary				
Rev	**Date**	**Prepared by**	**Checked by**	**Approved by**
01	08/10/2019	Paolo Pizzolla	Julia Bolton	Helen Walker

Description of Revisions			
Rev	**Page**	**Section**	**Description**
01	n/a	n/a	Final for Submission

Table of Contents

Chapter 10 Fish and Shellfish Ecology figures are presented in ***Volume 2*** and listed in the table below.

Figure number	Title
10.40	Sprat Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Fleeing Model)
10.41	Sandeel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Fleeing Model)
10.42	Mackerel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Fleeing Model)
10.43	Seabass Historic Fishing Areas in Relation to Worst Case Noise Impact Contour (Fleeing Model)
10.44	Tope and Thornback Ray Nursery Grounds in Relation to Worst Case Noise Impact Contour (Fleeing Model)
10.45	10 year IHLS data (2008-2018) in relation to Worst Case Noise Impact Contour (Fleeing Model)

Chapter 10 Fish and Shellfish Ecology appendices are presented in **Volume 3** and listed in the table below.

Appendix number	Title
10.1	Fish and Shellfish Ecology Consultation Responses
10.2	Fish and Shellfish Ecology Technical Appendix
10.3	Stationary Modelling Appendix

Glossary of Acronyms

AC	Alternating Current
BERR	Business Enterprise and Regulatory Reform
BOEM	Bureau of Ocean Energy Management
Cefas	Centre for Environment Fisheries and Aquaculture Science
CFWG	Commercial Fisheries Working Group
CPUE	Catch per Unit Effort
COWRIE	Collaborative Offshore Wind Research into the Environment
DATRAS	Database of Trawl Surveys
DCO	Development Consent Order
Defra	Department for Environment
DWR	Deep Water Route
EIA	Environmental Impact Assessment
EMF	Electromagnetic Fields
EMFF	European Maritime Fisheries Funded
EMODnet	European Marine Observation and Data Network
EPP	Evidence Plan Process
ES	Environmental Statement
ESFJC	Eastern Sea Fisheries Joint Commission
ETG	Expert Topic Group
EU	European Union
EUNIS	European Union Nature Information System
FAD	Fish Aggregation Device
FEPA	Food and Environmental Protection Act
FSA	Food Standards Agency
GOV	Grande Ouverture Verticale
HRA	Habitats Regulations Assessment
HVAC	High Voltage Alternating Current
ICES	International Council for Exploration at Sea
IBTS	International Beam Trawl Survey
IEEM	Institute of Ecology and Environmental Management
IFCA	Inshore Fisheries Conservation Authorities
IHLS	International Herring Larvae Survey
IMARES	Institute for Marine Resources and Ecosystem Studies
JNCC	Joint Nature Conservation Committee
MarLIN	Marine Life Information network
MARPOL	The International Convention for the Prevention of Pollution from Ships
MarSEA	Marine Evidence Based Sensitivity Assessment
MCEU	Marine Consent and Environment Unit
MCZ	Marine Conservation Zone
MMMP	Marine Mammals Mitigation Plan
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
nm	Nautical Miles
NMFS	National Marine Fisheries Service
NPS	National Policy Statement
OOOMP	Outline Offshore Operations and Maintenance Plan
ORJIP	Offshore Renewables Joint Industry Programme

OSPAR	Convention for the Protection of the Marine Environment of the North Atlantic
OWF	Offshore Windfarm
PEMP	Project Environmental Management Plan
REC	Regional Environmental Characterisation
SAC	Special Area of Conservation
SIP	Site Integrity Plan
SNCB	Statutory Nature Conservation Body
SPA	Special Protection Area
SPR	ScottishPower Renewables
SSCs	Suspended Sediment Concentrations
TAC	Total Allowable Catches
TSS	Traffic Separation Scheme
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance
WFD	Water Framework Directive

Glossary of Terminology

Applicant	East Anglia TWO Limited.
Beam trawl	A trawl net whose lateral spread during trawling is maintained by a beam across its mouth.
Bioelectric	Relating to electricity or electrical phenomena produced within living organisms.
Bony fish	Any of a major taxon (class Osteichthyes or superclass Teleostomi) comprising fishes with a bony rather than a cartilaginous skeleton.
Clupeid	Any of various fishes of the family Clupeidae, which includes the herrings, sprats, sardines and shads.
Construction, operation and maintenance platform	A fixed offshore structure required for construction, operation, and maintenance personnel and activities.
Crustacean	An arthropod of the large, mainly aquatic group Crustacea, such as a crab, lobster, shrimp, or barnacle.
Demersal	Living on or near the sea bed.
Development Area	The area comprising the Indicative Onshore Development Area and the Offshore Development Area
Diadramous	Migrating between fresh and salt water.
East Anglia TWO project	The proposed project consisting of up to 75 wind turbines, up to four offshore electrical platforms, up to one construction, operation and maintenance platform, inter-array cables, platform link cables, up to one operational meteorological mast, up to two offshore export cables, fibre optic cables, landfall infrastructure, onshore cables and ducts, onshore substation, and National Grid infrastructure.
East Anglia TWO windfarm site	The offshore area within which wind turbines and offshore platforms will be located.
Elasmobranch	Any cartilaginous fish of the subclass Elasmobranchii which includes sharks, rays and skates.
European site	Sites designated for nature conservation under the Habitats Directive and Birds Directive, as defined in regulation 8 of the Conservation of Habitats and Species Regulations 2017 and regulation 18 of the Conservation of Offshore Marine Habitats and Species Regulations 2017. These include candidate Special Areas of Conservation, Sites of Community Importance, Special Areas of Conservation and Special Protection Areas.
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA and the information required to support HRA.
Gadoid	A bony fish of an order (Gadiformes) that comprises the cods, hakes, and their relatives.
Gravid	Carrying eggs or young
Inter-array cables	Offshore cables which link the wind turbines to each other and the offshore electrical platforms, these cables will include fibre optic cables.
Landfall	The area (from Mean Low Water Springs) where the offshore export cables would make contact with land, and connect to the onshore cables.
Mollusc	An invertebrate of a large phylum which includes snails, slugs, mussels, and octopuses. They have a soft unsegmented body and live in aquatic or damp habitats, and most kinds have an external calcareous shell.
Natura 2000 site	A site forming part of the network of sites made up of Special Areas of Conservation and Special Protection Areas designated respectively under the Habitats Directive and Birds Directive.

Offshore cable corridor	This is the area which will contain the offshore export cables between offshore electrical platforms and landfall.
Offshore development area	The East Anglia TWO windfarm site and offshore cable corridor (up to Mean High Water Springs).
Offshore electrical infrastructure	The transmission assets required to export generated electricity to shore. This includes inter-array cables from the wind turbines to the offshore electrical platforms, offshore electrical platforms, and offshore export cables from the offshore electrical platforms to the landfall.
Offshore electrical platform	A fixed structure located within the windfarm area, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore.
Offshore export cables	The cables which would bring electricity from the offshore electrical platforms to the landfall. These cables will include fibre optic cables.
Offshore infrastructure	All of the offshore infrastructure including wind turbines, platforms, and cables.
Offshore platform	A collective term for the construction, operation and maintenance platform and the offshore electrical platforms.
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
Platform link cable	Electrical cable which links one or more offshore platforms, these cables will include fibre optic cables.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
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.

10 Fish and Shellfish Ecology

10.1 Introduction

1. This chapter of the Environmental Statement (ES) describes the fish and shellfish ecology baseline ('existing environment') in relation to the proposed East Anglia TWO project and includes an assessment of the potential impacts on these receptors during the construction, operation and maintenance (O&M) and decommissioning phases, along with proposed mitigation measures, where appropriate.

2. This chapter of the ES has been written by Royal HaskoningDHV, and has taken account of guidance provided in the National Policy Statements (NPS) for Overarching Energy EN-1 (Biodiversity and Geological Conservation) and Renewable Energy Infrastructure EN-3 (Offshore Wind Farm Impacts – Fish).

3. The characterisation of the existing environment and impact assessment have been derived using data and information from a number of sources, including the scientific literature, fisheries statistical datasets, and fish and shellfish surveys undertaken within the former East Anglia Zone. Consultation has been undertaken with statutory and non-statutory stakeholders including the Marine Management Organisation (MMO), Centre for Environment, Fisheries and Aquaculture Science (Cefas), Eastern Inshore Fisheries and Conservation Authority (EIFCA), Natural England and commercial fisheries organisations via the Commercial Fisheries Working Group (CFWG).

4. Impacts assessed on fish and shellfish ecology have potential inter-relationships with the following offshore environment topics:

- ***Chapter 7 Marine Geology, Oceanography and Physical Processes;***
- ***Chapter 8 Marine Water and Sediment Quality;***
- ***Chapter 9 Benthic Ecology;***
- ***Chapter 11 Marine Mammals;***
- ***Chapter 12 Offshore Ornithology;*** and
- ***Chapter 13 Commercial Fisheries.***

10.2 Consultation

5. Consultation is a key feature of the Environmental Impact Assessment (EIA) process, and continues throughout the lifecycle of a project, from its initial stages through to consent and post-consent.

6. To date, consultation with regards to fish and shellfish ecology has been undertaken via Expert Topic Group (ETG), described within ***Chapter 5 EIA Methodology***, with meetings held in April 2017 and June 2019, through the Scoping Report (SPR 2017) and the Preliminary Environmental Information Report (PEIR) (SPR 2019). Feedback received through this process has been considered in preparing the ES where appropriate and this chapter has been updated for the final assessment submitted with the Development Consent Order (DCO) application.

7. The responses received from stakeholders with regards to the Scoping Report, PEIR, as well as feedback to date from the ETGs, are summarised in ***Appendix 10.1***, including details of how these have been taken account of within this chapter.

8. Consultation specific to Marine Water and Sediment Quality, Marine Mammals, Offshore Ornithology and Commerical Fisheries are provided in ***Chapter 8 Marine Water and Sediment Quality***, ***Chapter 11 Marine Mammals***, ***Chapter 12 Ornithology*** and ***Chapter 13 Commerical Fisheries***, respectively.

9. Ongoing public consultation has been conducted through a series of Public Information Days (PIDs) and Public Meetings. PIDs have been held throughout Suffolk in November 2017, March / April 2018, June / July 2018 and February / March 2019. Details of the consultation phases are discussed further in ***Chapter 5 EIA Methodology.***

10. ***Table 10.1*** shows public consultation feedback pertaining to fish and shellfish ecology. Full details of the proposed East Anglia TWO project consultation process are presented in the Consultation Report (document reference 5.1), which is provided as part of the DCO application.

Table 10.1 Public Consultation Responses relevant to Fish and Shellfish Ecology

Topic	Response / where addressed in the ES
Phase 1	
None	n/a
Phase 2	
• Effects on marine life • Effects on breeding grounds	Potential impacts on all fish and shellfish ecology receptors during the construction, operation and decommission of the proposed East Anglia TWO project are assessed in ***sections 10.6.1, 10.6.2,*** and ***10.6.3.***

Topic	Response / where addressed in the ES
Phase 3	
• Damage to marine environment	Please see above.
Phase 3.5	
• Impacts on marine life	Please see above
Phase 4	
• Noise and vibration impact on fish. • Fish exposed to piling noise are more likely to move to the bottom of the water column – this should be changed to reflect the true nature of fish behaviours.	Potential impacts due to noise and vibration are assessed in ***section 10.6.1.4.3.*** An update to the noise modelling has been undertaken as discussed in ***section 10.6.1.4.3*** and detailed in ***Appendix 10.3.***

10.3 Scope

10.3.1 Study Area

11. The proposed East Anglia TWO project is encompassed within International Council for the Exploration of the Sea (ICES) Southern North Sea Division (IVc) statistical rectangles[1]. The East Anglia TWO windfarm site and part of the offshore cable corridor are within 33F2 and the near shore sections of the offshore cable corridor lie within 33F1, as shown in ***Figure 10.1.***

12. Fishing stocks are managed by ICES division and quotas are allocated per rectangle. ICES rectangles are the smallest spatial unit used to collate commercial fisheries data and the data from certain national and international fish surveys. Both commercial fisheries data and data gathered from various national and international fish surveys are recorded, collated and analysed using the ICES rectangles within each division. Given the availability of broad scale data sets at the level of ICES rectangles, it is appropriate to define the study area using these. Therefore the study area used for the bulk of this assessment (defined as the local study area) is the area encompassed by rectangles 33F1 and 33F2. The regional study area includes the wider Southern North Sea.

13. Where appropriate, broader geographic study areas have been used for the purpose of the fish and shellfish environmental baseline description and impact assessment. This has particular relevance to life history aspects such as the distribution of spawning grounds and migration.

1 The boundaries of each ICES rectangle aligns to 0.5° latitude by 1.0° longitude, giving whole rectangle dimensions of approximately 30 by 30 nautical miles (nm), at UK latitudes.

10.3.2 Worst Case

14. The design of the proposed East Anglia TWO project (including number of wind turbines, layout configuration, requirement for scour protection, electrical design, etc.) is not yet fully determined, and may not be known until sometime after the DCO has been granted. Therefore, in accordance with the requirements of the Project Design Envelope (also known as the Rochdale Envelope) approach to EIA (Planning Inspectorate 2018) (as discussed in ***Chapter 5 EIA Methodology***), realistic worst case scenarios in terms of potential effects upon fish and shellfish ecology are adopted to undertake precautionary and robust impact assessment.

15. Definition of the worst-case scenarios has been made from consideration of the proposed East Anglia TWO project that is presented in ***Chapter 6 Project Description***, alongside the mitigation measures that have been embedded in the design (***section 10.3.3***).

10.3.2.1 Offshore Infrastructure

16. A realistic ‘worst case’ scenario for the potential impacts of the proposed East Anglia TWO project on fish and shellfish receptors has been identified by using the project design envelope parameters described in ***Chapter 6 Project Description***.

17. The worst case scenario is based on wind turbines with a blade tip height of between 250 and 300m, therefore the worst case is based on either 60 x 300m or 75 x 250m wind turbines.

18. In addition, up to four offshore electrical platforms, one construction, operation and maintenance platform, one meteorological mast, up to 20 buoys (LiDAR, wave recording and guard) plus offshore cables (inter-array, platform link and export cables) are part of the worst case.

19. The design parameters which constitute the worst case scenario for fish and shellfish ecology are presented by impact in ***Table 10.2*** which outlines the worst case scenarios for each identified impact. Where percentage areas affected have been calculated, these are based on a total windfarm site area of 218.4km^2 and an offshore cable corridor area of 138km^2 which results in a total offshore development area for the assessment of 356km^2. As a worst case, the offshore cable corridor area has been calculated based on the northern route (see ***Figure 10.1***) which has the largest area of the two routes and from which the worst case export cable length was calculated. It would not be realistic to combine the areas for both route options as in reality only one of these routes will be used following final design of the project.

Table 10.2 Realistic Worst Case Scenarios

Impact	Parameter	Rationale
Construction		
Impact 1 Physical disturbance and temporary loss of sea bed habitat, spawning or nursery grounds during intrusive works.	Worst case scenario associated with 250m wind turbines with four-legged jacket suction caisson foundations. Preparation area per 250m wind turbine = **6,947.63m²** Sea bed preparation area for East Anglia TWO offshore development area: • Sea bed preparation for 75 x 250m wind turbine on four-legged jackets with suction caissons = **521,071.88m².** • Four offshore electrical platforms and one construction, operation and maintenance platform each with a sea bed preparation area of 37,312m² = **186,560m².** • One operational meteorological mast assumed to be the same as sea bed preparation for one 250m wind turbine four-legged jacket on suction caissons which is conservative = **6,947.63m²** Pre-lay grapnel run with a 20m wide swathe along the whole length of cable routes would disturb the following areas: • Up to two export cables, 160km = 3,200,000m² • 200km of inter-array cable = 4,000,000m² • Platform link cable = 1,500,000m² Sand wave levelling • Offshore cable corridor = 800,000m² • Platform link cables = 120,000m² • Inter-array cables = 320,000m²	The temporary disturbance relates to sea bed preparation and cable installation. The footprint of infrastructure including cable protection is assessed as a permanent impact in O&M impact 1. It should be noted that the sea bed preparation area for foundations is less than the footprint of the foundation scour protection. The area affected by sand wave levelling in the windfarm site would be encompassed by the pre-lay grapnel run while the area affected in the offshore cable corridor would differ at up to 800,000m² due to a wider (60m) dredge being required.

Impact	Parameter	Rationale
	Jack up barge sea bed footprint for 75 foundations (based on a jack up barge footprint of 3,000m² and three movements per foundation) the maximum disturbance would be **675,000m².** Boulder clearance in the offshore development areas – 300 boulders with a maximum diameter of 1m = **235.5m²** Anchoring of the export able laying vessel = **15,500m².** Worst case scenario total temporary disturbance footprint = **11,345,315.m²** which constitutes 3.19% of the maximum offshore development area. Any other works associated with cable installation would be encompassed by the footprints outlined above.	
Impact 2 Increased suspended sediments and sediment re-deposition	The worst case scenario would involve the maximum amount of sediment disturbance through preparation of the sea bed, including: **Sea bed preparation** • 75 x 250m wind turbines on four-legged jacket suction caisson foundations 23,731.9m³ per wind turbine totalling **1,779,890.63m³**. • Eight-legged jacket suction caisson foundations for up to four offshore electrical and one operations and maintenance platform would result in a maximum sediment release into the water column of **668,800m³.** • Four-legged suction caisson foundation for one meteorological mast. Therefore, the maximum possible	Sea bed preparation (dredging using a trailer suction hopper dredger and levelling layer) may be required up to a sediment depth of 5m. The worst case considers the maximum volumes for the project. The worst case would be defined by 75 250m wind turbines mounted on four-legged jacket suction caisson foundations. The meteorological mast would be installed on foundations which, in the worst case for sediment disturbance, would be four-legged jacket suction caisson foundations. As a worst case, the figure for sea bed preparation for a 250m wind turbine four-legged jacket on suction caissons has been used and is considered

Impact	Parameter	Rationale
	amount of sediment released into the water column would be up to **23,732m³.** **Sand wave levelling** The total volume of sediment excavated during sand wave levelling would not exceed the following: • Export cable – 1,000,000m3 • Platform link cable – 150,000m3 • Inter-array cables – 400,000m3 **Backhoe dredging requirements** There may also be a requirement for backhoe dredging along the offshore cable corridor e.g. in the near shore area around the HDD punch-out location during the installation of export cables. Based on EA1 values, although with adequate redundancy built in, it is assumed that up to 2.5% (1.9km) of each cable corridor will require dredging to a max of 8.6m wide by 4m deep which = **68,800m³** for both cables. Therefore, the total volume of sediment displacement / re-suspension (i.e. from the use of a dredger) in the offshore development area requiring to be disposed of would be: **4,091,222.50m³** **Cable Ploughing Sediment Disturbance** • Export cable – 96,000m³ • Inter array cables – 458,000m³ • Platform link cables – 171,750m³	conservative. For drill arisings the worst case for meteorological mast is based on a 300m wind turbine The worst case with regard to sediment displacement during installation of offshore platform foundations (including four electrical and one construction, operation and maintenance) would be from installation of eight-legged jacket suction caissons which would require the excavation of up to **668,000km³**.

Impact	Parameter	Rationale
	However, temporally, the maximum volumes of sediment affected would be up to 2,198.4m^3 per day **Drill Arisings** Should the installation of monopiles or jackets using pin piles be required, drilling may also be undertaken which would release subsurface materials into the water column. • Wind turbine foundations based on worst case volume associated with 10% of 60 300m wind turbines with monopile foundations requiring installation by drilling (45 m depth 15m diameter) = **47,713m^3** • Meteorological mast based on arisings from a 300m wind turbine monopile foundation which is conservative: **7,952.16m^3** • Offshore electrical and construction, operation and maintenance platforms (monopile foundation): **43,210m^3** **Total drill arisings = 98,874.56m^3** Sub-surface sediments have a different physical composition to near-surface sediments and may therefore be more widely dispersed by tidal currents. However, the volumes involved are far smaller than sea bed preparation for four-legged jacket suction caisson foundations (***Chapter 7 Marine Geology, Oceanography and Physical Processes***) and therefore it is considered that installation of four-legged jacket suction caisson foundations is the worst case scenario for re-suspension of sediments.	

Impact	Parameter	Rationale
	It should be noted that sea bed preparation is less likely to be required for piled foundations and, if required, would be significantly less than described above. Therefore, the volume of drill arisings and sea bed preparation outlined above are not cumulative.	
Impact 3 Re-mobilisation of contaminated sediment during intrusive works	As above	The worst case would involve the maximum amount of suspended sediment released into the water column. This is calculated in the row above.
Impact 4 Underwater noise impacts to hearing sensitive species during foundation piling	**Number of wind turbines** Up to 75 (250m wind turbines) or 60 (300m wind turbines)	The spatial worst case is a result of installation of piling using the maximum hammer energies. This would result in largest spatial noise impact at any given time and hence maximum impact on fish and shellfish receptors. Consideration has also been given to the worst case scenario in terms of piling duration. This would be associated with the installation of the maximum number of piles.
	Number of offshore platforms 4 x Offshore electrical 1 x Met mast 1 x construction, operation and maintenance = 6	
	Wind turbine foundation options Monopile = pile 4-leg jacket = pin-piles	Hammer piled foundations represent the worst-case scenario for underwater noise.

Impact	Parameter	Rationale
	Platform foundation options Offshore electrical platforms = jacket with pin-piles Met mast = monopile or jacket with pin-piles Construction, operation and maintenance platform = jacket with pin-piles	
	Proportion of foundations that are piled 100%	The maximum proportion of hammer piled foundations represents the worst-case scenario for underwater noise.
	Number of piles per infrastructure type Wind turbines = 1 monopile or 4 pin-piles Electrical platforms = 8 pin-piles per platform Met mast = 1 monopile or 4 pin-piles Construction, operation and maintenance platform = 8 pin-piles per platform	
	Number of piles for wind turbines 250m = 75 monopiles or 300 pin-piles 300m = 60 monopiles or 240 pin-piles	Maximum number of pin-piles for all wind turbine foundations is 300
	Number of piles for offshore platforms Offshore electrical platforms = 4 x 8 pin-piles = 32 pin-piles Met mast = 1 monopile or 4 pin-piles Construction, operation and maintenance platform = 8 pin-piles	Maximum number of pin-piles for all platform foundations is 44
	Total number of piled foundations Maximum number of pin-piles = 300 (250m wind turbines) + 44 (platforms) = 344; Or	

Impact	Parameter	Rationale
	Maximum number of monopiles = 75 (250m wind turbines) + 1 (met mast) = 676; plus 40 pin piles for offshore platforms	
	Hammer energy – monopiles Starting hammer energy of 400kJ will be used for 10 minutes. Ramp up will then be undertaken for at least 20 minutes to 80% of the maximum hammer energy applied. Following the ramp-up, hammer energy can increase to 4,000kJ if required until target penetration depth is reached. Maximum hammer energy applied = 4,000kJ for 300m wind turbines with 15m diameter monopile.	This is the worst-case scenario with potential underwater noise impacts greater than those for 75 250m wind turbine monopiles using a maximum applied hammer energy of 3,000kJ. If a hammer model is used that can generate energy levels greater than 4,000kJ, the hammer energy output will be modulated to a maximum of 4,000kJ.
	Hammer energy – pin piles Starting hammer energy of 240kJ will be used for 10 minutes. Ramp up will then be undertaken for at least 20 minutes to 80% of the maximum hammer energy applied. Following the ramp-up, hammer energy can increase to 2,800kJ if required until target penetration depth is reached. Maximum hammer energy applied = 2,400kJ for 4.6m diameter pin-piles (300m wind turbines or platforms).	This is the worst-case scenario with potential underwater noise impacts greater than those for 75 250m wind turbine pin-piles with the maximum applied hammer energy of 1,800kJ. If a hammer model is used that can generate energy levels greater than 2,400kJ, the hammer energy output will be modulated to a maximum of 2,400kJ.
	Pile diameter – monopiles Maximum monopile diameter of 15m for 300m wind turbines.	15m diameter is the worst-case scenario for monopiles, with potential underwater noise impacts greater than 13m diameter monopile for 250m wind turbines and 8m diameter monopile for met mast.
	Pile diameter – pin-piles Maximum pin-pile diameter of 4.6m for 300m wind turbines and platforms (electrical and construction, operation and maintenance platforms).	This is the worst-case, with the greatest potential underwater noise impact ranges for the installation of pin-piles.

Impact	Parameter	Rationale
	Total piling time – per wind turbine foundation for monopiles (including soft-start and ramp-up in accordance with the MMMP and providing allowance for issues such as low blow rate, refusal, etc.) 325 minutes (5.42hrs) x 60 (300m) monopiles = 325 hours	The maximum hammer piling duration of 325 hours (13.5 days) represents the temporal worst-case scenario for the installation of monopiles for the 300m wind turbines (this includes 10 minute soft-start and 20 minute ramp-up in accordance with the MMMP). This is greater than the maximum hammer piling duration of 137.5 hours for the installation of monopiles for the 250m wind turbines (110 minutes, including soft-start and ramp-up x 75).
	Total piling time – per wind turbine foundation for pin-piles (including soft-start and ramp-up in accordance with the MMMP and providing allowance for issues such as low blow rate, refusal, etc.) 199 minutes (3.32 hours) x 4 pin-piles x 60 (300m) = 796.8 hours	The maximum hammer piling duration of 796.8 hours (33.2 days) represents the temporal worst-case scenario for the installation of pin-piles for the 300m wind turbines (this includes 10 minute soft-start and 20 minute ramp-up). This is greater than the maximum hammer piling duration of 635 hours for the installation of pin-piles for the 250m wind turbines (127 minutes, including soft-start and ramp-up x 74 x 4).
	Total piling time – per platform foundation (including soft-start and ramp-up in accordance with the MMMP and providing allowance for issues such as low blow rate, refusal, etc.) 199 minutes x 8 pin-piles x 4 offshore electrical platforms = 106.1hrs 199 minutes x 8 pin-piles x 1 construction, operation and maintenance platform = 26.5hrs 127 minutes x 4 pin-piles x 1 Met mast = 8.5hrs Total = 141 hours (up to 6 days)	The maximum hammer piling duration of 141 hours (6 days) represents the temporal worst-case scenario for the installation of the platforms (including soft-start and ramp-up).
	Maximum total active piling time for wind turbines and platforms 938.8 hours (39.2 days)	Based on the worst-case scenario of pin-piles for wind turbines (33.2 days) and platforms (6 days).

Impact	Parameter	Rationale
Impact 5 Underwater noise impacts to hearing sensitive species due to other activities (vessels, sea bed preparation, cable installation etc.)	**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; and • Vertical injector. **Maximum length of cables**: • Inter-array cables: 200km • Platform link cables:75km • Export cables: 160km. **Vessels** • Maximum number of vessels on site at any one time: 74 • Maximum number of individual vessels during construction: 3,672	Underwater noise and vibration associated with sea bed preparation, rock dumping, cable installation and construction vessels. This would result in the greatest noise impacts as a result of project construction activities other than piling for foundation installation.
Impact 6: Underwater Noise Impacts to Hearing Sensitive Species due to unexploded ordnance (UXO) Clearance	**Underwater noise associated with UXO clearance** • Number of UXO: Up to 80 • Type and size of UXO: Up to 700kg (net explosive quantities NEQ)	Numbers based on East Anglia ONE UXO survey, but a detailed UXO survey will be completed prior to construction.
Impact 7 Changes in fishing activity	See ***Chapter 13 Commercial Fisheries***	Changes in fish stocks of commercial importance as a result of changes in fishing activity.

Impact	Parameter	Rationale
Operation		
Impact 1 Permanent habitat loss	The maximum possible sea bed footprint of the project including scour protection. The maximum size of the project footprint is based on the following: **Windfarm Site Infrastructure** 60m diameter gravity-based foundation and scour protection footprints together are calculated as 25,446.9m^2 per foundation (see ***Chapter 6 Project Description Table 5.7***). Therefore, for 60 foundations (see adjacent notes column) the maximum area of baseline habitat lost would be **1,526,814.03m^2** which is considered the worst case. The maximum area of baseline habitat lost due to installation of offshore electrical and construction, operation and maintenance platforms on four-legged jackets with suction caissons with associated scour protection would amount to 15,276m^2 per platform. There would be up to five such structures totalling **2,827.43m^2.** The gravity-base foundation and scour protection for one meteorological mast would be **2,827.43m^2.** **Cable Protection in the Windfarm Site** Cable protection for up to 7.5km of platform link cable due to ground conditions of up to **63,750m^2.** Additionally, up to **40,800m^2** of cable protection would be required for unburied platform link cables at cable crossings.	The scenario described gives rise to the greatest area of permanent sea bed habitat loss. Areas impacted by scour would be changed irreversibly and would therefore count as habitat loss. The worst case for the area lost due to meteorological mast installation has been determined from the area required for a 250m gravity based foundation which is considered conservative.

Impact	Parameter	Rationale
	Cable protection for up to 20km of inter-array cables due to ground conditions and for up to 25 crossings which amounts to **204,000m^2.** Therefore, a total area of up to **308,550m^2** of cable protection would be required in the windfarm site. **<u>Total Windfarm Site Infrastructure</u>** Total footprint during operation within the East Anglia TWO windfarm site which could be subject to permanent habitat loss is therefore **1,914,571.46m^2** which constitutes 0.89% of the windfarm site. **Export Cable** Cable protection due to an inability to bury export cables would result in a footprint of up to **68,000m^2** (5% of the length of each export cable) Protection associated with cable crossing for export cables would result in a footprint of up to **40,800m^2.** Total footprint which could be subject to permanent habitat loss during operation of the export cables is therefore **108,8000m^2** (0.08% of the northern offshore cable corridor area). The overall total footprint which could be subject to permanent habitat loss would therefore be 2,023,371.46m^2 (0.57% of the offshore development area).	

Impact	Parameter	Rationale
Impact 2 Increased suspended sediments and sediment re-deposition	The maximum amount of suspended sediment that would be released into the water column due to changes in tidal regime around infrastructure has been calculated based findings verified by field measurements (see ***Chapter 7 Marine Geology, Oceanography and Physical Processes section 7.6.2.4***). This has been calculated as a worst case scour volume under a 50-year return period event of about 5,000m^3 for an individual foundation of similar type and size to a worst case 60m gravity-base structure. Therefore, for 75 wind turbine foundations the maximum amount of scour material released into the water column would be **375,000m^3.**	The need for and type of scour protection would not be determined until the wind turbine location and associated foundation types are known, therefore the worst case scenario would involve the use of no scour protection. Of all the foundation options under consideration 75 60m diameter gravity-base structures would cause the greatest amount of scour. Assumptions for scour produced from ***Chapter 7 Marine Geology, Oceanography and Physical Processes***).
Impact 3 Re-mobilisation of contaminated sediment during intrusive works	The worst case scenario relates to activities that involves the increase of SSCs as set out above.	As above
Impact 4 Underwater noise impacts to hearing sensitive species due to other activities	It is difficult to estimate the noise produced during operational activities although it will be much less than that produced during construction due to the absence of piling. Noise will primarily be associated with vessel movements for which the annual number of vessel round trips is anticipated to be 687 with the additional use of a jack-up vessel to each wind turbine every two years and five uses of a cable laying vessel every year.	This results in the maximum potential for noise disturbance on fish and shellfish receptors during the operation and maintenance phase.

Impact	Parameter	Rationale
	The level of underwater noise from operational turbines is also difficult to estimate however noise levels would be low and would likely reach ambient levels 100m from turbines (MMO 2014).	
Impact 5 Introduction of wind turbine foundations, scour protection and hard substrate	This is detailed in operational Impact 1 above.	This would result in the greatest introduction of hard substrate and therefore in the greatest extent of impacts on fish and shellfish receptors
Impact 6 Electromagnetic fields	The greatest impact from electromagnetic fields (EMF) would occur if cables are unburied or buried to the shallowest depth of 1m, and the maximum amount of cable of the maximum cable rating is utilised, based on: • The maximum length of inter-array (up to 75kV of alternating current) cables would be up to 200km, with up to 24km unburied; • The maximum length of platform link cables would be up to 75km of 400kV HVAC cable, with up to 12.3km unburied; • The maximum length of offshore export cable (up to 600kV) would be 160km, with up to 12.8km unburied.	The maximum length of cables would result in the greatest potential for EMF related effects. Although it should be noted that where cables are unable to be buried they would be protected which would provide some degree of attenuation of EMF.
Impact 7 Changes in fishing activity	See ***Chapter 13 Commercial Fisheries***	Changes in fish stocks of commercial importance as a result of changes in fishing activity
Decommissioning		
No decision has been made regarding the final decommissioning policy, as it is recognised that industry best practice, rules and legislation change over time. The decommissioning methodology and programme would need to be finalised nearer to the end of the lifetime of the project so as to be in line with latest and current guidance, policy and legislation at that point. Any such methodology and programme would be agreed with the relevant authorities and statutory consultees, as secured under a requirement of the draft DCO. The worst case scenarios for decommissioning activities and associated implications for fish and shellfish are considered analogous with those assessed for the construction phase.		

10.3.3 Mitigation and Best Practice

20. 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.

21. 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 6 Project Description***, ***Chapter 4 Site Selection and Assessment of Alternatives***) including engineering requirements, ongoing discussions with stakeholders and regulators, commercial considerations and environmental best practice.

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

23. In addition to embedded mitigation, if further mitigation is required and possible, (i.e. those measures to prevent or reduce any remaining significant adverse effects) these are discussed in the relevant impact sections and the post-mitigation residual impact significance is provided. The embedded mitigation is specified below:

- The Applicant is committed to burying offshore export cables where possible (between 1m to 3m), reducing the effects of electromagnetic fields (EMF) and also reducing the need for surface cable protection which reduces the introduction of hard substrate and modification of habitat. A detailed offshore export cable installation study will be carried out post-consent to inform the potential for offshore export cable burial throughout the offshore cable corridor, which will form part of the Cable Laying Plan as required under a condition of the draft DCO.
- 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 near the offshore development area.

10.3.3.1 East Anglia TWO commitments

24. Project commitments made by the Applicant in order to minimise the impact of underwater noise on marine mammals are also of relevance to fish and shellfish ecology. These commitments are as follows:

- Only one unexploded ordnance (UXO) would be detonated at a time during UXO clearance operations in the East Anglia TWO offshore development area. There would be no simultaneous UXO detonations, but potentially more than one UXO detonation could occur in a 24 hour period.
- There would be no concurrent piling at East Anglia TWO, with only one pile being installed at a time, with no overlap in the piling duration of any two piles. Piles will be installed sequentially, and more than one pile could be installed in a single 24 hour period.
- There would be no UXO detonation in the East Anglia TWO offshore development area at the same time as piling in the East Anglia TWO offshore development area during the winter period, in that although they may occur in the same day or 24 hour period, they would not occur at exactly the same time.
- There would be no concurrent piling or UXO detonation between the proposed East Anglia TWO and East Anglia ONE North projects if both projects are constructed at the same time. This is stated within the draft Marine Mammal Mitigation Protocol (MMMP) (document reference 8.14) which is submitted with the DCO application. The final MMMP for piling will be produced pre-construction and is secured through the DCO.

10.3.3.2 Additional Mitigation

25. Further mitigation of relevance to fish and shellfish ecology includes:

- Soft start and ramp up protocol for pile driving would be implemented to allow mobile species to move away from the area of highest noise impact. This commitment is presented in the MMMP and is secured under the conditions of the draft DCO.
- A MMMP and Southern North Sea Special Areas of Conservation (SAC) Site Integrity Plan (SIP) for both piling and UXO clearance will be implemented for marine mammal mitigation, any mitigation beneficial to the marine mammals would also potentially reduce impacts on fish and shellfish ecology. Draft and in principle versions of these documents have been submitted with the DCO Application (document references 8.14 and 8.17).

10.3.4 Monitoring

26. Post-consent, the final detailed design of the proposed East Anglia TWO project will refine the worst-case parameters assessed in this ES. It is recognised that monitoring is an important element in the management and verification of the actual impacts based on the final detailed design however as stated in the In Principle Monitoring Plan (document reference 8.13) no monitoring is currently planned for fish and shellfish ecology subject to agreement with the MMO and relevant Statutory Nature Conservation Bodies (SNCBs).

27. Outline Management Plans as secured under the draft DCO which are relevant to fish and shellfish ecology include:

- In Principle Monitoring Plan (document reference 8.13);
- Draft Marine Mammals Mitigation Protocol (document reference 8.14);
- In-Principle Site Integrity Plan (document reference 8.17); and
- Project Environmental Management Plan.

10.4 Assessment Methodology

10.4.1 Guidance

28. The assessment of potential impacts on fish and shellfish ecology has been undertaken with specific reference to the relevant National Policy Statement (NPS). Those relevant to the proposed East Anglia TWO project are as follows:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a); and
- NPS for Renewables Energy Infrastructure (EN-3), July 2011.

29. The specific NPS (EN-3) assessment guidance relevant to fish and shellfish ecology is summarised below in ***Table 10.3.***

Table 10.3 NPS assessment requirements

NPS Requirement	NPS Reference	ES Reference
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 ***sections 10.6.1.1, 10.6.1.2, 10.6.1.4*** and ***10.6.3.***
The applicant should identify fish species that are the most likely receptors of impacts with respect to: • spawning grounds; • nursery grounds; • feeding grounds; • over-wintering areas for crustaceans; and • migration routes.	EN-3 section 2.6.74	Fish species which may be likely receptors of impact are identified in ***section 10.5.6***

NPS Requirement	NPS Reference	ES Reference
Where it is proposed that mitigation measures of the type set out in paragraph 2.6.76 below are applied to offshore export cables to reduce electromagnetic fields (EMF) the residual effects of EMF on sensitive species from cable infrastructure during operation are not likely to be significant. Once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement.	EN-3 section 2.6.75	***Section 10.6.2.6*** identifies and assesses potential impacts on fish and shellfish receptors due to EMF during operation. The use of armoured cables and cable burial depth as potential mitigation is discussed in ***sections 10.6.2.6*** and ***10.3.3***
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 10.3.3.***
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 10.6.1*** and ***10.6.2.***
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 10.6.1, 10.6.2*** and ***10.6.3*** assess the potential impacts of the proposed East Anglia TWO project during construction, operation and decommissioning on various fish and shellfish receptors.

NPS Requirement	NPS Reference	ES 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 10.2*** details consultation which has been undertaken with regards to fish and shellfish ecology. Responses to the Scoping Report and PEIR from statutory consultees can be found in ***Appendix 10.1.***
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 10.6.1*** and ***10.6.2.***
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 10.6.1*** and ***10.6.2*** assess the potential impacts (both positive and negative) of the proposed East Anglia TWO project 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	***Section 10.3.4*** discusses monitoring which may be implemented for the proposed East Anglia TWO project.

30. The Marine Policy Statement (MPS) (HM Government 2011) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic considerations that need to be taken into account in marine planning. 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.

31. With regard to the East Inshore and East Offshore Marine Plans (HM Government 2014) 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*" are of relevance to this chapter as 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 3 Policy and Legislative Context*** and ***Chapter 8 Water and Sediment Quality*** for more details), as well as other environmental, social and economic considerations.

32. 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…
  - 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
  - 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
  - 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.

33. In addition to the above, the following documents have been used to inform the assessment of potential impacts of the proposed East Anglia TWO project on fish and shellfish ecology:

- Guidelines for Ecological Impact Assessment in the UK and Ireland (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;
- Guidelines for ecological impact assessment in Britain and Ireland: Marine and Coastal Institute of Ecology and Environmental Management (IEEM) (2010);
- 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) Offshore Wind Farms - 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 offshore wind farm monitoring data associated with licence conditions (MMO 2014b);
- Renewable UK (2013) Cumulative impact assessment guidelines, guiding principles for cumulative impacts assessments in offshore wind farms;
- Monitoring Guidance for Underwater Noise in European Seas, Part II Monitoring Guidance Specifications. JRC Scientific and Policy Report EUR 26555 EN. (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 2017) which included scoping responses from statutory consultees.

10.4.2 Data Sources

34. As detailed in ***Appendix 10.2***, site specific data are available from previous projects in the former East Anglia Zone; however, given that 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).

35. It was agreed with stakeholders through the Evidence Plan Process (EPP) that sufficient publicly available information is available to undertake a robust assessment and that site specific fish sampling surveys were not required (see Appendix 2.3 of the East Anglia TWO Scoping Report (SPR 2017)). The fish and shellfish ecology assessment is based on data from the following sources detailed in ***Table 10.4.***

Table 10.4 Data Sources

Data	Year	Coverage	Confidence	Rationale
Site specific data	2010, 2013 and 2015	East Anglia Zone	High	Site specific fish surveys for East Anglia ONE, East Anglia THREE and East Anglia Zone Environmental Appraisal (ZEA)
East Anglia TWO offshore cable corridor benthic surveys (and ZEA, East Anglia ONE, East Anglia THREE/FOUR export cable corridor benthic surveys)	2011 and 2018	East Anglia TWO offshore development area	High	These surveys collected benthic data from areas of the offshore cable corridor not previously surveyed and contaminant samples from both the East Anglia TWO windfarm site and offshore cable corridor. These surveys can help characterise the habitats and feeding area of fish and shellfish species which may be found in the offshore development area.
MMO Landings Data (weight and value) by species	2017	UK	High	Illustrates species of commercial importance within the local study area. Not suitable for the evaluation of species abundance and distribution.
Distribution of Spawning and Nursery Grounds as defined in Coull et al. (1998) (Fisheries Sensitivity Maps in British Waters) and in Ellis et al. (2010) (mapping spawning and nursery areas of species to be considered in Marine Protected Areas	Coull et al. 1991 - 1996 Ellis et al. Varies by species but generally between 1983 and 2008	UK territorial waters and the remainder of the North Sea.	High	Coull et al. (1998) and Ellis et al. (2010; 2012) are considered the standard references to be used to provide an overview of the spatial extent of spawning grounds and the relative intensity and duration of spawning. Both are based on a compilation of a variety of data sources.

Data	Year	Coverage	Confidence	Rationale
(Marine Conservation Zones).				
North Sea International Bottom Trawl Survey (IBTS) Data	2008 to 2018	ICES rectangles 33F1 and 33F2	High	IBTS data has been accessed via the ICES Data Portal (DATRAS, the Database of Trawl Surveys: http://datras.ices.dk). Data presented refers to the average number of fish caught per hour (in those ICES rectangles corresponding to the defined local study area) by IBTS North Sea surveys conducted between 2008 and 2018.
Greater North Sea International Quarter 3 Otter Trawl Groundfish Survey Monitoring and Assessment Data (Moriarty and Greenstreet 2017)	1998 - 2016	North Sea	High	Surveys were primarily designed to determine the distribution and abundance of demersal fish species and to monitor environmental parameters.
ICES International Herring Larvae Survey (IHLS) data	2005 to 2017	Eastern and northern North Sea	High	The IHLS surveys routinely collect information on the size, abundance and distribution of herring eggs and larvae (and other species) in the North Sea.
ICES Working Group 2 on North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS2)	2004, 2009, 2010-2017	North Sea	High	This survey data provides recent information on cod spawning and could be used to determine the extent of any cod spawning activity that may be occurring within and in proximity to the offshore development area.
Eastern sea Fisheries Joint Committee (ESFJC) (2010)	2010	Southern North Sea	High	ESFJC compiled charts showing the extent of inshore fisheries for 17 commercially important fish and shellfish species in the offshore development area

Data	Year	Coverage	Confidence	Rationale
Institute for Marine Resources and Ecosystem Studies (IMARES) monthly ichthyoplankton surveys (van Damme et al. 2011)	April 2010 to March 2011	Southern North Sea	High	The report presents the results of twelve monthly ichthyoplankton surveys carried out from April 2010 until March 2011 in the southern North Sea.
East Coast Regional Environmental Characterisation (REC) (Limpenny et al. 2011)	2011	Southern North Sea	High	Geophysical, geological, archaeological and biological data-sets which provide context for a regional assessment of the physical, biological and archaeological environment.
Predictive European Nature Information System (EUNIS) sea bed habitats. European Marine Observation and Data Network (EMODnet) (2017). database containing information on the predicted sea bed habitats present across Europe, mapped in accordance with the EUNIS habitat classification system.	2009 – 2013, 2013 – 2016 and 2017-2019	Europe	High	The predicted habitat maps, when used in conjunction with the fish sensitivity maps, can provide an indication of the likelihood of suitable spawning or nursery habitat to be present within the offshore development area.
Offshore Renewables Joint Industry Programme (ORJIP) study on impacts from piling on fish at offshore windfarm sites (Boyle and New 2018)	2018	UK	High	This study undertook environmental research and review to inform current understanding on impact of piling during the construction of offshore windfarms upon herring spawning.

36. In addition to the data sources described above, the following resources have been accessed to inform the assessment:

- 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 (MMO 2014a);
- Marine Conservation Zone (MCZ) recommendations (Natural England 2018);
- Results of monitoring programmes undertaken in operational windfarms in the UK and other European countries; and
- Other relevant peer-review publications and assessments.

37. Assessments undertaken in ***Chapter 7 Marine Geology, Oceanography and Physical Processes***, ***Chapter 8 Water and Sediment Quality***, ***Chapter 9 Benthic Ecology, Chapter 11 Marine Mammals***, ***Chapter 12 Offshore Ornithology*** and ***Chapter 13 Commercial Fisheries*** will inform the assessments in this chapter.

10.4.2.1 Data Limitations, Sensitivities and Gaps

10.4.2.1.1 Spatial Extent of Spawning and Nursery Grounds

38. Coull et al. (1998) and Ellis et al. (2010; 2012) are frequently considered the standard references to be used to provide broad scale overviews of the potential spatial extent of spawning grounds and the relative intensity and duration of spawning. Both Coull et al. (1998) and Ellis et al. (2010; 2012) are based on a compilation of a variety of data sources. In the case of Coull et al. (1998), many of the conclusions are based on historic research and therefore may not take account in recent changes in fish distributions and spawning behaviour. Ellis et al. (2010; 2012) is also constrained by the wide scale distribution of the sampling sites used for the annual international larval survey data, resulting in broad scale grids of spawning and nursery grounds.

39. Aires et al. (2014) conducted a report to update fisheries sensitivity maps in British waters. This report focuses on aggregations of 0 group fish (fish in their first year of their lives) rather than “nursery areas”. Various species distribution models (MAXENT, based on presence-only data and Random Forest based on presences-absences data) were based on mostly survey data. It is important to note that Aires et al. (2014) study does not replace existing materials, and the authors encourage the findings to be used in conjunction with them.

40. The spatial extent of the spawning grounds and the duration of spawning periods given in these publications are therefore likely to represent the maximum theoretical extent of the areas and periods within which spawning by the species is considered. Therefore spawning grounds are likely to be smaller, with shorter spawning periods, or in certain cases no longer be active spawning grounds.

10.4.2.1.2 Landings Data

41. Landings data derived from UK registered vessels by species and ICES rectangle have been derived from catch statistics provided by the MMO.

42. It should be recognised that the Applicant is supportive of continued fishing by both UK and non UK registered vessels. Activity by these categories of vessels is described in ***Chapter 13 Commercial Fisheries***, and has been cross-referenced where appropriate.

43. Whilst landings statistics provide a good indication of the principal species targeted within a given area, assessments of the relative abundance and distribution of the species based on commercial landings should be made with caution due to factors such as; fisheries legislation and controls such as quotas and closed areas, and other factors such as gear selectivity and market forces.

10.4.2.1.3 ICES Survey Data

10.4.2.1.3.1 International Bottom Trawl Survey (IBTS)

44. IBTS data has been accessed via the ICES Data Portal (DATRAS, the Database of Trawl Surveys: http://datras.ices.dk). The DATRAS on-line database contains trawl information and biological data on all surveys conducted by the ICES IBTS sampling programme. Since 1997 surveys have employed a standardised method with a GOV[2] trawl used to sample a series of fixed stations, twice per year in the 1st and 3rd quarters of the year (IBTS 2015). The species abundance data presented refers to the average number of fish caught per hour (in those ICES rectangles corresponding to the defined local study area) by IBTS North Sea surveys conducted between 2008 and 2018.

45. Whilst IBTS provides valuable information on the distribution and relative abundance of demersal fish species, the limitations of bottom trawl surveys to adequately target some species (i.e. shellfish species, clupeids, sandeels and diadromous migratory fish) should be recognised.

10.4.2.1.3.2 International Herring Larvae Survey (IHLS)

46. IHLS data has been accessed via the ICES Data Portal (http://eggsandlarvae.ices.dk). The IHLS surveys routinely collect information on the size, abundance and distribution of herring eggs and larvae (and other species) in the North Sea. The values for larval abundance presented refer to the number of herring larvae in the smallest reported size category (<11mm total length) caught per square metre at each site sampled per fortnight in the 3rd quarter in each year between 2004 and 2017 (ICES 2018).

[2] GOV - "Grande Ouverture Verticale": Standard otter trawl gear used in the IBTS

10.4.2.1.4 Previous Surveys undertaken in the Former East Anglia Zone

47. A site specific fish survey was undertaken for East Anglia ONE for the purposes of informing the EIA in November 2010 and February 2011. This survey consisted of 18 demersal otter trawl tows and 18 2m scientific beam trawl tows. A further pelagic survey was undertaken during the same period focused on identifying herring spawning grounds. Demersal otter and beam trawl surveys were undertaken in February and May 2013 to inform the East Anglia THREE EIA, providing information on fish and shellfish assemblages.

48. It should also be noted that the surveys carried out only provide reliable information on the distribution and abundance of demersal fish species, in light of the specific gear types used (otter trawl, 4m beam trawl and 2m scientific beam trawl). The presence and abundance of some species/species groups may therefore be misrepresented in the survey results (i.e. shellfish species, clupeids, sandeels and diadromous migratory fish).

49. Epibenthic trawls were undertaken as part of benthic ecology surveys undertaken for the ZEA, East Anglia ONE and East Anglia THREE; these included fish and provide contextual information regarding potential habitats for fish and shellfish species and feeding areas.

50. Data derived from epibenthic surveys carried out for the East Anglia ONE, East Anglia THREE and the former East Anglia FOUR[3] projects, have been used to inform the fish and shellfish technical report (***Appendix 10.2***). Whilst the areas sampled in these surveys are not specific to the offshore development area, the findings of the surveys are of relevance to the proposed East Anglia TWO project, given its proximity to East Anglia ONE, East Anglia THREE and the former East Anglia FOUR.

51. Additionally, benthic sampling was undertaken in all areas of the offshore cable corridor which were not been sampled as part of the ZEA survey. Findings of these surveys are discussed in ***section 9.5.1*** of ***Chapter 9 Benthic Ecology.*** The methodologies of these surveys were designed and agreed in consultation with the MMO, Cefas and Natural England through the ETG. A summary of the site specific survey results is provided in ***section 10.5.2.1. Figure 10.2.2*** in ***Appendix 10.2*** shows the locations of benthic grab samples within the offshore development area, and a 10km buffer. The sediment distrubution of these benthic samples (***Figure 10.2.3***) has been used to characterise the habitat of fish and shellfish species, as discussed in ***Appendix 10.2,*** including sandeel as presented in ***Figure 10.2.4***

[3] This was a project in the northern part of the former East Anglia Zone which now forms part of the Norfolk Vanguard offshore windfarm.

10.4.2.1.5 Knowledge Gaps

52. It should be recognised that there are gaps in the understanding of the distribution, behaviour and ecology of certain fish and shellfish species. This is particularly evident for a number of migratory species, some of which are of conservation importance (e.g. lampreys and salmonids). At present little is known in relation to their migration routes and the use that they may make of discrete sea areas such as those of the East Anglia TWO windfarm site and offshore cable corridor.

10.4.3 Impact Assessment Methodology

53. The approach to assessment of potential impacts on fish and shellfish ecology has been agreed in consultation with statutory advisors (Natural England, MMO and Cefas) through the EPP (ETG Meeting 12th April 2017) and the provision of a Fish Ecology Method Statement (Appendix 2.3 of the East Anglia TWO Scoping Report (SPR 2017)).

54. The potential impacts that are relevant to the proposed East Anglia TWO project 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.

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

56. Cumulative impacts relevant to fish and shellfish ecology arising from other marine developments are discussed in ***section 10.7*** and inter-relationships with other receptor groups are described in ***section 10.9.***

10.4.3.1 Assessment Limitations

57. The impact assessment presented within this chapter of the ES is subject to certain limitations. Principally, these relate to knowledge gaps regarding the sensitivity of some species and / or species groups to particular impacts (e.g. impacts of noise on shellfish). Therefore, in some instances it has been necessary to use similar species, or species groups as a comparator. Further uncertainties relate to the distribution of some species and the degree to which they access the proposed East Anglia TWO project during key life history phases such as during spawning or migration.

10.4.3.2 Significance Criteria

58. The significance of potential impacts has been defined by considering receptor sensitivity in combination with the magnitude of a given impact. Due to a lack of suitable data to quantitatively assess impacts for the majority of the species under consideration, the assessment is qualitative and reliant on professional experience and judgement.

10.4.3.3 Sensitivity

59. 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)).

60. Throughout the assessment, receptor sensitivities have been informed by thorough review of the available peer-reviewed scientific literature, and assessments available on the Marine Life Information Network (MarLIN) database. It is acknowledged that the MarLIN assessments have limitations. These limitations have been taken in to account and other information and data accessed where relevant. Definitions of receptor sensitivity are provided in ***Table 10.5.***

61. 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 10.5 Definitions of Receptor Sensitivity for Fish and Shellfish Ecology

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.
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

10.4.3.4 Value

62. 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 10.6.***

Table 10.6 Definitions of the Value Levels for Fish and Shellfish Ecology

Value	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

10.4.3.5 Magnitude

63. The magnitude of an effect will be 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 10.7***.

64. With respect to duration of potential impacts, those associated with construction will be considered to be short term, occurring over a period of approximately 27 months. Impacts associated with operation will be considered longer term, occurring over the operational lifetime of the projects.

Table 10.7 Definitions of the Magnitude Levels for Fish and Shellfish Ecology

Value	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.

10.4.3.6 Impact Significance

65. ***Table 10.8*** outlines the significance criteria that will be applied to the assessment of an effect, taking into account the magnitude of effect and sensitivity of the receptor. In the context of impacts on fish and shellfish receptors, a low magnitude combined with a low sensitivity would result in a minor significance. Those effects which are moderate or major will be considered significant with respect to EIA assessments.

66. The matrix is seen as a framework to aid understanding of how a judgement has been reached from the narrative of each impact assessment and it is not a prescriptive formulaic method. To some extent defining impact significance is therefore qualitative and reliant on professional experience, interpretation and judgement.

Table 10.8 Impact Significance Matrix

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

67. As with the definitions of magnitude and sensitivity, the matrix used for a topic is clearly defined by the assessor within the context of that assessment. The impact significance categories are divided as shown in ***Table 10.9.***

Table 10.9 Impact Significance Definitions

Value	Definition
Major	Very large or large changes in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level
Moderate	Intermediate changes in receptor condition, which are likely to be important considerations at a local level.
Minor	Small changes in receptor condition, which may be raised as local issues but are unlikely to be important in the decision-making process.
Negligible	No discernible changes in receptor condition.
No change	No changes in receptor condition, therefore no impact

68. For the purposes of the EIA, 'major' and 'moderate' impacts are deemed to be significant. In addition, whilst 'minor' impacts are not significant in their own right, they may contribute to significant impacts cumulatively or through interactions.

69. Following initial assessment, if the impact does not require additional mitigation (or none is possible) the residual impact will remain the same. If however, additional mitigation is required there will be an assessment of the post-mitigation residual impact

10.4.4 Cumulative Impact Assessment

70. The potential for projects to act cumulatively on fish and shellfish ecology is considered in the context of the likely spatial and temporal extent of impacts as well as the combined impact on a sensitive or important habitat or species in the wider region arising from the proposed East Anglia TWO project and those arising from other projects either already constructed (where applicable and have not been considered as part of the baseline), consented or in the planning process.

10.4.5 Transboundary Impact Assessment

71. The distribution of fish and shellfish species is independent of national geographical boundaries and the assessment has taken into account fish stocks and populations distribution irrespective of national jurisdictions. In accordance with the Scoping Report (SPR 2017) and agreed by the Secretary of State in the Scoping Opinion, transboundary impacts have been scoped out of the EIA (Planning Inspectorate 2017).

10.5 Existing Environment

72. The characterisation of the existing environment is undertaken using data sources listed in ***Table 10.4*** plus other relevant literature.

10.5.1 Overview

73. The Southern North Sea (ICES Division IVc) is generally shallow (<50m depth) compared to the Central and Northern North Seas, with a greater species-richness and diversity (Calloway et al. 2002). As discussed in ***Chapter 13 Commercial Fisheries,*** the principal commercial species in terms of landings weights and values are plaice *Pleuronectes platessa* and sole *Solea solea,* with cod *Gadus morhua* and thornback ray *Raja clavata* also being of importance to the local inshore fleets. The average number (catch per standardised haul) of these species from 2008-2018 is shown in ***Figures 10.4, 10.2, 10.10,*** and ***10.7*** respectively.

74. The fish community also includes the smaller demersal species typically associated with the sea bed, including sandeels *Ammodytidae spp.*, dab *Limandalimanda*, solenette *Buglossidium luteum*, grey gurnard *Eutrigla gurnardus* and common dragonet *Callionymus lyra*, (Calloway et al. 2002). Dab and gurnard are generally the most abundant species recorded in the southern North Sea, feeding on numerous different prey taxa ability and able to exploit wider habitats (Sell and Kroncke 2013). Sandeels, alongside Gobies *Gobiidae spp*. (which are also present widely), play an important role as prey species (Teale 2011).

75. Other species often found in the southern North Sea include pogge *Agonuscataphractus*, and flounder *Platichthys flesus* in addition to more "southern" species including poor cod *Trisopterus minutus*, bib *Trisopterus luscus*, red mullet *Mullus surmuletus*, sardine *Sardina pilchardus*, lesser weever *Echiichthys vipera*, anchovy *Engraulis encrasicolus*, tub gurnard *Chelidonichthys lucerna*, John Dory *Zeus faber*, bass *Dicentrarchus labrax*, blacksea bream *Spondyliosoma cantharus*, horse mackerel *Trachurus trachurus* and mackerel *Scomber scrombus* (Cefas 2007; Corten et al. 1996).

76. Over 23 different elasmobranch species (sharks, skates and rays) have been recorded in the North Sea with the most common shark species, spurdog *Squalus acanthias*, lesser spotted dogfish *Scyliorhinus canicula* and smooth hound *Mustelus asterias* concentrated in the western part of the North Sea (Daan 2005). Among the rays, starry rays *Amblyraja radiata* are found offshore in the central North Sea within 50 - 100m depth, while thornback ray, spotted ray *Raja montagui* and blonde ray *Raja brachyura* are widespread in inshore waters around much of the British Isles (Cefas 2009a; Daan 2005). Juvenile undulate rays *Raja undulata* have been recorded off the Norfolk coast with egg cases recorded along the north Norfolk coast and at Felixstowe (Shark Trust 2012). Sightings or landings of other elasmobranch species, such as the common skate *Dipturus batis* complex,

basking shark *Cetorhinus maximus,* tope *Galeorhinus galeus,* thresher shark *Alopias vulpinus* and porbeagle *Lamna nasus* are infrequent or rare given their population status or their spatial distribution (Ellis 2005; NBN Gateway 2013).

77. Diadromous species have the potential to transit through the offshore development area during seasonal migrations between the sea and riverine environments, potentially for spawning and nursery life-history stages. Species with recorded presence in the southern North Sea, rivers and coastal regions of East Anglia are listed below.

- Sea lamprey *Petromyzon marinus* and river lamprey *Lampetra fluviatilis* are rarely observed in UK coastal waters, estuaries and accessible rivers (JNCC 2007).
- The East Anglian coastal waters are thought to be feeding areas for sea trout spawned in rivers in the north east of England as well as East Anglian rivers including; the Glaven, Wensum and Yare (Tingley et al. 2007).
- European eel *Anguilla Anguilla* is reported to migrate to local rivers including the Waveney, Yare, Bure and Deben (Defra 2010); and
- Smelt *Osmerus esperlanus* has been observed to shoal in estuaries including the lower tidal reaches of the Waveney and Yare and Alde-Ore Estuary (Colclough and Coates 2013; Natural England 2018).

78. Allis shad *Alosa alosa* and twaite shad *Alosa fallax* are considered to have a higher presence elsewhere in rivers and estuaries in Ireland, Wales and in the Solway Firth, than the Southern North Sea (Roche 2008, Aprahamian 1989; Maitland and Lyle 2005). Although formerly known to spawn in several English river systems, the only recently-confirmed spawning site in England is the Tamar Estuary, Devon (Jolly et al. 2012).

79. The southern North Sea (ICES Division IVc) supports commercially important shellfish species including brown crab *Cancer pagurus* lobster *Hommarus gammarus*, velvet swimming crab *Necora puber*, brown shrimp *Crangon crangon*, pink shrimp *Pandalus montagui* and the edible common whelk *Buccinum undatum*.

80. Shellfish species of lower commercial importance relevant to the offshore development area include common prawn *Palaemon serratus*,green crab *Carcinus maenas,* spider crab *Majidae*, cuttlefish *Sepiidae*, octopus *Octopoda*. and squid *Teuthida*.

81. A limited number of shellfish species including blue mussel *Mytilus edulis*, native oyster *Ostrea edulis*, Pacific oyster *Crassostrea gigas*, razor clams *Ensis spp.* and cockle *Cerastoderma edule* are harvested at localised inshore locations including areas classified as shellfish harvesting areas (FSA 2013).

10.5.2 Fish

10.5.2.1 Previous Surveys in the Former East Anglia Zone

82. Results of desk studies and East Anglia ONE and East Anglia THREE surveys show that species composition is similar across the regional study area, with abundance of key fish species varying seasonally and with distance from shore. Site specific surveys undertaken at East Anglia ONE and East Anglia THREE windfarm sites correlate with findings of other data available for the area (MMO landings data and IBTS data) and therefore it can be assumed with relatively high confidence that species composition in the East Anglia TWO offshore development area is the same as for East Anglia ONE and East Anglia THREE windfarm sites.

83. Considering the proximity and overlap between the projects, data from the ZEA used to inform the impact assessments for East Anglia ONE and East Anglia THREE is relevant for the proposed East Anglia TWO project, as discussed in ***Appendix 10.2***. Given the relatively homogenous nature of fish communities across the former East Anglia Zone, fish species composition and abundance in the offshore development area are unlikely to vary significantly to what has previously been recorded.

84. Scientific beam trawl surveys undertaken for East Anglia ONE recorded a total of 33 fish species. In general terms, the species caught in greatest numbers were sand goby *Pomatoschistus minutus*, solenette *Buglossidium luteum*, Raitt's sandeel *Ammodytes marinus* and lesser weever *Echiichthys vipera*. Greater sandeel *Hyperoplus lanceolatus*, sole *Solea solea*, pogge *Agonus cataphractus*, plaice *Pleuronectes platessa*, whiting *Merlangius merlangius* and lesser sandeel *Ammodytes tobianus* were also caught, although to a lesser extent. Elasmobranchs such as lesser spotted dogfish *Scyliorhinus canicula* and thornback ray *Raja clavata* were also found in beam trawl samples (EAOW 2012).

85. Otter trawl surveys undertaken for East Anglia THREE indicated that dab *Limanda limanda*, plaice and whiting had the highest abundance (based on catch per unit effort (CPUE)). Of the other 15 species recorded, the species with the highest CPUE was herring *Clupea herrangus*. Results from the 4m beam trawl survey also found that dab and plaice had the highest CPUE (with whelk *Buccinum undatum* being the third most recorded (EATL 2015).

86. Data sets from both East Anglia ONE and East Anglia THREE surveys were broadly similar in terms of species composition; however, there were differences in abundance considered to be a result of different distances offshore of sampling locations. It is expected that species composition of the East Anglia TWO windfarm site and offshore cable corridor will be similar to that of East Anglia ONE windfarm site and export cable route, due to the relative distance from shore and water depths.

10.5.2.2 International Beam Trawl Surveys

87. IBTS data recorded in the local study area (ICES rectangles 33F1, 33F2) have been analysed and used to further characterise the fish and shellfish community in the offshore development area.

88. The 65 species present in the local study area (***Figure 10.1***) expressed as their average abundance (CPUE) in IBT surveys (first and third quarters) for the years 2008-2018 is given in ***Table A10.6*** in ***Appendix 10.2***. Great sandeel CPUE was highest in the East Anglia TWO windfarm site (33F2) at 273.41 (***Figure 10.22***), followed by whiting at 110.01 (***Figure 10.8***) and herring at 53.91 (***Figure 10.13***). Whiting CPUE was highest in the offshore cable corridor (33F1) at 26.99 (***Figure 10.8***) followed by herring at 6.59 (***Figure 10.13***) and Dab at 4.96.

10.5.2.3 Commercial species

89. It is important to consider that commercial fisheries data do not necessarily provide an accurate picture of community or species composition, relative abundance or biomass. This is because the species and associated quantities available for landing are determined through the system of Total Allowable Catches (TACs) and quotas (***Chapter 13 Commercial Fisheries***) and allocated quota varies between fleets and individual vessels. Therefore, landings do not necessarily reflect either abundance or biomass and in any case are not corrected for effort.

90. Furthermore, vessels hold quotas for certain species and therefore focus on targeting these species whilst other species which cannot be landed due to a lack of quota are discarded at sea. Stock conservation measures (e.g. seasonal closures) may also influence the pattern of landings, and the absence of a species from statistics does not indicate that it is absent within a given sea area. In addition, 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. Commercial landings data cannot therefore be considered reflective of species composition in a given area.

91. MMO data has therefore been used to provide an indication of the commercial species present. These data have been presented by ICES rectangle and analysed in order to identify those species to be taken forward for the impact assessment, as detailed in ***section 10.5.5.***

10.5.2.3.1 UK MMO Landings data

92. The East Anglia TWO windfarm site and offshore cable corridor are within ICES rectangles 33F2 (offshore area) and 33F1 (inshore area). Historically key commercial fishing species landed from rectangle 33F1 (by % catch contribution) were; sprat (31%), cod (18%), sole (16%, skates and rays (9%) and whelks (8%). Key commercial species from rectangle 33F2 (% catch contribution) were; plaice (45%), sprat (15%), sole (11%), horse mackerel (8%) and cod (5%) (MMO landings data 2004-2013).

93. Data from 2012 to 2017 (***Table A10.7*** in ***Appendix 10.2***) show a difference in key commercial fishing species landed from rectangles 33F1 and 33F2 (by % catch contribution) are; whelks (51%) scallops (14%), brown shrimp (6%) cod (3%), sole (3%), herring (4%) and lesser spotted dogfish (2%). Key commercial species from rectangle 33F2 (% catch contribution) are; herring (58%), whelks (24%), and sole (3%) (MMO landings data 2018b).

10.5.2.4 Spawning and Nursery Grounds

94. Spawning and nursery grounds have been described as sensitive areas by ICES (ICES 2012). The location of these grounds and associated spawning intensity have been defined based on Coull et al. (1998), Ellis et al. (2012) and Aires et al. (2014). These papers are based on a review of published data and provide broad scale descriptions of the spatial and temporal extent of spawning grounds and spawning duration. Therefore in the context of the proposed East Anglia TWO project, use of these data sources can be considered to represent conservative (maximum) estimates.

95. ***Table 10.10*** and ***Figures 10.3, 10.5, 10.7, 10.9, 10.11, 10.14, 10.19, 10.21 10.26***, ***10.29, and 10.45*** show the spatial overlap of spawning and nursery grounds within the offshore development area and the importance of these species commercially and in terms of conservation designation. ***Table 10.11*** shows seasonal spawning activity, by species and overlap with the regional study area.

Table 10.10 Spatial Overlap between Offshore Development Area with Key Species Spawning and Nursery Areas.

	East Anglia TWO Overlap			
Species	**Spawning**	**Nursery**	**Commercial importance**	**Conservation Designation**
Plaice (***Figure 10.5***)	Y	Y	High	UK BAP, IUCN (least concern)
Sole (***Figure 10.3*** (Dover sole) and ***Figure 10.11*** (Lemon sole))	Y	Y	High	UK BAP
Cod (***Figure 10.7***)	Y	Y	Medium	UK BAP, OSPAR, IUCN (vulnerable)
Whiting (***Figure 10.9***)	Y	Y	Medium	IUCN (least concern)
Mackerel (***Figure 10.19***)	N	Y	Medium	IUCN (least concern)
Sandeel sp (***Figure 10.26***).	Y	Y	Low	UK BAP
Sprat (***Figure 10.21***)	Y	Y	Low	UK BAP
Atlantic herring (***Figure 10.14***)	N	Y	Low	UK BAP, IUCN (least concern)
Sea trout	N	N	Medium (targeted by licensed fisheries off the coast of East Anglia)	UK Biodiversity Action Plan (BAP), IUCN (lower risk/least concern)
Spurdog	Not defined	Not defined	Medium	UK BAP, OSPAR, IUCN (vulnerable)
Thornback ray (***Figure 10.28***)	Not defined	Y	Medium	OSPAR, IUCN (near threatened)
Tope (***Figure 10.28***)	Not defined	Y	Low	UK BAP, IUCN (vulnerable)

Table 10.11 Species with Spawning and/or Nursery Grounds in the Offshore Development Area (Coull et al. 1998; Ellis et al. 2010,2012)

Species	Spawning season and intensity in the offshore development area												Nursery Grounds	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	East AngliaTWO Windfarm site	Offshore cable corridor
Plaice	●	●											n/a	
Dover sole				●									n/a	
Cod		●	●											
Lemon sole														
Whiting													n/a	n/a
Mackerel*					●	●	●							
Sandeel sp.														
Sprat					●	●								
Herring*													n/a	
Thornback ray				●	●	●	●	●					n/a	
Tope	Gravid females present year round													

Spawning times and Intensity colour key: orange= high intensity spawning / nursery ground, yellow= low intensity spawning / nursery grounds, grey= unknown spawning / nursery grounds, ● = peak spawning, n/a= no overlap with spawning / nursery grounds
*For these species there is no overlap with spawning grounds however they are within close proximity to the offshore development area.

10.5.3 Shellfish

96. Shellfish landings within the former East Anglia Zone are comparatively low in a national context, constituting approximately 2.1% of landings by weight, with the majority consisting of edible crab *Cancer pagurus*. The shellfish reported in ICES rectangles covering the former East Anglia Zone are presented in ***Table 10.12*** in 2011.

Table 10.12 Shellfish reported in ICES rectangles covering the Offshore Development Area (MMO 2011).

List of Shellfish Species Landed from the former East Anglia Zone (MMO 2011)			
Species		**Presence within ICES Rectangles**	
Common Name	**Scientific Name**	**33F1**	**33F2**
Crustaceans			
Brown shrimp	*Crangon crangon*	✓	-
Common prawn	*Palaemon serratus*	✓	-
Velvet crab	*Necora puber*	✓	-
Edible crab	*Cancer pagurus*	✓	✓
Crawfish	*Palinurus spp.*	✓	-
Green crab	*Carcinus maenas*	✓	-
Squat lobster	*Galatheoidea spp.*	-	✓
Lobster	*Homarus gammarus*	✓	✓
Nephrops	*Nephrops norvegicus*	✓	✓
Spider crab	*Majidae spp.*	✓	✓
Molluscs and Bivalves			
Queen scallop	*Aequipecten opercularis*	✓	-
King scallop	*Pecten maximus*	✓	✓
Cephalopods			
Cuttlefish	*Sepiida*	✓	✓
Octopus	*Octopoda*	✓	✓
Squid	*Teuthida*	✓	✓
Gastropods			
Whelks	*Buccinum undatum*	✓	✓

97. Shellfish species landed from the regional study area, include cockles *Cerastoderma edule*, edible crab, lobster, whelks and brown shrimps *Crangon crangon*. The majority of landings for these species are however recorded in coastal rectangles (i.e. 34F1 and 32F1) to the north and south-west of the offshore development area.

98. Almost all commercial landings recorded from ICES statistical rectangles relevant to the proposed East Anglia TWO project come from the offshore cable corridor (inshore) (***Table A10.7*** in ***Appendix 10.2***). By weight, whelks constituted the highest landings, whilst those of edible crab and lobster, were considerably lower.

10.5.4 Designated Sites and Protected Species

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

- Diadromous migratory species (***section 10.5.4.1***);
- Elasmobranchs (***section 10.5.4.2***); and
- Other species with designated conservation status (***section 10.5.4.3***).

100. Detailed information on the ecology, conservation status and the use that these species may make of the offshore development area is detailed in ***Appendix 10.2***.

101. There are no Special Areas of Conservation (SACs) designated for the below species (either as a primary or secondary interest feature) within 50km of the East Anglia TWO windfarm site and offshore cable corridor (SPR 2017), however these Annex II species are considered within the EIA.

- Atlantic salmon *Salmo salar*;
- Sea lamprey;
- River lamprey;
- Allis shad; and
- Twaite shad.

102. A Habitats Regulations Assessment (HRA) screening exercise has been undertaken to consider possible impacts on any designated sites, and all sites have been screened out with regard to potential for likely significant effect. An Information to Support the Appropriate Assessment Report has been submitted with the DCO application (document reference 5.3).

103. There are areas of sandbank habitat inshore of the East Anglia TWO offshore cable corridor which are supporting features of the Outer Thames Estuary Special Protection Area (SPA). This SPA is designated for wintering populations of red-throated diver *Gavia stellata* that it supports. The primary prey of the red-throated diver is sandeel, although they are also considered to occasionally consume crustaceans and molluscs. Direct impacts on this habitat have been largely avoided through the site selection process however an assessment of construction and decommissioning impacts on sandeel and other fish species indirectly associated with the site is presented in ***sections 10.6.1*** and ***10.6.2.***

104. In addition, the offshore development area overlaps with the Southern North Sea SAC which is designated for harbour porpoise *Phocoena phocoena*.

105. The offshore cable corridor is 2.1km from the Orford Inshore MCZ. It is predicted that there would be no potential for the proposed East Anglia TWO project activities to adversely impact upon the sites' designated features of subtidal mixed sand and gravels. This is due to a lack of physical overlap and negligible impact in the far-field as a result of an increase in suspended sediment concentrations during construction (see ***section 7.6.1.5*** of ***Chapter 7 Marine Geology Oceanogrpahy and Physical Processes***). This conclusion is supported by an assessment (EATL 2016) that was carried out for the East Anglia THREE project which is closer to the MCZ at only 300m away. This assessment was carried out when the MCZ was a recommended MCZ (rMCZ). The East Anglia THREE assessment concluded that there would be, at worst, negligible impact from indirect effects and concluded no adverse effect on the site should it be designated. Therefore, the MCZ is not considered further.

106. No fish or shellfish species are listed as qualifying features for any of these designated sites. However, in the case of the Outer Thames Estuary SPA and and Southern North Sea SAC, the importance of some fish species as prey for marine mammals and birds, including Annex II species should also be acknowledged.

107. There are 35 species of fish included in Natural England's Priority Species List (formerly the UK BAP list). A summary of the fish and shellfish species with recognised conservation status which have the potential to be present within the development area is provided below.

108. Whilst not a designated species, seabass *Dicentrarchus labrax* has been placed under special protection measures due to fishing pressure and evidence of reduced reproduction output (MMO 2017). Whilst, there is little evidence of the offshore development area being an important environment for seabass, this ES considers impacts to important seabass habitats as discussed in ***sections 10.6.1*** and ***10.6.2*** and ***Figure 10.12*** shows historic seabass fishing areas.

109. Sea Bass Fisheries Conservation UK (SBFC UK) is a two-year European Maritime Fisheries Funded (EMFF) project led by Cefas committed to promoting long-term sustainable bass fisheries in the UK. Working closely with regional Inshore Fisheries Conservation Authorities (IFCAs), the project aims to establish regional fisher-led data collection surveys and collaborations to gather knowledge of regional and seasonal movements and distribution of bass throughout their life stages (juvenile, maturing and adult fish). Data from this project are not currently available.

10.5.4.1 Diadromous Species

110. Diadromous species with the potential to access the proposed East Anglia TWO project during the marine migration phase of their life cycle are listed in ***Table 10.13.*** None of these species was encountered during surveys for East Anglia THREE. The presence of certain species, however, (e.g. sea trout, European eel, smelt and river lamprey) is well documented in the offshore development area (Potter and Dare 2003, Colclough and Coates 2013) and these and the other species listed are also occasionally recorded in IBTS samples and MMO commercial landings statistics.

Table 10.13 Diadromous Species of Conservation Interest Potentially Present in the Offshore Development Area

Species	Conservation Status							
	UK BAP	OSPAR[4]	NERC 2006[5]	ICUN Red List[6]	Bern Convention	CITES	W&C 1981[7]	Habitats Directive
European eel	✓	✓	✓	Critically Endangered	-	✓	-	-
Allis shad	✓	✓	✓	Least Concern	✓	-	✓	✓
Twaite shad	✓	✓	✓	Least Concern	✓	-	✓	✓
Sea lamprey	✓	✓	✓	Least Concern	✓	-	-	✓
River lamprey	✓	✓	✓	Least Concern	✓	-	-	✓
Sea trout	✓	✓	✓	Least Concern	-	-	-	-

[4] OSPAR - Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic – Threatened or declining species
[5] NERC Act 2006
[6] IUCN - International Union for the Conservation of Nature – Red-listed species
[7] Wildlife and Countryside Act 1981

Species	UK BAP	OSPAR[4]	NERC 2006[5]	ICUN Red List[6]	Bern Convention	CITES	W&C 1981[7]	Habitats Directive
	Conservation Status							
Smelt	✓	✓	✓	Least Concern	-	-	-	-

10.5.4.2 Elasmobranch Species (sharks and rays)

111. Elasmobranchs have slow growth rates and low reproductive output compared to other species groups (Camhi et al. 1998). As a result, stock resilience to fishing mortality is low (Smith et al. 1998) and recovery rates are likely to be slow where fisheries have depleted abundance (Holden 1974, Bonfil 1994, Musick 2005). A summary of the principal species with conservation status and /or declining stocks potentially present in the vicinity of the local study area is given in ***Table 10.14***. Of the species listed below only thornback ray were recorded during site specific surveys.

Table 10.14 Elasmobranch Species of Conservation Interest Potentially Present in the Offshore Development Area

Species	Conservation Status							
	UK BAP	OSPAR	NERC 2006	ICUN Red List	Bern Convention	Habitats Directive	CITES	W&C 1981
Sharks								
Basking shark	✓	✓	✓	Vulnerable	✓	-	✓	✓
Starry smoothhound	-	-	-	Vulnerable	-	-	-	-
Smoothhound	-	-	-	Least Concern	-	-	-	-
Spurdog	-	✓	-	Vulnerable	-	-	-	-
Thresher shark	-	-	-	Vulnerable	-	-	-	-
Tope	-	-	✓	Vulnerable	-	-	-	-
Skates and Rays								
Blonde ray	-	-	-	Near threatened	-	-	-	-
Cuckoo ray	-	-	-	Least concern	-	-	-	-

Species	Conservation Status							
	UK BAP	OSPAR	NERC 2006	ICUN Red List	Bern Convention	Habitats Directive	CITES	W&C 1981
Common skate complex[8]	✓	✓	✓	Critically endangered	-	-	-	-
Spotted ray		✓		Least concern	-	-	-	-
Thornback ray		✓		Near threatened	-	-	-	-
Undulate ray[9]	✓	✓	✓	Endangered	-	-	-	-
White skate	✓	✓	✓	Endangered	-	-	-	-

10.5.4.3 Other Species of Conservation Importance

112. Other fish and shellfish species which have designated conservation status and are present (or potentially present) in the offshore development area are listed in ***Table 10.15***. It should be noted that a number of the species listed are targeted commercially in the offshore development area, as detailed in ***Chapter 13 Commercial Fisheries***.

[8] Iglesias et. al. (2010) has revealed that common skate actually comprises two species: *Dipturus intermedia* and *Dipturus flossada*. Common names already in use for these species are the flapper skate and blue skate respectively, although it remains to be seen if these become widely accepted (Iglesias et al*.* 2010, Shark Trust 2009).

[9] *Raja undulata* is considered to be occasionally present off the East Anglian coast (Shark Trust 2009) and occurs locally in the Eastern English Channel (Coelho et al. 2009).

Table 10.15 Conservation status of fish and shellfish species relevant to the proposed East Anglia TWO project

Species	Conservation Status							
	UK BAP	OSPAR	NERC 2006	ICUN Red List	Bern Convention	Habitats Directive	CITES	W&C 1981
Demersal Species								
Cod	✓	✓	✓	Vulnerable	-	-	-	-
Plaice	✓	-	✓	Least concern	-	-	-	-
Gobiidae: Sand goby, common goby	-	-	-	Least concern	✓	-	-	-
Lesser sandeel	✓	-	✓	-	-	-	-	-
Common sole	✓	-	✓	-	-	-	-	-
Whiting	✓	-	✓	-	-	-	-	-
Ling	✓	-	✓	-	-	-	-	-
European hake	✓		✓	-	-	-	-	-
Pelagic Species								
Herring	✓	-	✓	Least concern	-	-	-	-
Horse mackerel	✓	-	✓	-	-	-	-	-
Mackerel	✓	-	✓	Least concern	-	-	-	-
Shellfish								
Horse mussel	-	✓	-	-	-	-	-	-
Blue mussel	✓	✓	-	-	-	✓	-	-
Dog whelk	-	✓	-	-	-	-	-	-
Crawfish	✓		✓	-	-	-	-	-
Fan mussel	✓		✓	-	-	-	-	✓
Ocean quahog	-	✓	-	-	-	-	-	-
Native oyster	✓	✓	✓	-	-	-	-	-

10.5.5 Prey Species and Food Web Linkages

113. A number of species which occur in the local study area have a role in the North Sea's food web as prey for predators such as birds, marine mammals and piscivorous fish.

114. Abundant species with high biomass such as sandeels (Ammodytidae) and clupeids (e.g. herring and sprat) play an important functional role in North Sea food web dynamics. Such species represent an important food web link because they occupy intermediate trophic levels, are significant predators of zooplankton and represent a key dietary component for a variety of aquatic and terrestrial predators. The distribution of both these species groups overlap with the proposed East Anglia TWO project. IBTS survey data indicates that clupeids are more abundant than the Ammodytidae in those ICES rectangles that would be occupied by the proposed East Anglia TWO project (***Table A10.6*** in ***Appendix 10.2)***.

115. Species of the Ammodytidae and Clupeidae are important prey for piscivorous fish such as elasmobranchs, gadoids, bass, mackerel, and sea trout, amongst others (ICES 2005a; ICES 2005b ICES 2006; ICES 2008; ICES 2009). In addition, the demersal egg mats of herring are known to aggregate fish predators (Richardson et al. 2011). The diets of marine mammals such as seals *Phoca spp.* and harbour porpoise *Phocena phocena* are also subsidised by sandeels and clupeids to varying degrees (Santos and Pierce 2003; Santos et al. 2004). Both species groups are also an important resource for seabirds; this is especially true of sandeels which are important prey for kittiwakes, razorbills, puffins and terns, particularly during the breeding season (Wright and Bailey 1993; Furness 1999; Wanless et al. 1998; Wanless et al. 2005). ***Chapter 11 Marine Mammals*** and ***Chapter 12 Offshore Ornithology*** consider the impacts upon predator species resulting from impacts upon fish and shellfish prey species assessed within this chapter.

10.5.6 Species Taken Forward for Assessment

116. Key species identified, and the rationale for their inclusion within the assessment, are provided ***Table 10.16.*** Detailed information about the ecology of these species and the use that they may make of the study area is provided in ***Appendix 10.2.*** Note that for some impacts, species are not considered on an individual basis but by functional group (e.g. benthic, demersal or pelagic fish, or shellfish).

Table 10.16 Key fish and shellfish species taken forward for assessment of the potential impacts from the proposed East Anglia TWO project

Relevant Fish and Shellfish Species	Rationale
Commercial demersal fish species	
Dover sole	• Abundant throughout the regional study area • UK BAP species. • Commercially important species in the regional study area • High intensity spawning grounds in offshore development area • Low intensity nursery areas in the inshore and offshore cable corridor
Plaice	• Abundant throughout the regional study area. • UK BAP listed species. • Low intensity spawning areas in the regional study area • Commercially important species in the regional study area • Low intensity nursery areas in the inshore and offshore cable corridor
Cod	• UK BAP and OSPAR listed species and ‘vulnerable’ on the IUCN Red List. • Commercially important species to local fishing vessels in the study area • Low intensity spawning areas in the East Anglia TWO Windfarm site and outer edge of offshore cable route • Low intensity nursery areas in the regional study area
Whiting	• Abundant throughout the regional study area. • UK BAP listed species. • Extensive spawning grounds around the UK including in the regional study area • Low intensity spawning ground in offshore development area

Relevant Fish and Shellfish Species	Rationale
Lemon sole	• Present throughout the regional study area • Extensive North Sea spawning and nursery grounds including in the regional study area
Seabass	• Commercially important to local fisheries and relatively abundant, particularly in areas in the proximity of the offshore cable corridor • Recent conservation concerns have led to changes in regulation to the fishing of seabass
Commercial pelagic fish species	
Herring	• Present in the offshore development area • UK BAP listed species • Low intensity nursery habitats within the proposed East Anglia TWO windfarm site • Key prey species for fish, birds and marine mammals. • Demersal spawner. • Hearing specialist (potentially sensitive to underwater noise).
Sprat	• Present in the offshore development area. • Important prey species for fish, birds and marine mammal species. • Spawning areas (undefined intensity) present within the study area. • Nursery areas (undefined intensity) within the regional study area.

Relevant Fish and Shellfish Species	Rationale
Ammodytidae (Sandeels)	
Greater sandeel Lesser sandeel Smooth sandeel Small sandeel	• Present in the offshore development area • UK BAP listed species • Prey species for fish, birds and marine mammals, including Annex II species • Demersal spawner
Elasmobranchs	
Rays, Skates and Sharks	• Present in the offshore development area • Some species are UK BAP or OSPAR listed and several are classified on the IUCN • Red-List with landings restricted or prohibited • Some species have important local commercial value • The proposed East Anglia TWO windfarm site is situated within low intensity nursery area for tope and undefined intensity nursery for rhornback rays • The offshore cable corridor is situated within low intensity nursery grounds for tope and thornback rays
Spurdog	• Likely to be present in the study area • Classified as critically endangered on IUCN Red-List • Previously of commercial value, landings now prohibited (zero TAC)

Relevant Fish and Shellfish Species	Rationale
Diadromous fish species	
Sea trout	• Present inshore of the offshore cable corridor • UK BAP listed species • Feeding grounds located in the proposed East Anglia TWO windfarm site • May transit/feed in the offshore development area 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 • May transit / feed in the offshore development area during marine migration
European smelt	• Considered to be of national importance • UK BAP listed species • Spawning populations present in some East Anglian rivers • May transit / feed in the offshore cable corridor
River lamprey Sea lamprey	• Present in some East Anglian Rivers • Sea lamprey is present in the offshore cable corridor. • UK BAP listed species and sea lamprey listed by OSPAR as declining and/or threatened. • May transit / feed in the study during marine migration
Twaite shad Allis shad	• Twaite shad is present in the offshore development area. • Allis shad is present in the proposed East Anglia TWO windfarm site. • UK BAP listed species • Potential (rarely) transit / feed in the study area during marine migration

Relevant Fish and Shellfish Species	Rationale
Non commercial fish species	
Includes grey gurnard, lesser weever fish and solenette (characterising species of the fish assemblage), and small demersal species Gobies	• Present/ abundant throughout the offshore development area • Possible prey items for fish, bird and marine mammal species • Sand Goby protected under the Bern convention
Shellfish (including mollusc) species	
Brown (edible) crab	• Present in the offshore development area • Commercially important species • May overwinter within the regional study area
Lobster	• Present in the offshore development area • Commercially important species in the proposed East Anglia TWO project
Brown and pink shrimp	• Present in the regional study area • Important prey species for fish • Commercially important species in the regional study area
Whelk	• Of increasing commercial importance in the regional study area
Scallops	• Present in the offshore development area • Commercially important species

10.5.7 Anticipated Trends in Baseline Conditions

117. 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.

118. 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.

10.6 Potential Impacts

119. An assessment of the potential impacts of the proposed East Anglia TWO project on fish and shellfish receptors is given 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 windfarms and information and feedback obtained through consultation with statutory and non-statutory stakeholders. Potential impacts to be considered within the EIA have been agreed with statutory advisors (MMO, Natural England and Cefas) through the EPP (ETG meeting 12th April 2017). A summary of the potential impacts is provided in ***Table 10.17.***

Table 10.17 Potential Impact Pathways on Fish and Shellfish Receptors

East Anglia TWO project phase	Potential Impact Pathways
Construction	• Physical disturbance and temporary loss of sea bed habitat. • Increased suspended sediment concentrations and sediment re-deposition; • Re-mobilisation of contaminated sediments and sediment redistribution; • Underwater noise; and • Changes in fishing activity.
Operation	• Physical disturbance and permanent loss of sea bed habitat; • Re-mobilisation of contaminated sediments and sediment redistribution; • Introduction of hard substrate; • Operational noise; • EMFs; and • Changes in fishing activity.

East Anglia TWO project phase	Potential Impact Pathways
Decommissioning	• Physical disturbance and temporary loss of sea bed habitat. • Increased suspended sediment concentrations and sediment re-deposition; • Re-mobilisation of contaminated sediments and sediment redistribution; and • Changes in fishing activity.
Cumulative	• Increased suspended sediment concentrations; • Physical disturbance and permanent loss of sea bed habitat; • Introduction of hard substrate; and • Operational noise.

120. It is recognised that a progressive introduction of hard substrate and physical disturbance and loss / change to sea bed habitat for fish and shellfish would occur as project works advance and windfarm related offshore infrastructure is installed. Since it is expected that the full potential for impacts of the introduction of hard substrate would be most apparent during the operation phase rather than during construction, the introduction of hard substrate is assessed with other operational impacts in ***section 10.6.2.***

10.6.1 Potential Impacts during Construction

10.6.1.1 Impact 1 Physical Disturbance and Temporary Loss of Habitat;

121. During the construction phase, activities such as foundation installation (for wind turbines, offshore electrical platforms, construction, operation and maintenance platforms and met mast) and installation of inter-array, platform link and offshore export cables have the potential to result in physical disturbance and / or temporary loss of habitat to fish and shellfish receptors. Similarly, the presence of machinery on the sea bed (i.e. jack up vessels legs, vessel anchors) could also result in physical disturbance or temporary habitat loss.

122. As detailed in ***Table 10.2***, *a* maximum area of 11.35km^2 of sea bed habitat within the offshore development area would be temporarily disturbed or lost during the construction phase this equates to 3.19% of the offshore development area.

123. The disturbance would be temporary during the approximate 27 months of construction activity with the majority of disturbance occurring during installation of foundations and cables. Some elements of disturbance, such as that caused by jack-up vessel legs, will be highly localised and only occur over a period of a few days (see ***Chapter 6 Project Description***). Considering the availability of similar suitable habitat both in the offshore development area and in the wider context of the southern North Sea together with the intermittent and reversible nature of the effect, the magnitude of temporary sea bed disturbance during construction activities for the East Anglia TWO windfarm site is considered to be low.

124. During the foundation installation phase, temporary loss of habitat would be progressive leading up to that assessed for the operational phase in ***section 10.6.2.1*** resulting in a magnitude which would be at worst, low.

125. In the case of offshore export cable installation, the proportional loss of habitat would be considerably less than that associated with the East Anglia TWO windfarm site, temporary in duration and habitats would be expected to recover to pre-installation condition. This would occur as a result of the installation of up to two offshore export cables over a total distance of 160km (***Table 10.2***). The combined area of disturbance along the entire length of the offshore cable corridor would be 3.2km^2, as detailed in ***Table 10.2***. The installation of cable protection and cable crossings is regarded as permanent habitat loss / modification and are considered under the operational phase (Impact 1), see ***section 10.6.2.1***. In light of these considerations, the magnitude of effect for physical disturbance and temporary loss of habitat in the offshore cable corridor are considered to be low.

10.6.1.1.1 Impacts on Fish, Shellfish, Eggs and Larvae

126. Monitoring from North Hoyle and Barrow offshore windfarms in the UK, has shown that results from pre and post construction of commercial fish species being broadly comparable and with long term trends in the regional areas (Cefas 2009). In conjunction with this, sampling undertaken at reference sites associated with both of these windfarms, found no significant difference between the reference and windfarm sampling locations, or between fish species and numbers caught before both the windfarms were constructed (Cefas 2009).

127. In 2014 the MMO reviewed post-consent monitoring data, and also identified changes in fish and shellfish populations, although it was attributed to high natural variability rather than presence of windfarms (MMO 2014b). However, an increase in fish and shellfish abundance and diversity was reported in some UK and non UK windfarms (MMO 2014b). This effect was relatively minor in UK windfarms but more distinct changes were detected at some non UK windfarms, this may be due changes that develop as the project ages and the full effect may not be understood until after the stipulated three year post consent monitoring (MMO 2014b).

128. Thornback ray, blonde ray, lesser spotted dogfish, herring and sandeel are all benthic spawners. Herring and sandeel are however substrate specific spawners and therefore are potentially more susceptible to any impacts relating to physical disturbance and temporary habitat loss. Data relating to spawning grounds of thornback ray, blonde ray and lesser spotted dogfish is lacking from the scientific literature and are undefined by Ellis et al. (2010) and Coull et al. (1998). However, thornback ray, blonde ray and lesser spotted dogfish are not known to have the same degree of spawning substrate specificity as herring and sandeel. Therefore, any impacts relating to physical disturbance and temporary habitat loss will not exceed that assessed for herring and sandeel. As such, the receptors taken forward for assessment are herring and sandeels by virtue of their substrate specificity for benthic spawning and their habitat preferences (as shown in ***Table 10.16***).

129. In the case of herring, as shown by ***Figure 10.14***, the offshore development area does not overlap with spawning grounds as defined by Coull et al. (1998), however the East Anglia TWO windfarm site is 4.4km from a spawning area to the south-east. It can be seen from ***Figures 10.15*** to ***10.17*** that although herring larvae have been recorded within the East Anglia TWO windfarm site, this was at low abundances (2007-2017: 1-100 larvae per m^2), ***Figure 10.45*** also presents IHLS data in the form of a heat map where low abundances of larvae are also evident, with peak larval abundance associated with the Downs Stock further south in the English Channel.. North Sea herring larvae are known to drift in the order of hundreds of kilometres in the first 15 days after hatching (Dickey-Collas et al. 2009) and the origin of larvae may therefore be some distance from their eventual location. ***Chapter 7 Marine Geology, Oceanography and Physical Processes*** shows the sea bed across the offshore development area is relatively homogeneous and is characterised predominantly by sand, with some muddy sand, and does not represent suitable habitat for herring spawning.

130. As shown in ***Figure 10.26***, the offshore development area overlaps with sandeel spawning and nursery grounds indentified by Coull et al. (1998) and the whole offshore development areas overlaps with low intensity sandeel spawning and nursery grounds identified by Ellis et al. (2010). In the case of sandeels, due to their limited mobility, and in view of their ecological and conservation status and 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 (the boundary of the closest spawning group is located 4.4km away from the East Anglia TWO windfarm site) a medium sensitivity has also been assigned.

131. As stated above, the magnitude for physical disturbance and temporary loss of habitat for the offshore development area is considered as low. Therefore for both herring and sandeels an impact of **minor adverse** significance would be expected for the installation associated with the offshore cable corridor and **minor adverse** significance for other construction activities occurring within the East Anglia TWO windfarm site.

132. The eggs of the principal shellfish species in the offshore development area, such as edible crab, and lobster, remain attached to the abdomen of ovigerous females until hatching. Egg-bearing edible crabs typically remain buried in sediment for periods ranging from four to nine months, depending on the species. 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 the offshore development area 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). 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. However, due to the temporary and short-term nature of the effects, the sensitivity of these receptors is considered to be medium. As previously stated, the magnitude of the effect is negligible to low; therefore the resulting in an impact of **minor adverse** significance.

10.6.1.2 Impact 2: Increased Suspended Sediments and Sediment Re-Deposition

134. There is the potential for increased suspended sediment concentrations (SSC) and sediment re-deposition arising from different construction activities including; jacket suction caisson foundation preparation and installation, drilling operations, inter-array and platform link cable installation and offshore export cable installation.

135. The results of modelling SSCs and sediment redeposition across the offshore development area are described fully in ***sections 7.6.1.1, 7.6.1.3, 7.6.1.5*** and ***7.6.1.8*** of ***Chapter 7 Marine Geology, Oceanography and Physical Processes***. These sections also detail the type, duration and extent of each construction activity. The construction activities descibed above have the potential to disturb sediments from the sea bed to shallow depths of up to 3m (cable installation) and 45m depth.

136. For the installation of foundations, increases in SSC are likely to be low and within natural variability away from the immediate release locations, less than 10mg/l. These increases in SSCs will be found in the water column over a short period of time (a matter of days). Disturbed material will remain close to the sea bed and rapidly settle out (within tens of minutes). 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 becoming indistinguishable from background levels.

137. Cable installation is a relatively short term activity and therefore the effect is generally relatively short-lived. Enhanced concentrations will be greatest in the shallowest sections of the offshore cable corridor. In these locations the natural background concentrations are also greater than in deeper waters, typically up to 180mg/l. In shallow waters (less then 5m LAT) the concentrations of suspended sediment would approach 400mg/l at their peak. However, these plumes would be localised to within 1km of the release location and would persist for no longer than a few hours. After 180 hours following cessation of installation activities any plume would have been fully dispersed

138. As summarised above, during the construction period, disturbance to sea bed sediments would be limited in temporal and spatial extent due to the temporary nature of the activities and the dominance of sand sized material in the offshore development area.

139. Given that the expert-based assessments of the dynamic and passive plume effects on SSCs for the proposed East Anglia TWO project are consistent with the findings of the earlier modelling studies for the East Anglia ONE project (which showed limited extent and duration of increased SSCs), there is high confidence in the assessment of effects. This approach was also accepted for the consented East Anglia THREE project. Considering the relatively short duration and limited spatial extent of the effect, the magnitude of any impacts is assessed as low.

10.6.1.2.1 Physiological Effects of Fish Species

140. In general terms, juvenile and adult fish are mobile and would be able to avoid the localised areas disturbed by increased SSCs and sediment re-deposition. If displaced, these fish are able to move to adjacent, undisturbed areas within their normal habitat range.

141. Eggs and early larval stages of fish and shellfish do not however have the same capacity to avoid increased SSCs as juvenile or adult fish as they are either passively drifting in the water column or present on / attached to benthic substrates. The sensitivity of eggs and larvae is therefore considered to be higher than for later life stages and is the main focus of this assessment.

142. The re-deposition of sediments may affect fish eggs and larvae through smothering. Of the fish species, by virtue of being demersal spawners and the adhesive properties of the membranes, herring and sandeel eggs have the greatest potential to be affected by increased SSCs and sediment re-deposition. Consequently, herring eggs and larvae are considered to be the most sensitive to increased SSCs.

143. Laboratory studies have established that herring eggs are tolerant to elevated SSCs as high as 300mg/l and can tolerate short term exposure at levels up to 500mg/l (Kiørboe et al. 1981). These studies concluded that herring eggs suffered no adverse effects from suspended sediment concentrations in excess of the maximum levels expected from mining, dredging and similar operations. Herring eggs have been recorded to successfully hatch at SSCs up to 7000mg/l (Messieh et al. 1981).

144. Fine silt particles associated with increases in SSCs have the potential to adhere to the gills of larvae which could cause suffocation (De Groot 1980). Griffin et al. (2009) suggested that larval survival rates could be reduced at SSCs as low as 250mg/l. Larvae of most fish species are visual predators therefore, if visibility is reduced as a result of SSCs, this may impact foraging success (Johnston and Wildish 1981). Herring, plaice, sole and cod larvae sight prey at a distance of only a few millimetres (Bone and Moore 2008). There is evidence to suggest however that SSCs may enhance feeding rates by providing a visual contrast to prey items on the small perceptive scale used by the larvae. In addition larvae may be subject to reduced predation from larger visual planktivores in turbid environments (Bone and Moore 2008).

145. In a study which exposed Pacific herring *Clupea harengus pallasi* larvae to suspensions of estuarine sediment and volcanic ash at concentrations ranging from 0 to 8,000mg/l, Boehlert and Morgan (1985) found that maximum feeding incidence and intensity occurred at levels of suspension of up to 500mg/l above which feeding activity decreased.

146. Sandeels deposit eggs on the sea bed in the vicinity of their burrows between December and January. Grains of sand may become attached to the adhesive egg membranes. Tidal currents can cover sandeel eggs with sand to a depth of a few centimetres, however experiments have shown that the eggs are capable of developing normally and hatch as soon as currents uncover them again (Winslade 1971). Buried eggs experiencing reduced current flow, and therefore lower oxygen tension, can have delayed hatching periods, which is considered a necessary adaptation to survival in a dynamic environment (Dominguez and Vogel 2010, Hassel et al. 2004).

147. It is therefore considered that they represent the worst case and that eggs and larvae of other species are of lower sensitivity. The sensitivity of herring and sandeel eggs and larvae is taken as medium. Taking into account the low magnitude of effect predicted, the impact of increased SSCs on fish eggs and larvae is assessed to be of **minor adverse** significance.

10.6.1.2.2 Physiological Effects on Shellfish Species

148. Eggs and larvae are considered to be less tolerant to increased SSC than later life stages, with larvae being generally considered to be more sensitive than eggs (Appleby and Scarratt 1989). The eggs of edible crab and lobster remain attached to the abdomen of ovigerous females until hatching and the potential for eggs to be impacted by increased SCCs / sediment re-deposition is therefore at least partially influenced by the response / tolerance of the adult to increased SSC levels.

149. According to MarLIN (Neal and Wilson 2008), adult edible crab are considered to have a low sensitivity to increased suspended sediment concentrations (i.e. a change of 100 mgl^{-1} for 1 month) and a high rating for recoverability. The sensitivity of edible crab to smothering is also considered to be low. This is based on a benchmark which considers a scenario where the population of a species or an area of a biotope is smothered by sediment to a depth of 5cm for one month. Under this scenario crabs can escape from under silt and migrate away from an area, and consequently, smothering is not expected to result in mortality. As detailed in ***Chapter 7 Marine Geology, Oceanography and Physical Processes***, levels of sediment deposition associated with the project will not reach such a large level with modelled outputs for the cable corridor falling significantly under 1cm.

150. Migration of berried lobsters appears to be less extensive than that of berried edible crabs, and movements related to feeding or relocation to alternative habitat as size increases are also relatively localised (Pawson 1995). In a review of the effects of elevated SSCs on biota, Wilber and Clark (2001) report that in studies examining the tolerance of adult crustaceans, the majority of mortality was induced by concentrations exceeding 10,000mg/l (considerably higher than those generated by construction activity associated with the installation of the offshore export cable, which would reach 400mg/l at their peak).

151. Although there is no MarLIN benchmark assessment for lobster, they do however belong to the same taxonomic family (Nephropidae) as the spiny lobster for which there is a benchmark assessment, allowing relevant comparison. The MarLIN assessment concludes that spiny lobster are tolerant to increased SSCs and not sensitive to smothering. Given the physiological similarities between these species, it is reasonable to assume that sensitivities to increased SSCs and smothering will be similar for lobster. Taking a precautionary approach, a medium sensitivity has been assigned for shellfish as a whole, including whelks.

152. As stated above, the magnitude of effect for the installation of the offshore infrastructure in the offshore development area is considered to be low. Taking the medium sensitivity with the localised and temporary nature of the impact, meaning that area of habitat affected by the installation of the offshore cable corridor is proportionally small, the magnitude of effect on this receptor is low. In the case of crabs, the potential for any impact as a result of increased SSCs may further be reduced by their migration into deeper waters to spawn (Edwards 1979).

153. The impact of an increase in suspended sediment concentrations on general fish and shellfish egg and larval development is therefore assessed to be of **minor adverse** significance.

10.6.1.2.3 Physiological Effects on Sandeels

154. As sandeels spend a major proportion of their life cycle buried within the sea bed, increased SSCs and sediment re-desposition have the potential to adversely impact this species group.

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

156. From the above, it is apparent that sandeel adults have a comparatively high tolerance to SSCs and sediment re-deposition but in view of their limited mobility and substrate dependence, the sensitivity of sandeels to these effects is considered to be medium.

157. As shown by ***Figure 10.26*** the offshore development area overlaps with spawning and nursey areas, however the main sandeel habitats depicted by Jensen et al. (2011), do not overlap with the offshore development area. As discussed above, in view of the minimal spatial overlap with sandeel habitats and the short duration of the effect, the magnitude is assessed as low, giving an impact of **minor adverse** significance.

10.6.1.2.4 Changes to Composition of Demersal Spawning Grounds

158. Sediment re-deposition could result in changes to the particle size distribution of the sea bed giving rise to some loss of spawning grounds for substrate specific demersal spawning species such as herring. High levels of suspended sediments could also have the potential to deter spawning adults from entering traditional spawning areas.

159. Other than sandeels, (as discussed in ***section 10.6.1.2.3***), herring are the only demersal spawning species likely to be within the offshore development area. The offshore development area however does not overlap with defined herring spawning grounds but the closest spawning grounds are 4.4km from the East Anglia TWO windfarm site (***Figure 10.14***). Low abundances (<100 larvae per m^2) of ‘small’ herring larvae (categorised as <10mm by IHLS) have been recorded by the IHLS in some years (e.g. 2008-2018: 1-100 larvae per m^2) within the offshore development area (***Figures 10.15*** to ***10.17*** and ***Figure 10.45***). Based on the lack of suitable substrate for herring spawning within the offshore development area and the potential for herring larvae to potentially drift following hatching (Dicky-Collas et al. 2009), it is likely that these larvae originate from the nearby spawning grounds of the Downs stock.

160. As sediment re-deposition is localised and there is no suitable spawning substrate within the offshore development area, there is no potential for a change to the composition of established herring spawning grounds to occur (i.e. **no impact**). It is however acknowledged that there may be limited potential for increased SSCs to adversely impact on a negligible proportion of ‘small’ herring larvae (<10mm) (e.g. as assessed previously in ***section 10.6.1.2.1***, **minor adverse**).

10.6.1.2.5 Increased SSCs in Pelagic Spawning Areas

161. A limited number of spawning areas of pelagic spawning species overlap with the offshore development area (***Table 10.18***). It is important to consider that estimates of overlap are highly precautionary as suspended sediments will be released episodically and are unlikely to cover the whole of the overlap area at any one time. Note that values are given for both the total spawning area and discrete spawning area. Discrete spawning area refers to spawning grounds within close proximity to the offshore development area. These species do not however have the same level of spatial dependency on a specific substrate, unlike herring. In addition, it is recognised that sandeels show site fidelity to areas of the sea bed and do not tend to travel to spawn (Marine Climate Change Impacts Partnership 2018). Pelagic spawning species, in terms of potentially indirect effects on their spawning grounds are therefore considered to have a low sensitivity. As discussed above, the magnitude of the effect due to SSC is assessed as low, giving a significance of a **minor adverse** impact when combined with low sensitivity of pelagic spawning areas.

Table 10.18 Offshore Development Area Overlap with Pelagic Spawning Areas

Species	Total Spwaning Area (km^2)	Discrete Spawning Area (km^2)	Area of Offshore Development Area withing Discrete Spawning Area (km^2)	Percentage Overlap of Total Spawning Area	Percentage Overlap of Discete Spawning Area
Plaice	142,748	84,325	276	0.19%	0.33%
Cod	128,741	9,550	0	0%	0%
Whiting	120,436	14,544	247.9	0.21%	1.7%
Sandeel	251,257	40,383	302.9	0.12%	0.75%

10.6.1.3 Impact 3: Re-Mobilisation of Contaminated Sediments and Sediment Re-Deposition

162. As discussed in ***section 10.4.2.1.4***, benthic sampling was undertaken in all areas of the offshore cable corridor which were not sampled as part of the ZEA survey. As part of this, contaminant samples were collected from within the offshore cable corridor and windfarm site, as shown in ***Figure 8.2***.

163. Sediment disturbance could lead to the mobilisation of contaminants which may be lying dormant within sediment and could be harmful to fish and shellfish. The data in ***Table 8.12*** in ***Chapter 8 Marine Water and Sediment Quality*** illustrates that levels of contaminants within the East Anglia TWO windfarm site and offshore cable corridor are very low, therefore the magnitude of the effect is low. Marine Evidence based Sensitivity Assessment (MarESA) (MarLIN 2017) shows that, where contaminant levels are within environmental protection standards, marine species and habitats are not sensitive to changes that remain within these standards therefore the sensitivity of receptors is considered to be low.

164. All relevant construction activities would be covered by the 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.

165. As a result of the absence of significant existing contamination and the application of mitigation to avoid release of contaminants, the re-mobilisation of contaminated sediment during intrusive works is assessed to be of **negligible** significance.

10.6.1.4 Impact 4: Underwater Noise Impacts to Hearing Sensitive Species during Foundation Piling

166. The following assessment considers the potential for underwater noise generated by foundation piling to impact fish and shellfish receptors. Piles are generally expected to be driven but drilling may be required at some locations. In addition, other techniques, such as pile vibration, are also being considered (***Chapter 6 Project Description***). This will be confirmed post consent on receipt of more detailed geotechnical information.

167. It should be noted that both pile vibration and drilling are considered low-noise foundation installation methods in comparison to pile driving (Koschinski and Ludemann 2013). Therefore, for the purposes of this assessment under the worst case scenario (***Table 10.2***) it is assumed that all foundations will be installed using pile driving as this would result in the greatest noise impacts.

168. There are three main types of effect documented for fish:

- Physiological;
- Behavioural; and
- Environmental.

169. The physiological impacts associated with pile driving are considered to result in effects upon fish falling into the following categories: mortality (or death) ***section 10.6.1.4.5.1*** permanent injury or temporary injury (Boyle and New 2018), this is assessed in ***section 10.6.1.4.5.2*** . Behavioural impacts from pile driving range from small startled movements and / or swimming away from the noise source to changes in migratory patterns and / or cease reproductive activities (assessed in ***section 10.6.1.4.5.2***). Environmental effects include changes to prey species or feeding behaviour which are assessed in ***section 10.6.1.4.5.3.***

170. The following assessment is based on the outputs of the noise modelling undertaken by Subacoustech Environmental Ltd. and should be read with reference to ***Appendix 11.4.***

10.6.1.4.1 Fish and Shellfish Hearing

171. Depending on the hearing sensitivity of each particular species, the potential impact of noise on fish and shellfish may vary. From the limited studies conducted to date on the hearing of fish, it is evident that there are potentially substantial differences in auditory capabilities between individual fish species. The preferred approach to understand their hearing has therefore been 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). In line with this, the following groups have been proposed (Popper et al. 2014):

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

172. Hearing in shellfish species is poorly understood, however studies have shown that some species are able to detect sound. Pye and Watson (2004) reported that immature lobsters of both sexes detected sounds in the range 20–1000 Hz, whilst sexually mature lobsters exhibited two distinct peaks in their acoustic sensitivity at 20–300 Hz and 1000–5000 Hz.

10.6.1.4.2 Impact Criteria

173. The noise impact criteria used for assessment of the impact of piling noise are shown in ***Table 10.19***. These are based on Popper et al. (2014) which presents current best practice guidance on fish threshold criteria.

174. The sound pressure level (SPL) is used to characterise noise and vibration of a continuous nature. Peak SPLs (SPL_{peak}) are often used to characterise sound transients from impulsive sources, such as percussive impact piling. Sound exposure level (SEL) sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound source and the duration the sound is present in the acoustic environment. SEL_{cum} is the cumulative sound exposure level.

175. In some instances the noise levels used to define the Popper et al. (2014) criteria are the same for multiple effects. This is because data available to create the criteria is limited and therefore the approach is precautionary and most criteria are "greater than", (>) with a precise threshold not identified. All ranges associated with criteria defined as ">" are therefore somewhat conservative.

176. Furthermore, it should be noted that under Popper et al. (2014) guidance, the use of a quantitative approach for assessment of behavioural impacts on fish is not recommended, as the best research available is limited to very specific studies on species under artificial conditions. Behavioural criteria are instead described on the basis of the relative risk (high, moderate, low) to the animal at various distances from the source of noise (near (N), intermediate (I), and far (F)) (see ***Table 10.19***). For the purpose of this assessment, in line with the definitions suggested in Popper et al. (2014), these distances have been considered as follows:

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

177. For example, a species may theoretically show a reaction over 1km but it has low sensitivity in the far field meaning that the potential of an impact occuring is low.

178. Impulsive noise sources are described as having a rapid rise time, short duration and high peak pressure. A study into the distance at which underwater noise sources (from offshore windfarm piling and seismic surveys) 'transformed' from an impulsive to a non-impulsive noise revealed that, at a distance of between 2 - 3km the noise sources no longer contained the characteristics (in particular a high enough peak pressure) to be classed as an impulsive noise (Hastie et al. 2019). However, this study was completed in a shallow water environment, with a relatively flat sea bed, and the actual range at which a sound source transforms into a non-impulsive noise is likely to be dependent on a number of environmental variables and other sound source characteristics (Hastie et al. 2019).

Table 10.19 Impact Criteria used in the Assessment of Piling Noise on Fish (Source Popper et al. 2014)

Category	Mortality	Recoverable Injury	Temporary Threshold Shift (TTS)	Behavioural
Fish with no swim bladder	>219 dB SEL_{cum} or >213 dB SPL_{peak}	>216 dB SEL_{cum} or >213 dB SPL_{peak}	>>186 dB SEL_{cum}	(N) High (I) Moderate (F) Low
Fish with swim bladder not involved in hearing	210 dB SEL_{cum} or >207 dB SPL_{peak}	203 dB SEL_{cum} or >207 dB SPL_{peak}	>186 dB SEL_{cum}	(N) High (I) Moderate (F) Low
Fish with swim bladder involved in hearing	>219 dB SEL_{cum} or >213 dB SPL_{peak}	203 dB SEL_{cum} or >207 dB SPL_{peak}	186 dB SEL_{cum}	(N) High (I) High (F) Low
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

10.6.1.4.2.1 Assumptions and Considerations

179. It should be noted and taken into account that the underwater noise modelling and assessment is based on 'worst case' scenarios and precautionary approaches, this includes, but is not limited to:

- The maximum hammer energy to be applied and maximum piling duration is assumed for all piling locations; however, it is unlikely that maximum hammer energy applied and duration will be required at the majority of piling locations, as discussed in ***section 10.6.1.4.3.***

- The maximum predicted impact ranges are based on the location with the greatest potential noise propagation range and this was assumed as the worst case for each piling location.
- Impact ranges modelled for a single strike are from the piling location and do not take into account (i) the distance fish and shellfish species could move away from the piling location during mitigation measures, such as soft-start and ramp-up; or (ii) the potential disturbance and movement of fish and shellfish species away from the site as a result of the vessels and set-up prior to mitigation.

10.6.1.4.3 Noise Modelling

180. For the underwater noise modelling, two piling scenarios have been modelled, for both monopile and pin pile foundations, with the following maximum hammer energies;

- Monopiles up to 15m diameter with a maximum hammer blow energy of 4,000kJ (secured within the DCO and through the draft MMMP); and
- Pin piles up to 4.6m diameter with a maximum hammer blow energy of 2,400kJ (secured within the DCO and through the draft MMMP)..

181. A worst case scenario approach to the maximum hammer energy is required in the absence of detailed geotechnical information. However, the available evidence from construction surveys suggests that maximum hammer energy is rarely required. For example, at the recently constructed Beatrice Offshore Wind Farm, where within the ES it was estimated that the maximum hammer energy would be 2,300kJ, during the actual construction, the maximum hammer energy required ranged between 435kJ and 2,299kJ, with an average across the site of 1,088kJ (Beatrice Offshore Wind Farm Ltd 2018).

182. The East Anglia ONE Offshore Windfarm piling logs for the first four jacket foundations indicate that the maximum hammer energy used was 935kJ, 52% of the potential maximum hammer energy of 1,800kJ. The average hammer energy used over these first four jacket foundations was 787kJ, only 44% of the potential maximum hammer energy of 1,800kJ (East Anglia ONE Ltd 2019). This pattern is also shown for the remainder of the piling logs, with 74% of all the piled foundations using less than 50% of the 1,800kJ maximum hammer energy (less than 900kJ) and the remaining 24% of the piles foundations using between 50 and 63% of the 1,800kJ maximum hammer energy (up to 1,132kJ), with the actual maximum hammer of 1,132kJ only used for one pile location (taken from the Actual Pile Driving Energies Technical Note for East Anglia ONE Offshore Windfarm).

183. For each of the foundation types and hammer energies as outlined above, underwater noise modelling was undertaken at two representative locations within the East Anglia TWO windfarm site; one for the average water depth, and one for the worst-case water depth (*Table* 10.20). The modelling undertaken in the deepest water represents the worst-case scenario, as deeper water is conductive of higher noise levels and greater overall noise propagation (***Appendix 11.4***).

Table 10.20 Underwater noise modelling locations

Location	Worst-case location	Average water depth location
Latitude	52.1423°N	52.0564°N
Longitude	002.2541°E	002.1369°E
Water depth	55m	47.5m

184. To consider the cumulative Sound Exposure Levels (SEL_{cum}), the soft-start and ramp-up scenarios for both monopile and pinpile maximum hammer energies, along with the total duration and strike rates, were included in the noise modelling (***Table 10.21***). The ramp-up of maximum energy occurs over the first 30 minutes of piling, starting at ten percent of the maximum energy applied (of 400kJ for monopiles and 240kJ for pin piles), and gradually increasing in energy or strike rate until reaching up to eighty percent of the maximum. Following this, main piling commences, which may be carried out at up to maximum hammer energy applied where it stays for the remainder of the piling time for each monopile and pin pile. The monopile scenario includes a total of 9,300 strikes over 325 minutes (5 hours and 42 minutes). The pin pile scenario includes a total of 7,210 strikes over 199 minutes (3 hours and 31 minutes for each pin pile).

Table 10.21 Summary of the ramp-up scenario for monopiles and pin piles used for calculating the cumulative SELs

	Soft-start hammer energy	Ramp-up hammer energy	Maxmimum hammer energy applied (100%)
Monopile			
Monopile hammer energy	400kJ	Gradual increase from 400kJ to 3,200kJ (i.e. 10 to 80%)	4,000kJ
Number of strikes	150	300	Up to 8,850
Duration	10 minutes (15 strikes per minutes)	20 minutes (15 strikes per minute)	Up to 295 minutes (30 strikes per minute)

	Soft-start hammer energy	Ramp-up hammer energy	Maxmimum hammer energy applied (100%)
Pin pile			
Pin pile hammer energy	240kJ	Gradual increase from 240kJ to 1,920kJ (i.e. 10 to 80%)	2,400kJ
Number of strikes	150	300	Up to 6,760
Duration	10 minutes (15 strikes per minutes)	20 minutes (15 strikes per minute)	Up to 169 minutes per pile (40 strikes per minute)

185. For the SEL_{cum} criteria modelling, a fleeing animal approach was used, with a speed of 1.5m/s (Hirata 1999). All Popper et al. (2014) threshold criteria are unweighted. Further information on the parameters used for the underwater noise modelling and methodologies can be found in ***Appendix 11.4***.

186. Results of the underwater noise modelling using a fleeing animal approach in terms of maximum, minimum and mean impact ranges are shown in ***Table 10.22***. The impact ranges for fish mortality and potential mortal injury, recoverable injury and for temporary auditory injury (Temporary Threshold Shift (TTS)) are shown for both the installation of monopiles and pin piles, against their respective maxmimum hammer energies of 4,000kJ and 2,400kJ.

187. The installation of monopiles results in the greatest spatial impact range for fish species for SPL_{peak} thresholds, while the greatest impact for SEl_{cum} thresholds are from the installation of the pin piles. The greatest impact for each threshold criteria are therefore taken forward as the worst-case spatial impact for assessment (***Table 10.22***).

188. 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 500m and 470m for monopiles and pin piles respectively. The maximum impact ranges for the cumulative impact ranges are again for fish species with swim bladders for pin pile installation, with ranges of 6,000 and 29,000m for recoverable injury and TTS respectively (***Table 10.22***).

189. 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 piles (equating to 938 hours (39.2 days)) (***Table 10.2***).

190. 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.

191. The duration of piling is based on a worst case scenario and a very precautionary approach and as has been shown at other offshore windfarms, the duration used in the impact assessment can be overestimated. For example, during the installation of monopile foundations at the Dudgeon Offshore Windfarm (DOW) the impact assessment was based on an estimated time to install each monopile of up to 4.5 hours 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).

Table 10.22 Underwater noise modelling results for both monopile and pin pile maximum hammer energies, for the worst-case modelling location only (using a fleeing animal response). For the full set of modelling results (including for the average water depth modelling location) see *Appendix 11.4*.

Fish Group	Impact Criteria	Potential Impact	Range (m)					
			Monopile (maximum hammer energy 4,000kJ)			Pin pile (maximum hammer energy 2,400kJ)		
			Max	Mean	Min	Max	Mean	Min
Fish (no swim bladder)	>213 dB SPL_{peak}	Mortality and potential mortal injury	160	160	160	150	150	150
		Recoverable injury	160	160	160	150	150	150
	>219 dB SEL_{cum}	Mortality and potential mortal injury	<100	<100	<100	<100	<100	<100
	>216 dB SEL_{cum}	Recoverable injury	<100	<100	<100	<100	<100	<100
	>186 dB SEL_{cum}	TTS	27,000	22,000	17,000	29,000	24,000	19,000
Fish (with swim bladder not involved in hearing)	>207 dB SPL_{peak}	Mortality and potential mortal injury	500	500	500	470	470	470
		Recoverable injury	500	500	500	470	470	470
	210 dB SEL_{cum}	Mortality and potential mortal injury	<100	<100	<100	230	140	<100
	203 dB SEL_{cum}	Recoverable injury	4,500	3,900	3,100	6,000	5,200	4,300
	>186 dB SEL_{cum}	TTS	27,000	22,000	17,000	29,000	24,000	19,000
Fish (with swim bladder involved in hearing)	>207 dB SPL_{peak}	Mortality and potential mortal injury	500	500	500	470	470	470
		Recoverable injury	500	500	500	470	470	470
	207 dB SEL_{cum}	Mortality and potential mortal injury	1,200	960	690	2,200	1,800	1,400
	203 dB SEL_{cum}	Recoverable injury	4,500	3,900	3,100	6,000	5,200	4,300
	186 dB SEL_{cum}	TTS	27,000	22,000	17,000	29,000	24,000	19,000

10.6.1.4.4 Additional modelling – stationary animal model

192. Following from the underwater noise modelling results presented in ***Appendix 11.4*** and taking account of the feedback provided by the MMO to the PEIR (see ***Appendix 10.1***), additional modelling was conducted to explore the effects of using a stationary animal model for fish compared to the fleeing animal model. The additional stationary animal modelling is presented in ***Appendix 10.3,*** as agreed through the Benthic ETG in June 2019.

10.6.1.4.5 Noise Modelling Assessment

193. An assessment of the potential impact of underwater noise associated with piling activity is given below for fish and shellfish receptors.

194. In order to facilitate the assessment, and in line with Popper et al*.* (2014), fish receptors have been grouped into categories depending on their hearing system as outlined in ***Table 10.23.***

195. In the particular case of shellfish, given the lack of specific impact criteria, 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 10.23 Hearing Categories of Fish Receptors (* denotes uncertainty or lack of current knowledge with regards to the potential role of the swim bladder in hearing)

Category	Fish Receptors relevant to the proposed East Anglia TWO project
Fish with no swim bladder or other gas chamber	Sole Plaice Sandeels Mackerel Solenette Elasmobranchs River and sea lamprey Lesser weever
Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume	Atlantic salmon Sea trout Smelt(*) Seabass(*) Grey gurnard(*) Gobies

Category	Fish Receptors relevant to the proposed East Anglia TWO project
Fish in which hearing involves a swim bladder or other gas volume	Herring Sprat Cod Whiting European eel(*) Allis and Twait Shad

10.6.1.4.5.1 Mortality and Recoverable Injury

Fish with no swim bladder

196. 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 160m and up to 100m (for both mortality and potential for mortal injury at >219 dB SEL_{cum} and >216dB SEL_{cum} for recoverable injury) from the installation of monopiles (***Table 10.22***). Taking the small areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible.

197. The majority of fish receptors included within the group "fish with no swim bladder" (***Table 10.23***) 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 and the impact of mortality / recoverable injury is assessed to be of **negligible** significance.

198. An exception to this are sandeels, which given their burrowing behaviour and substrate dependence, may have limited capacity to flee the area compared to other fish species. They are therefore considered to be of medium sensitivity. This in combination with the negligible magnitude of the effect assessed, results in an impact of **minor adverse** significance..

Fish with swim bladder not involved in hearing

199. There is potential for mortality / potential mortal injury and recoverable injury to occur on fish with swim bladders not involved in hearing at ranges up to 500m (for >207dB SPL_{peak} criteria) from the installation of monopiles, and up to 230m (for mortaility / potential for mortal injury at >210 dB SEL_{cum}) from the installation of pin piles (***Table 10.22***). Taking the small areas potentially affected and the temporary, short term and intermittent nature of piling activity, the magnitude of the impact is considered to be negligible.

200. There is, however, the potential for recoverable injury to occur on fish with swim bladders not involved in hearing at ranges up to 6km (for 203dB SEL_{cum}) from the installation of pin piles (***Table 10.22***). Taking into account the spatial extent of the impact and the temporary, short term and intermittent nature of piling activity, and that any impact to fish species would be temporary, the magnitude of the impact is considered to be low.

201. The majority of fish receptors included within the group "fish with swim bladders not involved in hearing" (***Table 10.23***) 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. Taking this into account together with the negligible to low magnitude of effect, mortality and recoverable injury associated with piling noise would result in an impact of **negligible** to **minor adverse** significance**..**

202. An exception to this are sand gobies as they have limited mobility and therefore potentially a reduced capacity to escape the areas affected by the greatest noise levels. 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. Taking the negligible / low magnitude of the effect, potential mortality and recoverable injury associated with piling noise would result in an impact of **minor adverse** significance.

Fish with a swim bladder involved in hearing

203. 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 up of to 2,200m and 6,000m respectiveily from the installation of pin piles (***Table 10.22***). Taking into account the spatial extent of the impact and the temporary, short term and intermittent nature of piling activity, and that any impact to fish species would be temporary, the magnitude of the impact is considered to be low.

204. Whilst all the fish receptors included within the group "fish with swim bladders involved in hearing" (***Table 10.23***) 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 susceptible to barotrauma and detect sound pressure as well as particle motion. As such, they are considered receptors of medium sensitivity. This, in combination with the negligible or low magnitude of effect, mortality and recoverable injury associated with piling noise would result in an impact of **negligible** to **minor adverse** significance**..**

Eggs and Larvae

205. Impact criteria for potential mortality / potential mortal injury in eggs and larvae have been described in Popper et al. (2014) (>210 dB SEL_{cum} or >207 dB SPL_{peak}). The 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. Therefore, the levels adopted in Popper et al. (2014) are likely to be conservative. Given that the 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.

206. As outlined in ***Table 10.22***, these are as follows: 500m for monopiles (>207dB SPL_{peak}) and 230m for pin piles (210dB SEL_{cum}). Taking the small areas potentially affected and the temporary, short term and intermittent nature of piling activity the magnitude of the impact is considered to be negligible.

207. Eggs and larvae would not be able to flee the vicinity of the foundations during piling, however prolonged exposure could be reduced by any drift of eggs / larvae due to water currents which may reduce the risk of mortality.

208. The distribution of eggs and larvae of a given species extends over wide areas at a given time. Whilst eggs and larvae would not be able to flee the vicinity of piling, the probability and frequency of interaction with piling events is expected to be low. In this context, the small amount of egg / larval mortality associated with piling in relation to the naturally high mortality rates during these life stages should be noted. Taking the above into account, egg and larval stages are considered of medium sensitivity. This, in combination with the negligible magnitude of the effect, results in an impact of **minor adverse** significance.

Shellfish

209. There are no specific criteria currently published in respect of shellfish species, 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). Similarly, studies of marine bivalves (e.g. mussels *Mytilus edulis* and periwinkles *Littorina spp*) exposed to a single airgun at a distance of 0.5m have shown no effects after exposure (Kosheleva 1992).

210. 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 the impact expected to be negligible. 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. This, in combination with the negligible magnitude of the effect results in an impact of **minor adverse** significance**.**

10.6.1.4.5.2 Temporary Threshold Shift (TTS) and Behavioural Impacts

Magnitude of Effect

211. The outputs of the noise modelling for the spatial worst case scenario indicate that TTS from the installation of pin piles may occur at distances of up to 29km for all the fish groups modelled. Behavioural responses are anticipated to occur within this range and potentially in wider areas depending on the hearing ability of the species under consideration.

212. Impacts associated with TTS could result in reduced fitness of some species. For example, behavioural responses to underwater noise could result in decreased feeding activity, lead to the potential avoidance of spawning grounds, and act as a potential barrier to migration. Consequently, there is concern that behavioural responses could have an adverse impact on spawning behaviour and migration of certain species. 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.

213. As shown in ***Table 10.2***, in terms of the temporal worst case scenario, the maximum duration of piling would be equivalent of 39.2 days.

214. 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.

215. The assessment of the impact of TTS and behavioural impacts has been focused on key species, selected on the basis of the presence of known spawning and nursery grounds in the area of the project, conservation status, commercial value and specific concerns raised during consultation. The following sections therefore describe the sensitivity and significance of impact for each, based on the low magnitude of effect defined above.

Sole, Plaice and Cod

216. The East Anglia TWO windfarm site lies within a high intensity spawning ground for sole (***Figure 10.3***), within a low intensity spawning ground for plaice (***Figure 10.5***), and both the low intensity spawning and nursery grounds for cod (***Figure 10.7***). 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 (see ***Figures 10.35*** to ***10.37***). In addition, sole, plaice and cod are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

217. Sole and plaice lack a swim bladder, and according to the Popper et al. (2014) criteria for behavioural impacts (or TTS), would therefore 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 10.19***). Cod have a swim bladder which is involved in hearing, and are therefore considered to have a high risk of behavioural impact when near and in the intermediate vicinity of the piling location, and at low risk when far from the piling location. 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, given their low risk to behavioural reactions when far (thousands of metres) from the piling source, they are considered to be receptors of low sensitivity. With the low magnitude of effect, this results in an impact significance of **minor adverse** for these species.

Whiting and Sprat

218. The East Anglia TWO windfarm site lies within the low intensity spawning and nursery grounds of whiting (***Figure 10.9***) and within the both spawning and nursery grounds of sprat (intensity not defined) (***Figure 10.21***). 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 (***Figure 10.37*** for whiting and ***Figure 10.40*** for sprat). In addition, these species are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

219. 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 10.19***). 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, given their low risk to behavioural reactions when far (thousands of metres) from the piling source, they are considered to be receptors of low sensitivity. With the low magnitude of effect, this results in an impact significance of **minor adverse** for both species.

Lemon Sole

220. The East Anglia TWO windfarm site lies within both the spawning and nursery grounds of lemon sole (intensity not defined) (***Figure 10.11***). 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 (***Figure 10.38***). Further to this, lemon sole are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

221. Lemon sole lack a swim bladder, and according to the Popper et al. (2014) risk level would therefore be at high risk of behavioural impact near the piling locations (tens of metres), at moderate risk at intermediate distances (hundreds of metres) and at low risk when far (thousands of metres) from the piling location (***Table 10.19***). 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, given their low risk to behavioural reactions when far (thousands of metres) from the piling source, they are considered to be receptors of low sensitivity. With the low magnitude of effect, this results in an impact significance of **minor adverse.**

Herring

222. A study into the response of herring to underwater noise found that the species showed startle responses at received sound levels of 122 – 138dB re 1 µPa, and further observed that the repsonse seen depended on the size of the herring (Blaxter and Hoss 1981). Skaret et al. (2005) found that herring that spawned close to the sea bed did not show any sign of a reaction towards a survey vessel travelling at 10-11 knots at a distance of 8 – 40m (with SPLs ranging from 70 – 150 dB re 1 µPa). Studies into the behaviour of herring due to seismic surveys found that no changes in the swimming speed, direction or school size were observed with SELs of 125 to 155 dB re 1 µPa (Peña et al. 2013). This lack of response to seismic surveys from the herring was interpreted as a combination of the strong

motivation to spawn, and a progressively increased level of tolerance to the surveys over time.

223. Herring generally adopt low-risk behaviours, but at times predator avoidance must be balanced with other activities that affect their vigilance (Fernö et al. 1998; Axelsen et al. 2000). In the feeding season, the reaction of herring towards vessels is lower than that of the reactions in the wintering period (Misund 1994); the act of reproduction during the spawning season (November – January Coull et al. 1998) takes precendence over the aviodance reactions that are evident at other times of the year (Nøttestad et al. 1996; Skaret et al. 2003). Mohr (1971) observed herring swimming close to the sea bed with no avoidance reactions to a moving trawler, consistent with the high reaction thresholds of herring during the spawning period.

224. Whilst there are herring spawning grounds inshore to the northwest and offshore to the southeast, neither extend over the the East Anglia TWO windfarm site (***Figure 10.14***). The closest spawning ground is the Downs Stock located 4.4 km away from the closest point of the East Anglia TWO windfarm site (using Coull et al. 1998). ***Figure 10.39*** shows that the impact ranges associated with the potential for TTS onset overlap with the Downs spawning ground to the southeast, the area of overlap equates to 7.49% of the total area of spawing ground. However, larval surveys in the southern part of the East Anglia TWO windfarm site recorded a larval abundance of 1-100 individuals/m^2 in 2015 and 2016 and none in 2017, in comparison with abundances of 101-1000 and 1001-10,00/m^2 further offshore. Whilst the Coull et al. (1998) data suggests that East Anglia TWO windfarm site is in close proximity to the Downs Stock, data from the IHLS shows that the important area for herring spawning is located to the south in the English Channel. This is shown in ***Figure 10.45*** which the presents 10 year IHLS data against noise contours for pin piles.

225. As noted in ***paragraph 181***, it is unlikely that maximum hammer energies would reach 100% and therefore the area of overlap with the Downs Stock would be considerably smaller than 7.49%. This is a very precautionary approach considering the peak larval abundance associated with the Downs Stock is further south from the East Anglia TWO windfarm site and there is no overlap with the noise contours (***Figure 10.45***).

226. 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 meteres) and in the intermediate vicinity (hundreds of metres) of the piling location, but at low risk when far (thouands or metres) from the piling location (***Table 10.19***). Taking into account the location of herring spawning grounds identified by Coull et al. (1998) (4.4km from the East Anglia TWO windfarm site and therefore considered as ‘far’ from the piling location under Popper et al. (2014) risk level),

and the potential impact area where TTS and behavioural impacts could occur (as shown in ***Figure 10.39***), the potential for behavioural impact is considered to be low. Herring's substrate specific spawning behaviour mean that they are considered to be receptors of medium sensitivity.

227. With the application of the embedded mitigation (see ***section 10.3.3***), and the low magnitude of effect, this results in an impact significance of **minor adverse.**

Sandeels

228. The monitoring of lesser sandeel behavioural reactions to seismic surveys has shown behavioural reactions to noise source levels of 210 dB at 1 µPa (and therefore similar to piling), but with no increase in mortality or injurious effects at this level. Normal behaviour was seen to resume following the survey (Hassel et al. 2004). The results of this study indicates 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.

229. The East Anglia TWO windfarm site lies within both the low intensity spawning and nursery grounds of sandeel (for greater, lesser, smooth and small sandeel species) (***Figure 10.26***) and classification of sandeel habitat suitability in the East Anglia TWO windfarm site can be seen in ***Figure 10.2.4*** in ***Appendix 10.2***. 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 (***Figure 10.41***).

230. Sandeel species lack a swim bladder, and according to the 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 10.19***). Taking this, and their sea bed specific requirements, sandeels are considered to have medium sensitivity. With the low magnitude of effect, this results in an impact significance of **minor adverse.**

Mackerel

231. The East Anglia TWO windfarm site lies within a low intensity nursery ground of mackerel, but is not within a spawning ground (***Figure 10.19***). 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 (***Figure 10.42***). In addition, mackerel are pelagic spawners and therefore not dependent on discrete spawning grounds with particular substrate characteristics.

232. Mackerel lack a swim bladder, and according to the Popper et al. (2014) would therefore be at high risk of behavioural impact near the piling locations (tens of metres) , at moderate risk at intermediate distances (hundreds of metres) and at low risk when far (thousands of metres) from the piling location (***Table 10.19***). 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, given their low risk to behavioural reactions when far (thousands of metres) from the piling source, they are considered to be receptors of low sensitivity. With the low magnitude of effect, this results in an impact significance of **minor adverse.**

Seabass

233. Seabass are a commercially important species to local fisheries, and are relatively abudant in the East Anglia TWO windfarm site, particularly in the offshore export cable corridor (as shown in ***Figure 10.12***). This species is currently subject to new fisheries controls due to conservation concerns.

234. A number of studies have been undertaken to determine the potential for behavioural impact of underwater noise, with changes in swimming behaviours reported in response to impulsive sounds (Neo et al. 2015). The change in responsiveness have been reported in seabass that had been exposed to the playback of piling noise (Everly et al. 2015), and startle responses as a result of exposure to low frequency sounds (Kastelien et al. 2008).

235. TTS in fish species could occur at ranges up to 29km for pin piles (***Table 10.22***).. However, as seabass are a species with a swim bladder that is not involved in hearing, and following Popper et al. (2014) criteria for behavioural impact, seabass would be at a high risk of impact near (tens of metres) the piling operation, at moderate risk at intermediate distances (hundreds of metres) from the piling location and at low risk when far (thousands of metres) from the piling location (***Table 10.19***).

236. Seabass are anticipated to be more abundant near and within the offshore export cable corridor than within the East Anglia TWO windfarm site (***Figure 10.12***). Therefore, the potential for the interaction with underwater noise associated with piling is considered to be limited. Taking this into account along with the realtively small area where TTS and behavioural impact could occur (***Figure 10.43***), and in the context of the wide distribution range of seabass, the species is considered to have a low sensitivity to the impact. With the low magnitude of effect, the impact is assessed as being **minor adverse**.

Elasmobranchs

237. Elasmobranchs are considered to be sensitive to the particle displacement element of underwater noise, within the source sound range of 20–1,000 Hz (Casper and Maan 2006; 2009), athough it should be noted that studies have raised questions over shark species' capability of detecting sounds in the acoustic far field (Casper and Mann 2006).

238. Under the spatial worst case piling scenario, TTS may occur at ranges of up to 29km (***Table 10.22***). Elasmobranchs lack a swim bladder, and according to the criteria for behavioural impacts proposed in Popper et al. (2014) would be at high risk of behavioural impacts near (tens of metres) the piling operation, at moderate risk at intermediate distances (hundreds of metres) and at low risk when located far (thousands of metres) from the piling operation (***Table 10.19***).

239. The potential area affected by TTS and behavioural impacts is very small in the context of the wide distribution ranges of elasmobranch species, including those relating to spawning / nursery grounds for relevant species (namely thornback ray and tope) (***Figure 10.44***) and therefore any impact associated with piling is expected to be low. In respect of the above, elasmobranchs are considered to be receptors of low sensitivity. This in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

Diadromous species

240. Diadromous species included in the assessment include river lamprey, sea lamprey, sea trout, allis shad and twaite shad, European eel and smelt.

241. The potential ranges of behavioural impacts would depend on the hearing sensitivity of each of the listed species. As shown in ***Table 10.23***, river and sea lamprey fall within the species which lack a swim bladder category; sea trout and smelt, under the species with a swim bladder that is not involved in hearing and European eel and allis and twaite shad under the species with a swim bladder that is involved in hearing. According to Popper et al. (2014) the risk of behavioural impacts on these species would be:

- For species with no swim bladder and species with swim bladder which is not involved in hearing: high near the piling operation, moderate at intermediate distances and low when located far from the piling operation; and
- For species with swim bladders involved in hearing: high near the piling operation and at intermediate distances and moderate when located far from the piling operation.

242. As stated above, under the spatial worst case piling scenario, TTS may occur at ranges of up to 29km (***Table 10.22***).

243. It should be noted, however, that diadromous species are only likely to occur occasionally in the area of the East Anglia TWO windfarm site, and therefore the potential for these species to be subject to piling noise is very low. Furthermore, given the distance from the East Anglia TWO windfarm site to the coast, and therefore to rivers, there is no potential for piling noise to affect these species during critical periods of their migration such as river entry and river exit. In light of the above, diadromous species are considered receptors of low sensitivity. This in combination with the low magnitude of the impact results in an impact of **minor adverse** significance.

10.6.1.4.5.3 Changes to Prey Species or Feeding Behaviour

244. Fish species such as 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 may therefore be potential for changes in the behaviour of these prey species associated with piling noise to result in indirect impacts on the species that feed on them.

245. An assessment of the potential impact of changes in prey availability as a result of piling noise in respect of piscivorous fish is given below. Potential impacts on other receptors groups (namely marine mammals and birds) are assessed in ***Chapter 11 Marine Mammals*** and ***Chapter 12 Offshore Ornithology*** and are therefore not discussed here.

246. The outputs of the noise modelling for the spatial worst case scenario indicate that TTS may occur at distances of up to 29km for all the fish groups modelled. Behavioural responses are anticipated to occur within this range and potentially in wider areas depending on the hearing ability of the species under consideration.

247. As shown in ***Table 10.2,*** under the temporal worst case scenario (maximum number of piles) associated with 75 four-legged jacket foundations, five offshore platforms and one meteorological mast would take up to 938 hours (39.2 days).

248. Taking account of the spatial extent of the impact and 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 the impact is considered to be low.

249. Whilst it is recognised that changes in the distribution of key prey species to piscivorous fish may occur as a result of piling noise, as described in the assessment provided above in respect of TTS and behavioural impacts on herring, sandeels and sprat, significant impacts (i.e. above minor significance) have not been identified on any of these species. In addition, where avoidance or behavioural reactions take place, these would occur on both prey species and the fish species that feed on them. Taking this into account together with the wide distribution ranges of both, prey and piscivorous fish, the sensitivity is considered to be low. This, in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

10.6.1.5 Impact 5: Underwater Noise Impacts to Hearing Sensitive Species due to Other Activities

250. This section assesses the potential impacts associated with underwater noise during construction activities other than pile driving (***section 10.6.1.4***).

251. Potential sources of underwater noise include sea bed preparation, rock dumping cable installation. Of these, the activity that has the greatest potential noise impacts is cable installation and has therefore been assessed as a worst-case scenario (***Table 10.2***).

252. The cable installation methods that are currently being considered are:

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

253. 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).

254. In addition to potential noise impacts from cable installation activity, there will be an increase in the number of vessels transiting the area associated with construction works. This could also result in increased underwater noise levels and disturbance to fish species. In the context of this assessment, it should be noted that the maximum number of vessels on site at any one time during construction is estimated to be 74 vessels. Fish and shellfish species are therefore expected to be habituated to vessel noise to some extent (***Chapter 14 Shipping and Navigation***).

255. The limited underwater noise modelling specific to fish receptors that has been carried to date in respect of cable laying activities and vessel noise, suggests that behavioural impacts on fish species would be expected to occur in localised areas in the immediate proximity of the activities/vessels (i.e. from tens to few hundred metres) (MORL 2012; Statoil 2014).

256. For other construction activities, including vessel noise, underwater noise modelling was undertaken to determine the potential impact ranges on fish species from other construction activities. The modelling found that for all fish species, the impact range for recoverable injury (using the shipping and other continuous noise threshold of 170 dB SPL_{RMS}) would occur within 7m of dredging activites, 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 30m of dredging. It should be noted that all other impact ranges modelled, including for drilling, cable laying, rock placement and trenching had smaller impact ranges than for dredging (see ***Appendix 11.4*** for more information).

257. The underwater noise modelling undertaken for the impact of vessel noise on fish shows that for all fish, the impact of recoverable injury (using the shipping and other continuous noise threshold of 170 dB SPL_{RMS}) would occur within 2m of large vessels only, 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 13m for large vessels (see ***Appendix 11.4*** for more information).

258. Considering the limited areas potentially affected and the temporary nature of the construction phase, the magnitude of the impact is considered to be low.

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

10.6.1.6 Impact 6: Underwater Noise Impacts to Hearing Sensitive Species due to UXO Clearance

260. There is the potential requirement for UXO clearance prior to construction. Whilst any underwater UXO that are identified would preferentially be avoided, it is necessary to consider the potential for underwater UXO detonation where avoidance is not possible.

261. A detailed UXO survey would be completed prior to construction. The exact number of possible detonations and duration of UXO clearance operations is therefore not known at this stage. It has been estimated, based on the UXO survey for East Anglia ONE, that there could be up to 80 UXO within the East Anglia TWO offshore development area. As a worst-case scenario it has therefore been assumed that the maximum duration of UXO clearance could be 80 days, based on one UXO detonation per 24 hour period.

262. The size or type of the UXO that could be present is unknown. Based on the UXO survey for East Anglia ONE, a range of charge sizes has been assessed, with a maximum charge weight of 700kg. This is consistent with the approach taken for other projects, such as Norfolk Vanguard (Norfolk Vanguard Limited 2018).

263. There are no specific data currently published in respect of shellfish species, 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). Similarly, studies of marine bivalves (e.g. mussels *Mytilus edulis* and periwinkles *Littorina spp*) exposed to a single airgun at a distance of 0.5m have shown no effects after exposure (Kosheleva 1992). Therefore they are not assessed any further with regards to underwater noise impacts due to UXO clearance.

264. Whilst it is well established that explosions can result in potential mortality or injury to fish species at close range, there are no data on the effects of explosions on fish hearing (e.g. TTS) or behaviour currently available. 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).

265. In order to inform this assessment, estimated ranges of impact associated with UXO detonations for different charge weights have been calculated to provide an indication of the ranges at which mortality / potential injury may occur to fish species (***Appendix 11.4***). 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 229dB re 1µPa. The ranges at which this noise level could occur are provided in ***Table 10.24.***

Table 10.24 Calculated Mortal and Potential Injury Impact Ranges (m) for any fish species

	Charge Weight			
	200kg	**300kg**	**500kg**	**700kg**
Range (m)	580m	660m	790m	880m

266. The risk of recoverable injury (including PTS), TTS and behavioural impacts are presented qualitatively in line with Popper et al. (2014) approach in ***Table 10.19***. It should be noted that the risks outlined in ***Table 10.25*** 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 11.4***). As detailed in ***section 11.3.3.2.2*** of ***Chapter 11 Marine Mammals***, 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 reduce the risk to fish and shellfish species. A draft MMMP has been provided as part of the DCO application (document reference 8.14).

Table 10.25 Qualitative risk of recoverable injury, TTS and behavioural impact for fish species groups (Popper et al. 2014)

Category	Risk of Receiving a Recoverable Injury	Risk of Receiving Temporary Threshold Shift (TTS)	Behavioural
Fish with no swim bladder	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low
Fish with swim bladder not involved in hearing	(N) High (I) High (F) Low	(N) High (I) Moderate (F) Low	(N) High (I) Moderate (F) Low
Fish with swim bladder involved in hearing	(N) High (I) High (F) Low	(N) High (I) High (F) Low	(N) High (I) High (F) Low
Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F). (N), (I) and (F) are equivalent to tens, hundreds and thousands of metres respectively.			

267. As it is apparent from the above, where the detonation of UXO within the offshore development area is required, this may result in injury and disturbance to fish species in the vicinity of the detonation. Physical injury / trauma would occur in close proximity to the detonation, with TTS and behavioural effects occurring at greater distance. 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 the effect is considered to be low.

268. 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, fish species are considered receptors of medium sensitivity.

269. This, in combination with the low magnitude of the effect results in an impact of **minor adverse** significance.

10.6.1.7 Impact 7: Changes in Fishing Activity

270. The construction of offshore infrastructure could result in changes to fishing activity within the offshore development area but also in the wider area due to displacement of fishing activity into other areas. This could in turn result in changes to commercially targeted fish stocks.

271. Cod, plaice sole and thornback ray are the principal species targeted in the offshore development area. These species are targeted across wide areas in the Southern North Sea, and the offshore development area accounts for a small area in the context of the overall fishing grounds for these species (see ***Chapter 13 Commercial Fisheries***). Given the temporary short term impact of construction, and considering the above, the magnitude of the effect is assessed as low.

272. Shellfish species such as European lobsters and brown crabs are also targeted in the offshore development area. Roach et al. (2018) found that temporary restrictions of fishing areas offers respite for adult lobsters, leading to an increase in abundance and their size. As stated in ***section 10.6.1.1***, temporary restrictions of fishing activity allows uninterrupted contribution to the spawning stocks. 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 (Roach et al. 2018).

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

274. Furthermore, as described in ***Chapter 13 Commercial Fisheries***, significant impacts (i.e. exceeding minor significance) in respect of loss of fishing grounds and associated potential for displacement have not been identified for any of the fleets active in areas relevant to the project. Therefore, the sensitivity of commercially targeted fish stocks in respect of potential changes in fishing activity as a result of the project is considered to be low.

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

10.6.2 Potential Impacts during Operation

10.6.2.1 Impact 1 Permanent Habitat Loss

276. The worst case scenario in terms of permanent loss of habitat during the operational phase would occur from the presence of wind turbines, met mast, offshore platform foundations, cable protection and any required scour protection. This would result in worst case permanent net habitat loss of approximately 2.02km^2 (approximately 0.57% of the offshore development area) and it is not anticipated that it would be considered significant in the context of similar available habitat in the wider area. The worst case scenario is based on gravity base structures (GBS), scour protection for foundations and cable protection ***Table 10.2.***

277. The fish and shellfish receptors present in the offshore development area have comparatively large areas for spawning grounds, nursery grounds (as described in ***section 10.4.2.1.4***) and foraging, and many have wide distribution ranges; all of which may be spatially and temporally variable.

278. The loss of habitat resulting from the presence of GBS and scour materials, and any associated loss of habitat would be constant throughout the duration of the operational phase. Given the small spatial extent of any installed infrastructure, any effects are considered to be of a low magnitude.

279. The fish species taken forward for assessment (see ***section 10.5.6***) are unlikely to be affected by loss of habitat during the operation phase. The majority of species in the regional study area are considered to be of low sensitivity to loss of habitat during the operational phase.

280. Further, as indicated in ***section 9.6.2.1*** of ***Chapter 9 Benthic Ecology***, significant impacts on the benthos associated with permanent loss of habitat are not expected (impacts assessed as of minor adverse significance). Therefore, in general terms, impacts as a result of habitat loss are expected to be minimal and fish and shellfish species are considered receptors of low sensitivity. In combination with the low magnitude of effect assessed for the project, the impact of permanent loss of habitat is considered to be of **minor adverse** significance.

281. It is recognised, however that species that are highly dependent on the presence of specific sea bed substrates during sensitive periods of their life cycle such as sandeels and herring may have increased susceptibility to the potential impact of habitat loss. Impacts on these species are therefore assessed separately below.

10.6.2.1.1 Sandeel

282. Sandeels are dependent on the presence of an adequate sandy substrate in which to burrow, have a high level of site fidelity and little ability as re-colonisers (Jensen et al. 2011). Post construction monitoring at Horns Rev 1 windfarm found no impact upon sandeel population levels seven years after construction was completed (Stenberg et al. 2011). Greater Sandeel was the top species present during the IBTS (average 2008-2018) within the East Anglia TWO specific study areas with a moderate - low CPUE in the offshore cable corridor.

283. Furthermore, they are demersal spawners which lay their eggs on the sea bed. Therefore, there could be potential for the permanent loss of sea bed habitat associated with the project to result in a loss of habitat to sandeels, including a loss of spawning habitat.

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

285. Sandeels have been recorded within the study area by the IBTS, particularly in ICES rectangles 33F1 and 33F2 and during epibenthic surveys carried out in the former East Anglia FOUR, in East Anglia ONE, East Anglia THREE and in the former East Anglia Zone (***Appendix 10.2***). In addition, the majority of sediment in the offshore development area is suitable as sandeel habitat (***Appendix 10.2, Figure 10.2.4***) and the offshore development area overlaps within low intensity spawning and nursery grounds defined for sandeels (***Figure 10.26***).

286. Even though sandeels are expected to be present, analysis of IBTS data for the wider North Sea (***Figure 10.22*** to ***Figure 10.25***), the distribution of high intensity spawning / nursery grounds for this species (***Figure 10.26***) and of sandeel fishing density in the wider North Sea suggests that the offshore development area is of comparatively low importance in the context of the Sandeel Assessment Area 1r (Jensen et al. 2011). The findings of the sandeel habitat mapping exercise presented in Jensen et al. (2011) indicate that key areas for sandeels are located to the north and east of the offshore development area.

287. Additionally, PSA of benthic grab samples taken within the offshore development area (***Figure 10.2.3*** in ***Appendix 10.2***) has identified the sandy nature of the offshore development area. As shown in ***Figure 10.2.4*** in ***Appendix 10.2***, preferred and marginal sandeel habitat has been identified across the majority of the offshore development area, with unsuitable areas identified at discrete locations in the offshore cable corridor (***Appendix 10.2, Figure 10.2.4***). It should be noted that the habitat classification on which the analysis is based (Marine Space 2013) relies on sediment composition only rather than evidence of sandeel usage of the area. Therefore the presence of suitable sediment does not necessarily imply that sandeels are significantly abundant in a particular area.

288. As discussed in ***Chapter 13 Commerical Fisheries***, Sandeels are not targeted commercially on the East Anglia TWO windfarm site by the Danish fishing fleet, in contrast to, for example, the Dogger Bank and the surrounding area, suggesting this is not an area of high importance for the species (see ***Figure 13.38***). Therefore, considering the suitable sandeel habitat displayed in ***Figure 10.2.4*** (in ***Appendix 10.2***), the low importance of the area and medium sensitivity of sandeels with regard to the population structure within the Southern North Sea, it is considered that the loss of habitat during the operational phase of the windfarm would be of **minor adverse** significance.

10.6.2.1.2 Herring

289. Herring are demersal spawners requiring the presence of specific substrate, therefore they are considered to be receptors of medium sensitivity. However, as the offshore development area does not overlap defined herring spawning grounds (***Figure 10.14)***, the magnitude of effect is considered to be negligible. As a result the impact of permanent loss of habitat to herring is assessed as being of **negligible** significance.

10.6.2.1.3 Shellfish

290. The loss of sea bed habitat associated with the presence of the offshore export cable, inter-array cables and platform link cables during the operational phase is very small in the context of the distribution of shellfish species present in the area of the offshore cable corridor, including areas used for spawning, as nursery, feeding or overwintering grounds. The magnitude of effect is therefore low.

291. Shellfish species are of low abundance within the East Anglia TWO windfarm site, with an increased abundance within the offshore cable corridor. Shellfish species are considered to have a low sensitivity to a change in substrate and habitat loss due to their ability to recolonise quickly (MarLIN 2014). It is acknowledged that the MarLIN assessments have limitations. Therefore post construction studies from other offshore windfarms have been utilised to further complement the assessment of the impact of loss of sea bed habitat. For example, post construction surveys at Horns Rev 1 (Stenberg et al. 2011) and Barrow offshore windfarms (Barrow Ofshore Wind 2008) have shown that loss of habitat due to installation of foundations and scour protection have not had a discernible negative impact upon population levels of shellfish such as edible crab. The new hard substrate increases shelter for shellfish and has been found to increase biodiversity and biomass of associated fauna in some areas (Roach et al. 2018). Sensitivity is therefore categorised as low.

292. Taking into account the low sensitivity of the receptors and the low magnitude of the effect, the permanent habitat loss as a result of the proposed East Anglia TWO project on shellfish species is assessed to be of **minor adverse** significance.

10.6.2.2 Impact 2 Increased Suspended Sediments and Sediment Re-Deposition

293. Small volumes of sediment could be re-suspended during maintenance activities such as unplanned cable repair or from disturbance caused by jack up vessel legs and work vessel anchors. The volume of sediment arisen would be lower than during construction. Changes in coastal processes in the area caused by the deployment of the proposed East Anglia TWO project may also lead to increased sediment deposition on the sea bed however it is not expected that there would be significant smothering effects during operation.

294. ***Section 7.6.2.4*** of ***Chapter 7 Marine Geology, Oceanography and Physical Processes*** assessed the potential for suspended sediment to arise as a result of scour around foundation structures. The assessment found that under a worst case assumption of a 1 in 50 year return period, up to 5,000m^3 per turbine could potentially be released.

295. These values are considerably less than the worst case volumes of sediment potentially released following sea bed preparation activities which are around five times greater per turbine. Therefore, the magnitude of effect would be negligible. Given the high recoverability of species in the offshore development area to increases in suspended sediment, the sensitivity would be low (see ***section 10.6.1.2***). Therefore, an overall impact of **negligible** significance would result.

10.6.2.3 Impact 3: Re-Mobilisation of Contaminated Sediments and Sediment Re-Deposition

296. As discussed in ***section 10.6.1.3***, effects from the remobilisation of contaminated sediments and sediment redeposition are likely to be less than during the construction of the proposed East Anglia TWO project.

297. Taking account of the low receptor sensitivity and magnitude of the effect the resulting impact arising from remobilisation of contaminated sediments and sediment re-deposition is considered of **minor adverse** significance.

10.6.2.4 Impact 4 Underwater Noise Impacts to Hearing Sensitive Species due to Operational Noise

298. Sources of operational noise could include wind turbine vibration, the contact of waves with offshore infrastructure and maintenance vessel engines. It is likely that these would increase noise levels above existing baseline levels.

299. Background levels of noise in coastal waters in the UK are commonly 130 dB re μPa (Nedwell et al. 2003). Noise monitoring studies in the UK have shown operational noise levels from North Hoyle, Scroby Sands, Kentish Flats and Barrow windfarms to be only marginally above ambient noise levels (Cefas. 2010, Nedwell et al. 2007 and Edwards et al. 2007). Operational noise measurements undertaken in Germany have also found that noise levels were similar to background ambient noise levels (Betke et al. 2004).

300. 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 11.4***. As suggested above, however this has been shown to be low, only slightly elevated above background ambient noise levels.

301. 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 1m of the wind turbine, 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 5m of the wind turbine (see ***Appendix 11.4*** for more information).

302. Operation and Maintenance vessels servicing the project would also generate noise. Note that at worst, a maximum of 687 vessel round trips are expected to occur each year during the operational phase. This would be very small in the context of the current levels of vessel traffic in the area which is located 8.9 nautical miles (nm) from the Deep Water Route (DWR) and 7.3nm from the Traffic Separation Scheme (TSS) (16.4km and 13.5km respectively) (***Chapter 14 Shipping and Navigation***).

303. Taking the small increase above background noise levels expected during operation and the localised nature of operational noise the magnitude of the impact for the project is considered to be low.

304. A review of monitoring data from operational UK offshore windfarms by Cefas (2009) 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. Furthermore, recent studies involving comprehensive fish surveys in operational windfarm sites have found no evidence of avoidance by mobile fish species (Leonhard et al. 2011; Walls et al. 2013) while the abundance of some species increased compared to pre-construction, baseline levels (Leonhard et al. 2011).

305. Monitoring during the operational phase at the Horns Rev 1. offshore windfarm 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).

306. In view of the above, the sensitivity of fish and shellfish species to operational noise is considered to be low. This, combined with the low magnitude of the effect, would result in an impact of **minor adverse** significance.

10.6.2.5 Impact 5: Introduction of Wind Turbine Foundations, Scour Protection and Hard Substrate

307. The introduction of sub-surface infrastructure associated with the proposed East Anglia TWO project has the potential to alter the structure of benthic habitats and associated faunal assemblages. As described in ***section 9.6.2.1*** of ***Chapter 9 Benthic Ecology***, this represents a potential change from the existing environmental baseline and as such, is not considered to be beneficial.

308. Substrates across both the offshore cable corridor and the East Anglia TWO windfarm site are relatively homogenous being characterised predominantly by sand and muddy sand (***Chapter 7 Marine Geology, Oceanography and Physical Processes***). Therefore, introduction of hard substrate would increase habitat heterogeneity.

309. This new habitat may in turn, be colonised by new faunal communities and species, potentially increasing the diversity and overall biomass of the local marine community (***section 9.6.2.4*** of ***Chapter 9 Benthic Ecology***). With respect to fish species these expected changes would potentially result in an increase in biomass and diversity through the introduction of new habitat, nursery areas and increases in prey productivity (Hoffman et al. 2000).

310. Hard substrates introduced by the project would include foundations and scour protection for wind turbines, offshore platforms, meteorological masts and cable protection. In light of the 3-dimensional nature of much of this structure the total volume is not easy to predict. However, under the worst case scenario the area of introduced substrate would likely be in excess of 2.02km^2 in the offshore development area. The introduction of hard substrate into a predominantly soft substrate habitat would be expected to increase biodiversity and overall biomass due to an increase in habitat heterogeneity.

311. Lindeboom et al. (2011) found that new hard substrate introduced by the construction of the Dutch Egmond aan Zee windfarm (OWEZ) acted as a new habitat type with a higher biodiversity of marine organisms. The potential for marine subsea structure, whether man-made or natural, to attract and concentrate fish is well documented (Goriup 2017, Sayer et al. 2005; Bohnsack 1989; Bohnsack and Sutherland 1985; Jørgensen et al. 2002, Hoffman et al. 2000).

312. A study carried out at Swedish windfarms showed that the bases of the foundations acted as a fish aggregation device (FAD) for both demersal and pelagic species (Inger et al. 2009).The study concluded that the effect of a FAD was that the biomass of fish species was higher around foundations compared to areas where there was no FAD present (Wilhelmsson et al. 2006). It was hypothesised that fish aggregated from the surrounding areas as they were attracted to the new habitat by increased feeding opportunities (Andersson and Ohman 2010; Bohnsack 1989).

313. A review of the short term ecological effects of the OWEZ in the Netherlands, based on two year post-construction monitoring (Lindeboom et al. 2011) found some effects upon fish assemblages, especially near the monopiles. These effects include the switch of dominant pelagic species, from herring to sandeel and species richness of dermersel fish increased after the first year of construction (Lindeboom et al. 2011). It was suggested that species such as cod may find shelter within the windfarm. A long running fish monitoring survey at the Lillgrund offshore windfarm, also 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 the MMO (2014b) study, where there were minor changes in fish communities due to the addition of hard substrate at sites including North Hoyle and Kentish Flats.

314. Crustaceans would be expected to exhibit the greatest affinity to scour protection material and foundation bases through the expansion of their natural habitats (Linley et al. 2007). Post-construction monitoring surveys at the Horns Rev 1 offshore windfarm noted that the hard substrates were used as a hatchery or nursery grounds for several species, and was particularly successful for edible crab. They concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult 2006). 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).

315. It is anticipated that any hard substrate associated with of the installation of suction caisson foundations and scour protection, other offshore infrastructure and inter-array, plantform link and offshore export cable protection (including cable crossings) would be in discrete areas and would not be continuous along large lengths of either inter-array or offshore export cables. The magnitude of effect of the introduction of hard substrate in this case is therefore considered to be low.

316. 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 and shellfish receptors to the introduction of hard substrate is considered to be low to medium. As a result of the low magnitude and the low to medium sensitivity of the receptors, the impact is expected to be of **minor adverse** significance.

10.6.2.6 Impact 6 Electromagnetic Fields

317. As stated in the section describing embedded mitigation (***section 10.3.3***) Inter-array, platform link, and offshore export cables would be buried to a target depth of between 1 and 3m. Where substrate conditions prevent burial, and at cable crossings additional cable protection would be deployed.

318. The worst case scenario in respect of EMF related impacts would result from the minimum cable burial depth (1m) and installation of the maximum cable lengths and the highest power rating. This would be 200km of 75kV Alternating Current (AC) inter-array cables, 75km of 400kV platform link cables and 160km of 600kV High Voltage Alternating Current (HVAC) offshore export cables.

319. Cable burial depth will depend on substrate composition. For example, in those substrates that are potentially mobile, such as sands and fine sediments, cables will be buried to depths that are sufficient to account for any sediment movement. Therefore, in such substrate, even in the event of substantial sediment movement, cable burial is unlikely to be less than 0.5m and exposure of cables is unlikely to occur.

320. As noted in Table 10.3, NPS EN-3 suggests that *"where cables are buried at depths greater than 1.5m below the sea bed impacts are likely to be negligible"* . Although the minimum burial depth is potentially less than 1.5m, the use of armoured cables and cable burial would help to provide a physical barrier between electrosensitive species and the strongest fields lying immediately adjacent to the cable. Therefore, once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement, as discussed in ***sections 10.6.2.6.1*** to ***10.6.2.6.6*** below.

321. During the operational phase AC cables (inter-array, platform link and offshore export cables) would generate an electric field (E) and a magnetic field (B). The total E field cancels itself out to a large extent and the remaining E field is shielded by the metallic sheath and the cable armour. The varying magnetic field (B), however, produces an associated induced electric field (Ei); therefore both B and Ei fields would be generated by inter-array, platform link and offshore export cables during the operational phase.

322. Normandeau et al. (2011) modelled expected magnetic fields using design characteristics taken from 24 undersea cable projects. Of the 10 AC cables modelled, in eight of these it was found that the intensity of the field was roughly a direct function of voltage (ranging from 33kV to 345kV) although separation between the cables and burial depth also influenced field strengths. The predicted magnetic fields were strongest directly over the cables and decreased rapidly with vertical and horizontal distance from the cables (***Table 10.26***). The averaged modelled values of the magnetic field strengths from AC cables assumed a 1m burial depth.

323. A desk study undertaken for Rijkswaterstaat found that the strength of EMFs rapidly decreases with distance from the cable and EMFs are limited spatially (both vertically and horizontally) (Snoek et al. 2016). However, EMFs of both AC and DC cables are likely to reach at minimum up to a number of meters in the water column, possibly more). They recommend that burial depth, and clever positioning of the cables, can decrease the strength of the EMFs that reach the marine environment (Snoek et al. 2016). This is further confirmed by a study undertaken by the Bureau of Ocean Energy Management (BOEM) which found that EMF produced by cables diminshed to background levels about one metre away from the cable and recommended that cable burial, at sufficient depth, would be an adequate tool to prevent EMF emissions from being present at the seafloor (Love et al. 2016).

Table 10.26 Averaged Magnetic Field Strength Values from AC Cables Buried 1m (Normandeau et al. 2011)

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

324. The areas affected by EMFs generated by the worst case scenario cabling (minimum cable burial depth (1m) and installation of the maximum cable lengths and the highest power rating) associated with the proposed East Anglia TWO project are expected to be small, being limited to the offshore development area, restricted to the immediate vicinity of the cables within the range of metres. In addition, EMFs are expected to attenuate quickly in both the horizontal and vertical planes with distance from the source. The magnitude of the effect is therefore considered to be low.

325. With regards 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 (Baruah 2016, Gill and Taylor 2001; Gill et al. 2005; Snoek et al. 2016). These organisms can be categorised into two groups based on their mode of magnetic field detection, which may be induced electric field detection or direct magnetic field detection.

326. The first group are those species that are electro-receptive, the majority of which are elasmobranchs (sharks, skates and rays). These can detect the presence of a magnetic field either indirectly by detection of the electrical field induced by the movement of water through a magnetic field or directly by their own movement through that field. The magnetic field could be the Earth's geomagnetic field or a magnetic field produced by a power cable. In natural scenarios, induction of the electric field usually results from organisms positioning themselves in tidal currents and animals may time activities such as foraging or migration by detecting diurnal cues resulting from varying tidal flows.

327. The second group are believed to use magnetic particles (magnetite) within their own tissues in magnetic field detection (Kirshvink et al. 1997). Whilst the exact mechanism is still unknown, it is generally believed that they are able to detect magnetic cues such as the Earth's geomagnetic field to orientate during migration. With reference to the proposed East Anglia TWO project the relevant groups are teleosts (bony fishes, i.e. salmon and eels), crustaceans (lobsters, crabs, prawns and shrimps) and molluscs (snails, bivalves and cephalopods).

328. The sensitivity of the main receptors found in the study area for which there is evidence of a response to E or B fields, together with an assessment of the potential impacts arising from the proposed worst case cabling, is given separately for elasmobranchs, diadromous migratory species and other fish species.

10.6.2.6.1 Elasmobranchs

329. Elasmobranchs are the species group considered to be the most electro-sensitive. These species naturally detect bioelectric emissions from prey, conspecifics and potential predators and competitors (Gill et al. 2005). They are also known to detect magnetic fields. Laboratory and field experiments using AC cables of the type used by the offshore renewable energy industry, showed that EMF emitted was within the range of detection by electro sensitive species such as rays and dogfish. It was not possible to determine whether the EMF emitted from the power cables had a direct impact on the species used (Gill and Taylor 2001; Gill et al. 2005; Gill et al. 2009; CMACS 2003; COWRIE 2009).

330. For AC cables rated between 33kV and 132kV iE fields which could cause avoidance in elasmobranchs are not expected. Such iE fields are only expected to occur within 1m or less from the cable surface of 220kV and 275 kV HVAC cables. Burial would reduce this small avoidance zone either completely, should burial be to a depth of 1m (effectively negating avoidance).

331. It has been speculated that elasmobranchs may be confused by anthropogenic E field sources that lie within similar ranges to natural bioelectric fields. Laboratory behavioural studies have demonstrated both AC and DC artificial electric fields stimulating feeding responses in elasmobranchs (Kalmijn 1982; Tricas and Sisneros 2004; Kimber et al. 2011). Work using lesser spotted dogfish *Scyliorhinus canicula* suggests that despite the ability to distinguish certain artificial E fields (strong versus weak; DC versus AC), sharks seemed either unable to distinguish, or showed no preference between, anthropogenic (dipole) and natural (live crab) DC E fields of similar strengths (Kimber et al. 2011).

332. An experiment undertaken by Hutchison et al. (2018) used large netted enclosures to assess the behavioural response of electro-sensitive little skate when exposed to the EMF from a power cable. The study found that skates exposed to EMF from a power cable behaved differently than those in a controlled area with no EMF (they travelled further but at a slower speed, closer to the sea bed and with an increased proportion of large turns). This difference is indicative of a strong behavioural response by the skates to the EMF of the power cable but the cable itself did not represent a barrier unable to be crossed by the skates (Hutchison et al. 2018).

333. Information gathered as part of the monitoring programme at Burbo Bank Offshore Windfarm suggested that certain elasmobranch species feed inside the windfarm and demonstrated that they are not excluded during periods of power generation (Cefas 2009).

334. In line with the above, the following was stated in respect of EMF effects in the review of environmental data associated with post-consent monitoring of licence conditions of offshore windfarms published in 2014 (MMO 2014b):

“From the results of post-consent monitoring conducted to date, there is no evidence to suggest that EMFs pose a significant threat to elasmobranchs at the site or population level, and little uncertainty remains. Targeted research using high tech equipment and experimental precision has been unable to ascertain information beyond that of fish being able to detect EMFs and at what levels they become attracted or abhorrent to them. EMFs emitted from standard industry cables for OWFs are unlikely to be repellent to elasmobranchs beyond a few metres from the cable if buried to sufficient depth. It is likely that the more

subtle effects of EMF, including attraction of elasmobranchs, inquisitiveness and feeding response to low level EMFs, may occur. The Burbo Bank OWF post-consent monitoring undertook EMF specific surveys including stomach analysis of common elasmobranch species. Fish caught at the cable site (and hence subject to EMFs) were well fed. No deleterious effects were recorded to fish populations, at least when this effect occurs in association with the probable increased feeding opportunities reported as a result of increased habitat heterogeneity. The effects of EMFs upon migratory and diadromous species is less well researched and needs to be better understood."

335. At worst, any EMF related effects are therefore only expected to result in temporary behavioural reactions rather than to cause a barrier to migration or result in long term impacts upon feeding or confusion in elasmobranch species. Taking the above into account and the likely presence of elasmobranch species both in the East Anglia TWO windfarm site and along the offshore cable corridor, this species group are considered to be receptors of medium sensitivity. In combination with the low magnitude of the effect the impact of EMFs on elasmobranch species is therefore considered to be of **minor adverse** significance.

10.6.2.6.2 Lamprey

336. Lampreys, like elasmobranchs, possess electroreceptors that are sensitive to weak, low-frequency electric fields (Bodznick and Northcutt 1981; Bodznick and Preston 1983). Whilst responses to E fields have been reported in these species, information on the use that they make of the 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 (Normadeau et al. 2011). Lampreys are expected to only occasionally be present in the offshore development area; spawning takes place in the rivers and therefore they are not expected to be exposed to EMFs during this stage. As a consequence, the sensitivity of lampreys to EMFs associated with the proposed East Anglia TWO project is considered to be low, resulting in an impact of **minor adverse** significance.

10.6.2.6.3 Salmon and Sea Trout

337. As indicated in ***section 10.5.4,*** there are no salmon rivers in the vicinity of the East Anglia TWO windfarm site and offshore cable corridor. In the case of salmon, there is therefore little potential for any EMF related impacts to occur. In the case of sea trout however, there is potential for the species to transit the offshore development area during migration and as part of their foraging activity.

338. Swedpower (2003) found no measurable impact when subjecting salmon and sea trout to magnetic fields twice the magnitude of the geomagnetic field. Similarly, studies conducted by Marine Scotland Science (Armstrong et al. 2016) and Walker (2001) found no evidence of unusual behaviour in Atlantic salmon associated with magnetic fields and EMFs produced by cables. This is further confirmed by a study undertaken by BOEM which found that energised cables do not appear to present a strong barrier to the natural seasonal movement patterns of migratory fish (BOEM 2016).

339. Any potential impacts on movement and behaviour in salmonids would be closely linked to the proximity of the fish to the EMF source. Gill and Barlett (2010) suggest that any impact associated with EMFs on the migration of salmon and sea trout would be dependent on the depth of water and the proximity of home rivers to development sites. During the later stages of marine migration, 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.

340. Taking the above into account, salmon are considered receptors of negligible sensitivity. Therefore, the impact of EMFs on salmon assessed as being of **negligible** significance.

341. Sea trout are considered to be receptors of low sensitivity and as a result the impact of EMF on sea trout is likely to be of **minor adverse** significance.

10.6.2.6.4 European Eel

342. European eel may transit the offshore development area. It has been shown that a B-Field from the cable connecting the windfarm at Nysted, to the mainland at around 5μT (Eltra 2000) resulted in some deviation in the swimming direction of european eel. However, this result was found to be statistically insignificant Westerberg (1994). Furthermore, mark and recapture experiments showed that eels did cross the offshore export cable (Hvidt et al. 2005). Similarly, a study carried out by Marine Scotland Science (Orpwood et al. 2015) where European eels were exposed to an AC magnetic field of 9.6μT found no evidence of a difference in movement, nor observations of startle or other obvious behavioural changes associated with the magnetic fields.

343. Taking the above into account, European eels are considered receptors of medium sensitivity and taking the low magnitude, the impact of EMFs is assessed to be of **minor adverse** significance.

10.6.2.6.5 Other Fish Species

344. Further to the species mentioned above, there is some evidence of a response to EMFs in other fish species, such as cod and plaice (Gill et al. 2005).

345. As suggested in the assessments of operational noise and introduction of hard substrate (***sections 10.6.2.3*** and ***10.6.2.5***), the results of monitoring programmes carried out in operational windfarms to date do not suggest that significant changes in the fish assemblage have occurred during the operational phase. It has been suggested that the presence of the foundations and scour protection and potential changes in the fisheries related to offshore windfarm development would have the most impact upon fish species (Lindeboom et al. 2011) and that noise from the wind turbines and EMFs 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 (Leonhard and Pedersen 2006).

346. In line with this, research carried out at the Nysted offshore windfarm in Denmark that focused on detecting and assessing possible impacts of EMFs on fish during power transmission (Hvidt et al. 2005) found no differences in the fish community composition after the windfarm became operational. In light of the above, other fish species for which there is some evidence of a response to EMFs are considered receptors of low sensitivity. This in combination with the low magnitude of effect assessed for the project results in an impact of **minor adverse** significance

10.6.2.6.6 Shellfish

347. Research on the ability of marine invertebrates to detect EMF has been limited to date. Although there is no direct evidence of effects to invertebrates from undersea cable EMF (Love et al. 2016; Normandeau et al. 2011), the ability to detect magnetic fields has been studied for some species and there is evidence in some of a response to magnetic fields, including molluscs and crustaceans.

348. 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). However, it is uncertain if other crustaceans including commercially important brown crab and European lobster are able to respond to magnetic fields in this way. 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 et al. 2011; Ueno et al. 1986).

349. Hutchison et al. (2018) studied the effect of EMF on the lobster *Homarus americanus* which exhibited a statistically significant but subtle change in behavioural activity when exposed to the EMF from an HVDC cable. The EMF associated with the power cable did not constitute a barrier to movements across the cable for the lobsters (Hutchsion et al. 2018). Additionally, indirect evidence from post construction monitoring programmes undertaken in operational windfarms does not suggest that crustaceans or molluscs have been affected by the presence of submarine power cables.

350. Research undertaken by Bochert and Zettler (2004), where a number of species, including brown shrimp, were exposed to a static magnetic fields for several weeks, found no differences in survival between experimental and control animals. Therefore, the effect of EMF on shellfish is expected to be limited to behavioural responses.

351. The role of the magnetic sense in invertebrates has been hypothesised to function in relation to orientation, navigation and homing, using geomagnetic cues (Cain et al. 2005; Lohmann et al. 2007). Research undertaken on the Caribbean spiny lobster (Boles and Lohmann 2003) suggests that this species derives positional information from the Earth's magnetic field that is used during long distance migration.

352. Based on the research available, the sensitivity of crustaceans to EMFs is considered to be negligible. This in combination with the low magnitude of effect assessed for the project, results in an impact of **negligible** significance.

10.6.2.7 Impact 7 Changes in Fishing Activity

353. Changes in fishing activity during operation are expected to be similar, if not less, than during the construction of the proposed East Anglia TWO project, as discussed in ***Chapter 13 Commercial Fisheries***.

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

10.6.3 Potential Impacts during Decommissioning

355. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in ***Chapter 6 Project Description*** and the detail will be agreed with the relevant authorities at the time of decommissioning and be based on best available information at that time.

356. During the decommissioning phase, there is potential for wind turbine, foundation and cable removal activities to cause changes in suspended sediment concentrations and / or sea bed or shoreline levels as a result of sediment disturbance effects.

357. The types of effect would be comparable to those identified for the construction phase, namely:

- Impact 1: Physical disturbance and temporary loss of sea bed habitat;
- Impact 2: Increased Suspended Sediment Concentrations and sediment re-deposition;
- Impact 3: Re-mobilisation of contaminated sediment during intrusive works; and
- Impact 4: Underwater noise impacts to hearing sensitive species due to decommmissioning activities.

358. The sensitivity of receptors during the decommissioning is assumed to be the same as given 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. Therefore, it is anticipated that any decommissioning impacts would be no greater, and probably less than those assessed for the construction phase.

10.7 Cumulative Impacts

359. As discussed in ***section 10.4.4***, the CIA considers plans or projects where the predicted impacts have the potential to interact with impacts from the construction, operation and maintenance or decommissioning of the proposed East Anglia TWO project.

360. As agreed in the with stakeholders in the ETG and detailed in the Scoping Opinion (Planning Inspectorate 2017), the cumulative assessment will only consider cumulative noise impacts, habitat loss and changes to sea bed habitat. All other project alone impacts have been excluded in the cumulative asssessment due to the negligible project alone impacts on fish and shellfish receptors.

361. The approach to considering plans and projects with the potential to impact fish and shellfish has followed that taken for marine mammals (***Chapter 11 Marine Mammals***). The plans and projects screened in to the CIA either:

- Overlap with the same spawning and / or nursery grounds for fish and shellfish species as the proposed East Anglia TWO project; or

- Are located in the regional study area and are likely to impact the same fish and shellfish receptors; and
- Have potential that construction, operation, and decommissioning phases could overlap with the construction, operation, and decommissioning of the proposed East Anglia TWO project, and
- Where there is sufficient information and certainty in project programmes to allow for a meaningful assessment.

362. Full information on the CIA screening methods and approach to considering projects screened in to the CIA for marine mammals (of which this chapter followed) are provided in ***Appendix 11.3***.

363. Project tier definitions have been identified in the project list (***Table 10.27***) and follow the approach suggested by Natural England and the Joint Nature Conservation Committee (JNCC) for East Anglia Three as follows:

- Tier 1 – Built operational projects;
- Tier 2 – Projects under construction;
- Tier 3 – Consented;
- Tier 4 – Application submitted and not yet determined;
- Tier 5 – In planning (scoped), application not yet submitted; and
- Tier 6 – Identified in strategic plans but not yet in planning.

364. Note that projects in Tier 1 are already operational and therefore are considered part of the baseline and not included in the CIA.

Table 10.27 Summary of Projects considered for the CIA in Relation to Fish and Shellfish Ecology Receptors

Project	Status	Development period	[10]Distance from East Anglia TWO windfarm site (km)	[11]Distance from East Anglia TWO offshore cable route(km)	Project data status	Included in CIA	Rationale
Windfarms							
Tier 2							
East Anglia ONE	Under construction	2018-2020	10	15	Complete/high	Yes	Potential for cumulative permanent habitat loss and sea bed changes.
Hornsea Project 1	Under construction	2018-2020	176	166	Complete/high	Yes	
Tier 3							
East Anglia THREE	Consented	2022-2025 Piling: 2020 – 2022	48	45	Incomplete/low	Yes	Potential for cumulative permanent habitat loss and sea bed changes and underwater operational and decommissioning noise impacts.
Dogger Bank Teesside A	Consented	2021-2028	302	293	Incomplete/low	Yes	
Sofia (previously Dogger Bank Teesside B)	Consented	2020-2028	291	280	Incomplete/low	Yes	
Dogger Bank Creyke Beck A	Consented	2021-2027	268	207	Incomplete/low	Yes	

[10] Shortest distance between the considered project and East Anglia TWO windfarm site– unless specified otherwise
[11]Shortest distance between the considered project and East Anglia TWO offshore cable route– unless specified otherwise

Project	Status	Development period	[10]Distance from East Anglia TWO windfarm site (km)	[11]Distance from East Anglia TWO offshore cable route(km)	Project data status	Included in CIA	Rationale
Dogger Bank Creyke Beck B	Consented	2021-2028	291	280	Incomplete/low	Yes	
Triton Knoll	Consented	Construction begins in 2020	152	135	Incomplete/low	Yes	
Hornsea Project 2	Consented	2020-2022	180	168	Incomplete/low	Yes	
Tier 4							
Hornsea Project 3	In determination	Construction: 2022-2029 Piling: 2022-2023 and 2027-2028	165	156	Incomplete/low	Yes	Potential for cumulative permanent habitat loss and sea bed changes and underwater construction, operational and decommissioning noise impacts.
Norfolk Vanguard	In determination	Construction and piling: 2024 – 2028	63	55	Incomplete/low	Yes	
Thanet Extension	In determination	2024-2028	74	78	Incomplete/low	Yes	Potential for cumulative permanent habitat loss and sea bed changes and underwater construction, operational and decommissioning noise impacts.
Norfolk Boreas	Application accepted	Construction and piling: 2024 – 2028e	78	72	Incomplete / low	Yes	
East Anglia ONE North	Application submitted	2026 - 2028	10	0	Incomplete/low	Yes	Potential for cumulative permanent habitat loss and sea bed changes and underwater construction, operational and decommissioning noise impacts.

Project	Status	Development period	[10]Distance from East Anglia TWO windfarm site (km)	[11]Distance from East Anglia TWO offshore cable route(km)	Project data status	Included in CIA	Rationale	
Tier 5								
Marine Aggregate Dredging Projects Scoped in								
Area Number	**Distance from East Anglia TWO windfarm site**	**Distance from offshore cable corridor**	**Area Number**	**Distance from East Anglia TWO windfarm site**	**Distance from offshore cable corridor**	**Area Number**	**Distance from East Anglia TWO windfarm site**	**Distance from offshore cable corridor**
430	3	3	**401/2A**	22	11	**401/2B**	23	11
498	13	12	**512**	28	13	**507/5**	19	14
511	32	16	**507/2**	26	16	**513/2**	29	17
507/6	17	17	**507/1**	29	20	**525**	30	20
228	34	20	**240**	35	20	**507/4**	24	21
507/3	28	21	**513/1**	34	21	**242/361**	34	24
254	41	27	**212**	43	31	**494**	46	34
509/1	47	38	**509/2**	48	40	**524**	34	44
509/3	47	45	**508**	47	45	**510/1**	47	45
510/2	44	46	**501**	38	50	**528/2**	54	56
521	101	105	**484**	136	125	**515/2**	146	130
481/2	149	131	**515/1**	148	132	**530**	129	132
481/1	152	133	**483**	152	143	**106/3**	164	145
400	167	148	**106/2**	167	149	-	-	-

10.7.1 Cumulative Habitat loss and Changes to Sea Bed Habitat during Construction and Operation.

365. There is potential for construction and operational works at other projects to result in additional disturbance and temporary habitat loss to fish and shellfish receptors to that identified for the project alone where construction schedules significantly overlap. For cumulative impacts to occur those projects / activities would also need to interact with suitable habitat habitats. Whilst suitable habitat for all receptors is extensive there are also areas that are already impacted or which do not provide suitable habitat and therefore are not likely to be impacted cumualtively. In addition, given the distances to other projects / activities in the region, such as offshore windfarms and aggregate areas, and the localised nature of the impacts, there is no pathway for interaction between impacts cumulatively.

366. Whilst it is recognised that across the former East Anglia Zone there will be additive effects in respect of the above impacts, the overall combined magnitude of these will be negligible relative to the scale of the fish and shellfish receptors potentially affected. In the case of physical disturbance and habitat loss during construction there is only potential for such additive impacts if project construction schedules overlap, therefore impacts are expected to be at worst of **minor adverse** significance.

10.7.2 Cumulative Noise

10.7.2.1 Underwater Noise from Piling

367. There is potential for piling at the proposed East Anglia TWO project and other windfarm projects to result in cumulative impacts on fish species.

368. The potential cumulative impact would be the result of either spatial or temporal effects resulting from concurrent or sequential piling at different offshore windfarms, or a combination of both. Of particular concern in this regard is the potential for cumulative behavioural impacts to occur on species which use the area for spawning, however consideration has also been given to other fish species.

369. Species with spawning grounds in the area relevant to the proposed East Anglia TWO project include

- Plaice;
- Sole;
- Cod;
- Mackerel;
- Whiting;
- Sandeel;

- Sprat; and
- Herring.

370. It should be noted that in the particular case of herring, the offshore development area does not overlap any spawning grounds.The closest known spawning grounds (Downs herring) are located 4.4km from the East Anglia TWO windfarm site, however data from the IHLS shows that the important area for herring spawning is located further to the south towards the English Channel, as displayed in ***Figure 10.45***.

371. As shown in ***section 10.6.1.4.5.2***, based on the known spawning grounds of herring, and the low risk of behavioural impact when far (i.e. thousands of metres) from the piling location (Popper et al. 2014) there is low potential for the underwater noise associated with the construction of East Anglia TWO to impact on herring associated with the Downs stock during spawning. Furthermore there is no temporal or spatial overlap of other projects under going construction at the same time as the proposed East Anglia TWO project with the Downs Stock. Whilst there could be a number of projects overlapping with other spawning grounds, these effects are likely to be minimal due to the large areas over which herring spawn and therefore there is little potential for cumulative impact on herring spawning with other projects.

372. With regard to sandeels, the East Anglia TWO windfarm site overlaps with low intensity spawning grounds for the species; with high intensity spawning grounds located to the north near the Dogger Bank area, a considerable distance from the East Anglia TWO windfarm site. Whilst there could be a number of projects overlapping with other spawning grounds, these effects are likely to be minimal due to the large areas over which sandeel spawn. Therefore, the potential for underwater noise associated with the proposed East Anglia TWO project to significantly contribute to the cumulative impact on sandeel spawning grounds is limited.

373. Taking into account the above, and considering their sea bed habitat requirements, both herring and sandeel are considered to be of medium sensitivity.

374. Other species with known spawning grounds in the area have very wide spawning grounds, with a very localised and limited proportion of the total available habitat predicted to be impacted from underwater noise associated with the construction of East Anglia TWO. In addition, the areas predicted to be impacted by underwater noise from the construction of East Anglia TWO are not predicted to be within high intensity spawning grounds, with the exception of Dover sole. Therefore, the

remaining fish species are considered to be of low sensitivity, with Dover Sole of medium sensitivity.

375. The CIA has been based on single piling within the East Anglia TWO windfarm site, with single or concurrent piling in the other offshore windfarms identified to take place at the same time as piling at the proposed East Anglia TWO project.

376. For the CIA, the potential piling period for the proposed East Anglia TWO project has been based on the widest likely range of offshore construction dates between 2025 and 2027, as a very precautionary approach and to allow for any delays to the proposed schedule. In line with the Marine Mammal assessment, see ***section 11.7.4*** in ***Chapter 11 Marine Mammals***.

377. The most realistic worst-case scenario takes into account the most likely and most efficient build scenarios, based on certain assumptions e.g. developers of more than one site are unlikely to develop more than one site at a time, as it is more efficient and cost effective to develop one site and have it operational prior to constructing the next site. It has therefore been assumed that there will be no overlap in the piling of the Thanet Extension, Norfolk Vanguard and Norfolk Boreas, or between the East Anglia THREE, and the proposed East Anglia ONE North and East Anglia TWO projects, and that only two of the four Dogger Bank projects could be piling at the same time. It has however been assessed that these projects could have overlapping construction windows, and therefore all offshore windfarm projects with overlapping offshore construction windows with the East Anglia TWO project have been included for the assessment of other construction activities, unless they have previously been included within the assessment for cumulative piling with East Anglia TWO (i.e., projects that have overlapping overall construction windows with the proposed East Anglia TWO project, but do not have overlapping piling periods, have been included in the other construction activities assessment).

378. At East Anglia TWO the maximum total piling duration for wind turbines and offshore platforms (including soft-start and ramp-up in accordance with the MMMP) would be up to 938 hours (39.2 days) (***Table 10.2***). The maximum active piling duration based on the worst-case scenario would be 8.6% of the indicative 27 month construction period.

379. These figures are typical of offshore windfarms and when comparing the potential cumulative impact of several projects it is important to note that the likelihood of several projects all piling at the same time is comparatively low as the length of piling time per project construction period is very low (typically in the order 3-5% depending on construction programme). The potential of concurrent piling occurring between offshore windfarms is also affected by other factors including

seasonality, vessel market conditions and by weather in the North Sea. Therefore, it is considered that the number of projects (Creyke Beck B, Sofia, Hornsea Project 3 and Norfolk Boreas, see ***Table 11.57*** in ***Chapter 12 Marine Mammals***) included in the concurrent piling estimate is a precautionary worst case.In light of the above, and the low magnitiude of effect, the cumulative impact of consutruction noise from piling at the proposed East Anglia TWO project and other windfarm projects on fish species is considered to be of **minor adverse** significance.

10.7.2.2 Noise from Other Activities during Construction

380. As described in ***section 10.6.1.5***, potential disturbance to fish and shellfish species associated with construction activities other than piling (vessels, sea bed preparation, cable installation) would occur over very small areas (i.e. within 30m for construction activities and within 13m for vessels as shown by the underwater noise modelling; ***Appendix 11.4***).

381. Whilst the potential for additive disturbance to occur as a result of construction activities in other windfarms, either temporally or spatially , is recognised, given the small areas affected and the distance between the projects considered in the assessment and the proposed East Anglia TWO project (***Table 10.27***), the magnitude of the cumulative impact is considered to be low.

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

10.7.2.3 Noise from UXO Clearance during Construction

383. As described for the assessment of noise from UXO removal for the project alone (***section 10.6.1.6***), the detonation of UXO associated with other offshore windfarms, could also result in injury and disturbance to fish species in the vicinity of the detonation. Physical injury / trauma would occur in close proximity to the detonation with TTS and behavioural effects occurring at greater distance.

384. Whilst it is recognised that the number of UXO detonations required will increase (considering the other projects included for cumulative assessment), UXO clearance will still be an activity which is short term and 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 the effect is considered to be low.

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

10.7.2.4 Operational Noise

386. During the operational phase there may be potential for operational noise from the proposed East Anglia TWO project to add cumulatively to operational noise from other offshore windfarms.

387. However, as outlined for assessment of operational noise for the project alone, the increase above background noise levels expected during operation would be very small and localised in nature. With this in mind and taking the distance between the proposed East Anglia TWO project and other projects (***Table 10.27***), the magnitude of the effect is considered to be low.

388. Monitoring data from operational windfarms does not suggest that operational noise has potential to result in any discernible effect on fish and shellfish species. With this in mind, fish and shellfish species are considered receptors of low sensitivity. This, combined with the low magnitude of the effect, would result in an impact of **minor adverse** significance.

10.8 Transboundary Impacts

389. The distribution of fish and shellfish species is independent of national geographical boundaries. The proposed East Anglia TWO project impact assessment has been undertaken taking account of the distribution of fish stocks and populations irrespective of national jurisdictions. As a result, it was considered that a specific assessment of transboundary effects was unnecessary.

10.9 Inter-relationships

390. The construction, operation and decommissioning phases of the East Anglia TWO project 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.

391. 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. The assessment of significance of these impacts on other receptors are provided in the chapters listed in ***Table 10.28.***

Table 10.28 Chapter Topic Inter-Relationships

Topic and description	Related Chapter	Where addressed in this Chapter
Benthic Ecology	9	***Sections 10.6.1*** and ***10.6.2***
Commercial Fisheries	13	**Section 10.5.2.3**
Physical Processes	7	***Sections 10.6.1*** and ***10.6.2***
Marine Mammals	11	***Section 10.5.5***
Ornithology	12	***Section 10.5.5***

10.10 Interactions

392. The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts as a result of that interaction. The areas of interaction between impacts are presented in ***Table 10.29***,**,** along with an indication as to whether the interaction may give rise to synergistic impacts. This provides a screening tool for which impacts have the potential to interact. ***Table 10.30*** then provides an assessment for each receptor (or receptor group) related to these impacts in two ways. Firstly, the impacts are considered within a development phase (i.e. construction, operation or decommissioning) to see if, for example, multiple construction impacts could combine. Secondly, a lifetime assessment is undertaken which considers the potential for impacts to affect receptors across development phases. The significance of each individual impact is determined by the sensitivity of the receptor and the magnitude of effect; the sensitivity is constant whereas the magnitude may differ. Therefore, when considering the potential for impacts to be additive it is the magnitude of effect which is important – the magnitudes of the different effects are combined upon the same sensitivity receptor. If minor impact and minor impact were added this would effectively double count the sensitivity.

393. For the purposes of this ‘Interactions’ assessment a single receptor group of fish and shellfish has been considered for simplicity and brevity. Obviously there would be no potential for interaction of noise or EMF impacts with other impacts for non-noise/EMF sensitive species.

Table 10.29 Interactions between Impacts

	Potential interaction between impacts						
	Construction						
	1 Physical disturbance and temporary loss of sea bed habitat, spawning or nursery grounds	2 Increased suspended sediments and sediment re-deposition	3 Re-mobilisation of contaminated sediment during intrusive works	4 Underwater noise impacts to hearing sensitive species during foundation piling	5 Underwater noise impacts to hearing sensitive species due to other activities	6 Underwater noise impacts to hearing sensitive species due to UXO clearance	7 Changes in fishing activity
1 Physical disturbance and temporary loss of sea bed habitat, spawning or nursery grounds		Yes	Yes	No	No	No	No
2 Increased suspended sediments and sediment re-deposition	Yes		Yes	No	No	No	No
3 Re-mobilisation of contaminated sediment during intrusive works	Yes	Yes		No	No	No	No
4 Underwater noise impacts to hearing sensitive species during foundation piling	No	No	No		Yes	Yes	No
5 Underwater noise impacts to hearing sensitive species due to other activities	No	No	No	Yes		Yes	No

Potential interaction between impacts							
6 Underwater noise impacts to hearing sensitive species due to UXO clearance	No	No	No	Yes	Yes		No
7 Changes in fishing activity	No	No	No	No	No	No	
Operation							
	1 Permanent habitat loss	2 Increased suspended sediments and sediment re-deposition	3 Re-mobilisation of contaminated sediment during intrusive works	4 Underwater noise impacts to hearing sensitive species due to operational activities	5 Introduction of wind turbine foundations, scour protection and hard substrate	6 EMF	7 Changes in Fishing Activity
1 Permanent habitat loss		Yes	Yes	No	Yes	No	No
2 Increased suspended sediments and sediment re-deposition	Yes		Yes	No	No	No	No
3 Re-mobilisation of contaminated sediment during intrusive works	Yes	Yes		No	No	No	No
4 Underwater noise impacts to hearing sensitive species due to operational activities	No	No	No		No	No	No

Potential interaction between impacts							
5 Introduction of wind turbine foundations, scour protection and hard substrate	Yes	No	No	No		No	No
6 EMF	No	No	No	No	No		No
7 Changes in Fishing Activity	No	No	No	No	No	No	
Decommissioning							
	It is anticipated that the decommissioning impacts will be similar in nature to those of construction.						

Table 10.30 Potential Interactions Between Impacts on Fish and Shellfish Ecology

	Highest level significance				
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 and therefore there is limited potential for interaction with habitat disturbance from sea bed preparation, installation of cables etc and associated effects (increased SSC and resuspension of contaminants). The effects resulting from	**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 impact during construction and operation will be small scale, highly localised and episodic. There is no evidence of long

	Highest level significance				
Receptor	Construction	Operation	Decommissioning	Phase Assessment	Lifetime Assessment
				habitat disturbance will be localised 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 increase in the significance level overall. ***Operation*** Operational noise impacts from wind turbines will be highly localised to within close proximity of each wind turbine, whilst the majority of disturbance to or loss of habitat for will also be confined to the immediate footprint of wind turbine. The magnitude of effect is negligible and relates to largely the same spatial footprint. Therefore, there is no greater impact as a result of any interaction of these impacts. EMF effects and disturbance to or loss of habitat for will be confined to the immediate footprint of cables and again the magnitude of effect is negligible and relates to largely the same spatial footprint. It is therefore considered that these impacts would not interact to increase in the significance level overall.	term displacement of fish or shellfish from operational windfarms. It is therefore considered that over the project lifetime these impacts would not combine and represent an increase in the significance level.

10.11 Summary

394. Numerous data sources have been used to characterise the species of fish and shellfish that could be impacted by the proposed East Anglia TWO project. These data show that over 100 species of fish and shellfish may be present within the area. Of these species, only those which were considered to have potential to be impacted (termed receptors), were taken forward for assessment.

395. The receptors that have been identified in specific relation to fish and shellfish ecology include a number of species of interest due to ecosystem and, or commercial value. Other species such as salmon and lamprey were taken forward for assessment due to their conservation value and seabass due to conservation measures currently in place.

396. The construction, operation and decommissioning of the proposed East Anglia TWO project could cause a range of effects to fish and shellfish ecology which are summarised in ***Table 10.31.*** The magnitude of these effects has been assessed using expert assessment, drawing from a wide science base that includes project-specific surveys and assessments from other chapters of this ES.

397. The effects that have been assessed are anticipated to result in changes of **negligible** or **minor adverse** significance to the above-mentioned receptors. No additional mitigation measures, other than those that form part of the embedded mitigation, are suggested.

Table 10.31 Potential Impacts Identified for Fish and Shellfish Ecology

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
Construction						
Impact 1: Physical disturbance and temporary loss of sea bed habitat, spawning or nursery grounds during intrusive works.	Shellfish, Eggs and Larvae	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Herring and Sandeel	Medium	Low	Minor adverse	N/A	**Minor adverse**
Impact 2: Increased suspended sediments and sediment re-deposition	Physiological Effects on Fish Species	Low	Low	Minor adverse	N/A	**Minor adverse**
	Physiological Effects on Shellfish Species	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Physiological effects on Sandeels	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Changes to composition of Demersal Spawning Grounds	Low	Low	Minor adverse	N/A	**Minor adverse**

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
	Increased SSCs in Pelagic Spawning Areas	Low	Low	Minor adverse	N/A	**Minor adverse**
Impact 3 Re-mobilisation of contaminated sediment during intrusive works	Fish and shellfish in general	Low	Low	Negligible	N/A	**Negligible**
Impact 4A: Underwater noise impacts to hearing sensitive species during foundation piling (mortality / recoverable injury)	Fish with no swim bladder	Low (medium for Sandeels)	Negligible	Negligible (minor for Sandeels)	Nothing further to embedded mitigation	**Negligible (minor adverse for Sandeels)**
	Fish with Swim Bladder Not Involved in Hearing	Low (medium for gobies)	Negligible for mortality Low for recoverable injury	Negligible for mortality (minor for gobies) Minor adverse for recoverable injury	Nothing further to embedded mitigation	**Negligible (minor adverse for gobies)**
	Fish with Swim Bladder Involved in Hearing	Medium	Low	Minor adverse	Nothing further to embedded mitigation	**Negligible to minor adverse**
	Eggs and Larvae	Medium	Negligible	Negligible	Nothing further to embedded mitigation	**Minor adverse**
	Shellfish	Medium	Negligible	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
Impact 4B: Underwater noise impacts to hearing sensitive species during foundation piling (TTS and Behavioural)	Sole, Plaice and Cod	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Whiting and Sprat	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Lemon Sole	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Herring	Medium	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Sandeels	Medium	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Mackerel	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Seabass	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Elasmobranchs	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Diadromous species	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
Impact 4C: Underwater noise impacts to hearing sensitive species during foundation	Piscivorous fish	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
piling (Changes to Prey Species or Feeding Behaviour)						
Impact 5: Underwater noise impacts to hearing sensitive species due to other activities	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Impact 6: Underwater noise impacts to hearing sensitive species due to UXO clearance	Fish and shellfish in general	Medium	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
Impact 7: Changes in fishing activity	Commercially targeted stocks	Low	Low	Minor adverse	N/A	**Minor beneficial**
Operation						
Impact 1: Permanent habitat loss	Sandeel	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Herring	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Shellfish	Low	Low	Minor adverse	N/A	**Minor adverse**
Impact 2: Increased suspended sediments and	Fish and shellfish in general	Low	Low	Negligible	N/A	**Negligible**

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
sediment re-deposition						
Impact 3: Re-mobilisation of contaminated sediment during intrusive works	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Negligible**
Impact 4: Underwater noise impacts to hearing sensitive species due to operational noise	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Impact 5: Introduction of wind turbine foundations, scour protection and hard substrate	Fish and shellfish in general	Low	Negligible	Minor adverse	N/A	**Minor adverse**
Impact 6: EMF	Elasmobranchs	Medium	Low	Minor adverse	N/A	**Minor adverse**
	Lamprey	Low	Low	Minor adverse	N/A	**Minor adverse**
	Salmon and Sea Trout	Negligible	Low	Negligible	N/A	**Negligible**
	European Eel	Medium	Low	Minor adverse	N/A	**Minor adverse**

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
	Other Fish Species	Low	Low	Minor adverse	N/A	**Minor adverse**
	Shellfish	Negligible	Low	Negligible	N/A	**Negligible**
Impact 7: Changes in Fishing Activity	Commercially targeted stocks	Low	Low	Minor adverse	N/A	**Minor beneficial**
Decommissioning						
Impact 1: Physical disturbance and temporary loss of sea bed habitat, spawning or nursery ground	As above for the construction and likely less					
Impact 2: Increased suspended sediments and sediment re-deposition	As above for the construction phase and likely less					
Impact 3: Re-mobilisation of contaminated sediment during intrusive works	As above for the construction phase and likely less					
Impact 4: Underwater noise impacts to	As above for the construction and likely less					

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
hearing sensitive species due to other activities						
Impact 5: Changes in fishing activity	As above for the construction and likely less					
Cumulative						
Construction						
Impact 1: Cumulative changes to sea bed habitat	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
	Species which depend on specific substrates or species/life stages of limited mobility	Medium	Low	Minor adverse	N/A	**Minor adverse**
Impact 2: Cumulative underwater noise from piling (behavioural)	Fish in general (including species with spawning grounds)	Low	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
	Sandeel and Herring	Medium	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
Impact 3: Cumulative noise from other construction activities	Fish and shellfish in general	Low (medium for Dover sole)	Low	Minor adverse	N/A	**Minor adverse**

Potential Impact	Receptor	Value / Sensitivity	Magnitude	Significance	Mitigation Measures	Residual Impact
Impact 4: Cumulative noise from UXO clearance	Fish and shellfish in general	Medium	Low	Minor adverse	Nothing further to embedded mitigation	**Minor adverse**
Operation						
Impact 1: Cumulative permanent habitat loss	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Impact 2: Cumulative changes to sea bed habitat	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Impact 3: Cumulative underwater noise	Fish and shellfish in general	Low	Low	Minor adverse	N/A	**Minor adverse**
Decommissioning						
As above for the construction stage and likely to be less						

10.12 References

Aires, C., Manuel González-Irusta, J. and Watret, R. (2014) Scottish Marine and Freshwater Science; Updating Fisheries Sensitivity Maps in British Waters.

Andersson, M. (2011) Offshore Wind Farms. Ecological Effects of Noise and Habitat Alteration on Fish. PhD Thesis, Department of Zoology, Stockholm University. [cited 10/04/14]. Available from: http://su.diva-portal.org/smash/record.jsf?pid=diva2:391860. [Accessed 10/05/19].

Andersson, M. and Öhman, M. (2010) Fish and Sessile Assemblages Associated with Wind-Turbine Constructions in the Baltic Sea. Marine Freshwater Research, vol. 61, pp. 642-650.

Appleby, J. P. and Scarratt, D. J. (1989) 'Physical effects of suspended solids on marine and estuarine fish and shellfish, with special reference to ocean dumping: a literature review', *Canadian Technical Report of Fisheries and Aquatic Sciences*, (1681), p. 41.

Aprahamian, M. (1989) The diet of juvenile and adult twaite shad (*Alosa fallax*) (lacépède) from the rivers Severn and Wye (Britain). Hydrobiologia, vol. 179 (2), pp. 173-182.

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

Axelsen, B.E., Nøttestad, L., Fernö, A., Johannessen, A. and Misund, O.A.(2000) "Await" in the pelagic: a dynamic trade-off between reproduction and survival within a herring school splitting vertically during spawning. Marine Ecology Progress Series 2000. vol. 205 (pg. 259-269).

Barrow Offshore Wind (2008) Barrow Offshore Wind Farm Post-Construction Monitoring Report. Report by BOWind, Centrica Renewable Energy Ltd, and DONG Energy. pp 60.

Baruah, E. (2016) A review of the evidence of electromagnetic field (EMF) effects on marine organisms. Journal of Ecology and Environmental Sciences. Volume 4, Issue 4.

Beatrice Offshore Wind Farm Ltd (2018). Beatrice Offshore Wind Farm Piling Strategy Implementation Report. Available from: http://marine.gov.scot/sites/default/files/lf000005-rep-2397_bowlpilingstrategyimplementationreport_rev1_redacted.pdf Accessed 01/08/2019

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

Betke, K, M Schultz-von Glahn, and R Matuschek. “Underwater noise emissions from offshore wind turbines.” Proc CFA/DAGA, 2004.

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

Blaxter, J. and Hoss, D. (1981). Startle response in herring: the effect of sound stimulus frequency, size of fish and selective interference with the acoustico-lateralis system. Journal of the Marine Biological Association of the United Kingdom, vol. 61(04), pp. 871-879.

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. Available at: https://tethys.pnnl.gov/sites/default/files/publications/Blyth-Skyrme-2010.pdf [Accessed 20/05/19]

Bochert, R. and Zettler, M.L. (2004). Long-term exposure of several marine benthic animals to static magnetic fields. Bioelectromagnetics 25: 498-502.

Boehlert, G. and Morgan, J. (1985) Turbidity enhances feeding abilities of larval Pacific herring, Clupea harengus pallasi, Hydrobiologia, vol. 123(2), pp. 161-170.

BOEM (2016) Assessment of Potential Impact of Electromagnetic Fields from Undersea Cable on Migratory Fish Behaviour. Available at: https://www.boem.gov/2016-041/ [Accessed 20/05/19].

Bohnsack, J. (1989). Are high densities of fishes at artificial reefs the result of habitat limitation or behavioural preference? Bulletin of Marine Science, vol. 44(2), pp. 631-645

Bohnsack, J. and Sutherland, D. (1985). Artificial reef research: a review with recommendations for future priorities. Bulletin of Marine Science, vol. 37, pp. 11-39.

Boles, L., and Lohmann, K. (2003). True navigation and magnetic maps in spiny lobsters. Nature, vol. 421(6918), 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

Bone, Q. and Moore, R. (2008). Biology of fishes. Taylor & Francis.

Bonfil, R. (1994) Overview of world elasmobranch fisheries. FAO Fisheries Technical Paper No. 341 Rome, FAO.

Boyle, G., New, P. (2018) ORJIP Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options Collision and Avoidance Study

Cain, S.D. Boles, L.C. Wang, J.H. and Lohmann, K.J. (2005). Magnetic orientation and navigation in marine turtles, lobsters and molluscs: Concepts and conundrums. Integrative and Comparative Biology 45, pp. 539-546

Callaway, R., Alsvag, J., de Boois, I., Cotter, J., Ford, A., Hinz, H., Jennings, S., Kroncke, I., Lancaster, J., Piet, G., Prince, P. and Ehrich, S. (2002) Diversity and community structure of epibenthic invertebrates and fish in the North Sea. ICES Journal of Marine Science, vol. 59, pp. 1199-1214.

Camhi, M., Fowler, S., Musick, J., Brautigam, A., Fordham, S. (1998) Sharks and their Relatives: Ecology and Conservation. Occasional Paper of the IUCN Species Survival Commission, vol. 20, pp. 39.

Carlson, T., Hastings, M. and Popper A. (2007) Update on recommendations for revised interim sound exposure criteria for fish during pile driving activities. California Department of Transportation, San Diego 8.

Carroll, A.G., Przeslawski, R,. Ducan, A., Guning, M., and Bruce, B. (2017) A critical review of the potential impacts of marine seismic survey on fish and invertebrates. Marine Pollution Bulletin, Volume 114, 2-24

Casper, B. and Mann, D. (2006), Evoked potential audiograms of the nurse shark (*Ginglymostoma cirratum*) and the yellow stingray (*Urobatis jamaicensis*). Environmental Biology of Fishes, vol. 76(1), pp. 101-108.

Casper, B. and Mann, D. (2009) Field hearing measurements of the Atlantic sharpnose shark *Rhizoprionodon terraenovae*. Journal of Fish Biology, vol. 75, pp. 2768-2776.

Centre for Environment, Fisheries and Aquaculture Science, Department of Environment and Regulatory Affair, Department of Trade and Industry, and Marine Consents and Environment Unit (2004) Offshore wind farms: Guidance note for environmental impact assessment in respect of FEPA and CPA requirements Version 2, Marine Consents Environment Unit, pp. 48, [Online], Available at: http://www.cefas.co.uk/publications/files/windfarm-guidance.pdf, [Accessed 20/08/18]

Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2009) Strategic review of offshore wind farm monitoring data associated with FEPA Licence Conditions. Fish. Contract: ME1117, Version 1.5., [Online], Available at: https://tethys.pnnl.gov/publications/strategic-review-offshore-wind-farm-monitoring-data-associated-fepa-fish [Accessed 20/05/19]

Cefas (2009a) Skates and rays, Available at: http://www.cefas.defra.gov.uk/media/291463/skatesandrays.pdf. [Accessed: 26/09/18].

Cefas (2010). Strategic review of offshore wind farm monitoring data associated with FEPA Licence Conditions. Fish. Contract: ME1117, Version 1.5., [Online], Available from: http://www.cefas.defra.gov.uk/publications-and-data/miscellaneous-publications/strategic-review-of-offshore-wind-farm-monitoring-data-associated-with-fepa-licence-conditions.aspx, [Accessed 20/105/19].

Cefas (2011) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Contract report: ME5403, September 2011.

Centre for Marine and Coastal Studies (CMACS). (2003). A Baseline Assessment of Electromagnetic Fields Generated by Offshore Windfarm Cables. Report No. COWRIE EMF-01-2002, 66. Centre for Marine and Coastal Studies, Birkenhead, UK.

Centre for Marine and Coastal Studies (CMACS) (2004) Kentish Flats Offshore Wind Farm. EMF Modelling and Interpretation for Electrosensitive Fish Species. CMACS Report J3025/v1.2/10-04.

Colcough, S. and Coates, S. (2013) A review of the status of Smelt (Osmerus eperlanus) (L.) in England and Wales - 2013. Environment Agency Report: SC2 Reference: EA/001.

Collaborative Offshore Wind Research into the Environment (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2. EMF-sensitive fish response to EM emissions from sub-sea cables of the type used by the offshore renewable energy industry. Ref: EP-2054-ABG

Corten, A. and van de Kamp, G. (1996) Variation in the abundance of southern fish species in the southern North Sea in relation to hydrography and wind. ICES Journal of Marine Science, vol. 53, pp.1113-1119.

Coull, K., Johnstone, R. and Rogers, S. (1998) Fisheries sensitivity maps in British Waters. UKOOA Ltd, Aberdeen, pp. 63.

Daan, N., Heessen, H. and Hofstede, R. (2005) North Sea Elasmobranchs: distribution, abundance and biodiversity. Theme Session on Elasmobranch Fisheries Science. ICES CM 2005/N:06. International Council for the Exploration of the Sea.

De Groot, S. (1980) The consequences of marine gravel extraction on the spawning of herring, Clupea harengus Linné. Journal of Fisheries Biology, 16, pp. 605-611.

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., 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 Business Enterprise and Regulatory Reform (BERR). (2008). Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry.

Department for Environment, Food and Rural Affairs (2010) Eel management plans for the United Kingdom. Overview for England and Wales, [Online] Available: http://archive.defra.gov.uk/foodfarm/fisheries/documents/fisheries/emp/overview.pdf. [Accessed 26/09/18].

Department for Environment, Food and Rural Affairs (2018) Orford Inshore Recommended Marine Conservation Zones. Available at: https://consult.defra.gov.uk/marine/consultation-on-the-third-tranche-of-marine-conser/supporting_documents/Orford%20Inshore%20Factsheet.pdf [Accessed 20/05/19]

Department of Energy and Climate Change (2011) Overarching NPS for Energy (EN-1).

Department of Energy and Climate Change (2011) NPS for Renewable Energy Infrastructure (EN-3).

Dickey-Collas M, Bolle, LJ, Beek, van JKL, Erftemeijer, PLA (2009). Variability in transport of fish eggs and larvae. II. The effects of hydrodynamics on the transport of Downs herring larvae. Marine Ecology Progress Series 390: 183-194

DOWL (2016). Dudgeon Offshore Wind Farm - Piling Summary and Lessons Learned. August 2016.

East Anglia Offshore Wind (EAOW) (2012). East Anglia ONE Environmental Statement

East Anglia ONE Limited (2019) Actual Pile Driving Energies – East Anglia ONE. Internal Technical Note.

East Anglia THREE Limited (EATL) (2015). East Anglia THREE Offshore Wind Farm Environmental Statement.

East Anglia THREE Limited (EATL) (2016) Orford Inshore rMCZ Assessment. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010056/EN010056-001460-4.Other%20Environmental%20Information%20Volume%202%20-%20Orford%20Inshore%20rMCZ%20Assessment.PDF [Accessed 20/05/19].

Edwards, E. (1979) The edible crab and its fishery in British Waters, Buckland Foundation. Books.

Ellis., J.R.A., Cruz-Martinez, A., Rackham, B.D., and Rogers, S.I. (2005) The distribution of Chondrichthyan Fishes Around the British Isles and Implications for Conservation. Journal of Northwest Atlantic Fisheries Science, vol. 35, pp. 195-223.

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

Ellis, J., Milligan, S., Readdy, L., South, A., Taylor, N. and Brown, M. (2010) MB5301 Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones). Report No. 1: Final Report on development of derived data layers for 40 mobile species considered to be of conservation importance. Final version. August 2010.

Eltra, (2000) Beregning og måling af magnetfelter omkring kabler og vindmøller. Notat elt. vol. 2000, pp. 240.

Everley, K.A., Radford, A.N. and Simpson, S.D. (2015). Pile-Driving Noise Impairs Anti-Predator Behaviour of the European sea Bass *Dicentrarchus labrax*. A.N. Popper, A.D. Hawkins (Eds.), The Effects of Noise on Aquatic Life II, Springer, New York (2015), pp. 273-279.

Fernö A., Pitcher, T., Melle, W., Nøttestad, L., Mackinson, S., Hollingworth, C., and Misund, O. (1998). The challenge of the herring in the Norwegian Sea: making optimal collective spatial decisions. Sarsia, vol. 83, pp. 149–167.

Food Standards Agency (2013) Shellfish Harvesting Classifications England and Wales: 2013-2014. [Online]. Available at: http://www.food.gov.uk/enforcement/monitoring/shellfish/shellharvestareas/shellfishharvestingclassengwales/shellclassew201314, [Accessed 26/09/18].

Furness, R.W. 1999. Does harvesting a million metric tons of sand lance per year from the North Sea threaten seabird populations? Pp. 407-424 In: Ecosystem Approaches for Fisheries Management, Alaska Sea Grant College Program AKSG-99-01, Fairbanks.

Gill A., Gloyne-Phillips, I., Neal, K. and Kimber, J. (2005). The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. Report to Collaborative Offshore Wind Research into the Environment (COWRIE) group, Crown Estates.

Gill, A.B. and Taylor, H. (2001). The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes, Countryside Council for Wales, Contract Science Report 488.

Gill, A.B. Huang, Y. Gloyne-Philips, I. Metcalfe, J. Quayle, V. Spencer, J. and Wearmouth, V. (2009). COWRIE 2.0 Electromagnetic Fields (EMF)Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Commissioned by COWRIE Ltd (project reference COWRIE-EMF-1-06.

Goriup, P. D. (2017) Management of Marine Protected Areas: A Network Perspective, Chicheser: Wiley Blackwell.

Griffin, F., Sith, E., Vines, C. and Cherr, G. (2009). Impacts of suspended sediments on fertilization embryonic development, and early larval life stages of the Pacific herring, Clupea pallasi. Biological Bulletin, vol. 216, pp. 175-187.

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., Løkkeborg, S., Misund, O. A., Øivind, Ø., Fonn, M. and Haugland, E. K. (2004) Influence of Seismic Shooting on the Lesser Sandeel (Ammodytes marinus), ICES Journal of Marine Science, vol. 61, pp. 1165-1173.

Hastie, G., Merchant, N.D., Götz, T., Russell, D.J., Thompson, P. and Janik, V.M., 2019. Effects of impulsive noise on marine mammals: investigating range-dependent risk. Ecological Applications, p.e01906. Available from: https://research-repository.st-andrews.ac.uk/bitstream/handle/10023/17882/Hastie_2019_EA_Impulsivenoise_AAM.pdf?sequence=1&isAllowed=y. Accessed 01/08/2019

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.

Hirata K (1999). Swimming speeds of some common fish. National Maritime Research Institute (Japan). Data Sourced from Iwai T, Hisada M (1998). Fishes – Illustrated Book of Gakken (in Japanese), Gakken. Accessed 8th March 2017 at http://www.nmri.go.jp/eng/khirata/general/ speed/speede/htm

Hoffman, E., Astrup, J., Larsen, F. and Munch-Petersen, S. (2000). Effects of Marine Windfarms on the distribution of fish, shellfish and marine mammals in the Horns Rev area. Baggrundsrapport nr 24 to ELSAMPROJEKT A/S. pp. 42.

Holden, M. (1974) Problems in the rational exploitation of elasmobranch populations and some suggested solutions. Sea Fisheries Research, pp. 117-137.

Holland, G. J., Greenstreet, S.P.R., Gibb, I.M., Fraser, H.M., Robertson, M.R. (2005) Identifying sandeel *Ammodytes marinus* sediment habitat preferences in the marine environment, Marine Ecology Progress Series, 303(January 2014), pp. 269–282. [Online] Available at: doi:10.3354/meps303269 (Accessed 07/05/19).

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, [Accessed 20/05/19]

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, [Accessed 20/08/18]

Hutchinson, 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. Available at: https://www.boem.gov/espis/5/5659.pdf [Accessed 120/05/19

Hvidt, C.B. Kaustrup, M. Leonhard, S.B. and Pedersen, J. (2005). Fish along the cable trace. Nysted Offshore Wind Farm. Final Report 2004.

ICES (2005a) ICES FishMap, [cited 8/08/2014]. Available from: http://www.ices.dk/marineworld/fishmap/ices/. Accessed 20/05/19.

ICES (2005b) Report of the Study Group of Multispecies Assessment in the North Sea (SGMSNS), 5 -8 April 2005, ICES Headquarters. ICES CM 2005/D. vol. 06. pp. 163.

ICES (2006) Report of the Planning Group on Herring Surveys (PGHERS). ICES CM 2006/LRC:04.

ICES (2008) Report of the Working Group on Multispecies Assessment Methods (WGSAM), 6–10 October 2008, ICES Headquarters, Copenhagen. ICES CM 2008/RMC:06. pp. 113.

ICES (2009) Report of the Working Group of Multispecies Assessment Methods (WGSAM), 5- 9 October 2009. ICES Headquarters, Copenhagen. ICES CM 2008/RMC. vol. 06. pp. 113.

ICES (2012) Report of the Herring Assessment Working Group for the Area South of 62 N (HAWG), ICES HAWG Report 2012, ICES Advisory Committee, 13-22 March 2012 Available at: http://www.ices.dk/workinggroups/viewworkinggroup.aspx?id=25 [Accessed 020/05/98]

Inger, R., Attril, M.J., Bearhop, S., Broderick, A.C., Grecian, W.J., Hodgson, D.J., Mills, C., Sheehan, E., Votier, S.C., Witt, M.J., and Godley, B.J. (2009) Marine Renewable Energy: Potential Benefits to Biodiversity? An Urgent Call for Research. Journal of Applied Ecology, vol. 46, pp. 1145-1153

Institute of Ecology and Environmental Management (2010) Guidelines for Ecological Impact Assessment in Britain and Ireland - Marine and Coastal, Institute for Ecology and Environmental Management, Winchester, UK, pp. 72.

International Council for the Exploration of the Sea (ICES) (2015) Manual for the International Bottom Trawl Surveys. Series of ICES Survey Protocols SISP 10 - IBTS IX. 86 pp.

Jørgensen, T., Løkkeborg, S. and Soldal, A. (2002). Residence of fish in the vicinity of a decommissioned oil platform in the North Sea. ICES Journal of Marine Science: Journal du Conseil, vol. 59, suppl. pp. S288-S293.

Jensen, H., Rindorf, A., Wright, P.J. and Mosegaard, H. (2011.) Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery. ICES Journal of Marine Science 68(1), pp. 43–51.

Johnston, D. and Wildish, D. (1981). Avoidance of dredge spoil by herring (Clupea harengus harengus). Bulletin of environmental contamination and toxicology, vol. 26(1), pp. 307-314.

Joint Nature Conservation Committee (2007) Second Report by the UK under Article 17 on the implementation of the Habitats Directive from January 2001 to December 2006. Peterborough: JNCC. [Online], Available: www.jncc.gov.uk/article17, [220/505/919].

Jolly, M. (2012) Population genetic structure of protected allis shad (Alosa alosa) and twaite shad (Alosa fallax). Marine Biology, vol. 159 (3), pp. 675-687.

Kalmijn, J. (1982). Electric and magnetic field detection in elasmobranchfishes. Science 218, pp. 916-918

Kastelein, R.A.,van der Heul, S.,Verboom, W.C., Jennings, N., van der Veen, J. and de Haan, D. (2008). Startle response of captive North Sea fish species to underwater tones between 0.1 and 64 kHz. Mar. Environ. Res., 65 (2008), pp. 369-377

Kimber, J.A., Sims, D.W., Beltany, P.H. and Gill, A.B. (2011). The ability of benthic elasmobranches to discriminate between biological and artificial electric fields. Mar. Bio. Vo 158, (1) pp.1-8.

Kiørboe, T., Frantsen, E., Jensen, C. and Sorensen, G. (1981).Effects of suspended sediment on development and hatching of herring (*Clupea harengus*) eggs. Eastuarine, Coastal and Shelf Science. 13(1), 107-111.

Kiorbe, T., Munk, P., Richardson, K., Christensen, V., Paulsen, H. (1988) Plankton dynamics and larval herring growth, drift and survival in a frontal area. Marine Ecology Progress Series vol. 44, pp. 205-219.

Koschinski, S. and Ludemann, K. (2013). Development of Noise Mitigation Measures in Offshore Wind Farm Construction. Report commissioned by the Federay Agency for Nature Conservation (Budnesamt fur Naturschutz, BfN).

Kosheleva, V. (1992) The impact of air guns used in marine seismic explorations on organisms living in the Barents Sea. Fisheries and Offshore Petroleum Exploitation 2nd International Conference, Bergen, Norway.

Leonhard, S. and Pedersen, J. (2006) Benthic Communities at Horns Rev Before, During and After Construction of Horns Rev Offshore Wind Farm.

Leonhard, S., Stenberg, C., Stottrup, J. Eds: (2011) Effect of the Horns Rev 1 Offshore Wind Farm 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.

Limpenny, S., Barrio Frojan, C., Cotterill, C., Foster-Smith, R., Pearce, B., Tizzard, L., Limpenny, D., Long, D., Walmsley, S., Kirby, S., Baker, K., Meadows, W., Rees, J., Hill, J., Wilson, C., Leivers, M., Churchley, S., Russell, J., Birchenough, A., Green, S., and Law, R., (2011) The East Coast Regional Environmental Characterisation. Cefas Open report 08/04.pp. 287.

Lindeboom, H., Kouwenhoven, H., Bergman, M., Bouma, S., Brasseur, S., Daan, R., Fijn, R.C. de Haan, D., Dirksen, S., van Hal, R., Hille Ris Lambers, R., ter Hofstede, R., Krijgsveld, K., Leopold, M. and Scheidat, M. (2011). Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environmental Research Letters, vol. 6(035101), pp. 13

Linley, E.A.S., Wilding, T.A., Black, K., Hawkins, A.J.S. and Mangi S. (2007) Review of the Reef Effects of Offshore Wind Farm Structures and their Potential for Enhancement and Mitigation. Report from PML Applications Ltd and the Scottish Association for Marine Science to the Department for Business, Enterprise and Regulatory Reform (BERR), Contract No: RFCA/005/0029P.

Lohmann, K., Lohmann, C., Putman, N. (2007) Magnetic maps in animals: nature's GPS., Journal of Experimental Biology, vol. 210, pp. 3697.

Love, M. S., M. M. Nishimoto, S. Clark, and A. S. Bull. 2016. Renewable Energy *in situ* Power Cable Observation. U.S. Department of the Interior, Bureau of Ocean Energy Management, Pacific OCS Region, Camarillo, CA. OCS Study 2016-008. 86 pp

Maitland, P. and Lyle, A. (2005) Ecology of Allis Shad Alosa alosa and Twaite Shad Alosa fallax in the Solway Firth, Scotland. Hydrobiologia, vol. 534 (1-3), pp. 205-221.

Marine Climate Chane Impacts Partnership (2018) Climate change and marine conservation. Sandeels and their availability as seabird prey. [online] available at: http://www.mccip.org.uk/media/1818/mccip-sandeels-and-their-availability-as-prey.pdf [Accessed 29/05/2019].

Marine Life Information Network (MarLIN) sensitivity assessments, May 2014, Available from: http://www.marlin.ac.uk/sensitivityrationale.php [Accessed 20/05/19]

Marine Management Organisation (2013). Landings data, 2004- 2013 within ICES rectangles 33F1 and 33F2.

Marine Management Organisation (2014a) East Marine Plans Document. Available at: https://www.gov.uk/government/publications/east-inshore-and-east-offshore-marine-plans [Accessed 20/05/19]

Marine Management Organisation (2014b) Review of post-consent offshore wind farm 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 [Accessed 20/05/19]

Marine Management Organisation (2017) Statutory Guidance Bass Fishing: Catch limits, closures and minimum size Available at: https://www.gov.uk/government/publications/bass-fishing-guidance/bass-fishing-guidance [Accessed 20/05/19]

MarLIN (2017). Marine Evidence based Sensitivity Assessment (MarESA). Available at: http://www.marlin.ac.uk/species/sensitivity_rationale [Accessed 20/05/19]

McCauley, R., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M., Penrose, J., Prince, T., Adhitya, A., Murdoch, McCabe, K. (2000) Marine seismic surveys - a study of environmental implications. APPEA Journal, pp 692 - 708.

McQuaid, N., Briggs, R., Roberts, D. (2009). Fecundity of Nephrops norvegicus from the Irish Sea, Journal of the Marine Biological Association of the United Kingdom. vol. 89, pp. 1181

Messieh, S., Wildish, D., and Peterson, R. (1981). Possible Impact from Dredging and Soil Disposal on the Miramichi Bay Herring Fishery. Can. Tech. Rep. Fish. Aquat. Sci., vol. 1008, pp. 33 Cited in: Engel-Sørensen, K., and Skyt, P. (2001). Evaluation of the Effect of Sediment Spill from Offshore Wind Farm Construction on Marine Fish. Report to SEAS, Denmark, pp. 18

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.

Mohr, H. (1971). Behaviour patterns of different herring stocks in relation to ship and midwater trawl. Modern fishing gear of the world 3. pp. 368-371.

Moriarty, M., Greenstreet, S. 2017. Greater North Sea International Otter Trawl Quarter 3 Groundfish Survey Monitoring and Assessment Data Products. doi: 10.7489/1923-1

MORL (2012). Moray Offshore Renewables Limited. Environmental Statement Telford, Stevenson and MacColl Offshore Wind Farms and Transmission Infrastructure. Chapter 7 Biological Environment. Section 7.2. Fish and Shellfish Ecology

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.

Musick, J. and Bonfil, R. Eds. (2005) Management techniques for elasmobranch fisheries. FAO Fisheries Technical Paper. No. 474. Rome, FAO.

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.

Natural England (2018) Summary of Natural England's confirmed advice provided to Defra on Marine Conservation Zones to be considered for consultation in 2018 (JP026) Available at: http://publications.naturalengland.org.uk/publication/6079955233931264 [Accessed 20/05/19]

NBN Gateway (2012) Lampetra fluviatilis (Linnaeus, 1758) jawless fish (Agnatha) River Lamprey, Lampern, [Online], Available: https://data.nbn.org.uk/Taxa/NBNSYS0000188584, [26/09/18].

Neal, K and Wilson, E (2008). Cancer pagurus. Edible crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme. Plymouth: Marine Biological Association of the United Kingdom.]. Available at: <http://www.marlin.ac.uk/speciesimportance.php?speciesID=2872>.:[Accessed 20/05/19]

Nedwell, J., Langworthy, J., and Howell, D. (2003) Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise. Subacoustech Report No. 544R0424.

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

Neo, Y.Y., Ufkes, E., Kastelein, R.A., Winter, H.V., ten Cate, C. and Slabbekoom, H. (2015). impulsive sounds change European seabass swimming patterns: influence of pulse repetition interval. Mar. Pollut. Bull., 97 (2015), pp. 111-117.

Norfolk Vanguard Limited (2018). Norfolk Vanguard Offshore Wind Farm Environmental Statement.

Normandeau, Exponent,Tricas, T. and Gill, A. (2011). Effects of EMFs from Undersea PowerCables on Elasmobranchs and Other Marine Species.OCS Study BOEMRE 2011-09, U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, California

Nøttestad, L., Aksland, M., Beltestad, A., Ferno, A., Johannessen, A., and Misund, O. (1996). Schooling dynamics of Norwegian Spring spawning Herring (*Clupea harengus* L.) in a coastal spawning area. Sarsia, vol. 80, pp. 277-284.

Orpwood, J.E., Fryer, R.J., Rycroft, P. and Armstrong, J.D. (2015).Effects of AC Magnetic Fields (MFs) on swimming activity in European Eels Anguilla anguilla. Scottish Marine and Freshwater Science Vol. 6. No.8.

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

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.

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.

Pearson, W., Skalski, J., Skalski, J., Malme, C. (1992) Effects of Sounds from a Geophysical Survey Device on Behavior of Captive Rockfish (Sebastes spp.), Canadian Journal of Fisheries and Aquatic Sciences. vol. 49(7), pp. 1343.

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.

Pérez-Domínguez, R. and Vogel, M. (2010). Baseline larval fish assemblages along the Dutch coast, Southern North Sea. Report to Port of Rotterdam. Project Organization Maasvlakte 2 (PMV2). Institute of Estuarine and Coastal Studies University of Hull, UK Report: ZBB727-F-201

Planning Inspectorate (2017) East Anglia TWO Scoping Opinion.

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

Popper AN, Carlson TJ, Hawkins AD, Southhall BD and Gentry RL (2006):Interm Criteria for injury of Fish Exposed to a pile Driving Operation: A white Paper, available from ttp://www.wsdot.wa.gov/NR/rdonlyres/84A6313A-9297-42C9-BFA6-750A691E1DB3/0/BA_PileDrivingInterimCriteria.pdf, 2006.

Potter, E. and Dare, P. (2003) Research on migratory salmonids, eel and freshwater fish stocks and fisheries. Science Series Technical Report, CEFAS Lowestoft, vol. 119, pp. 64.

Pye, H.J. and Watson, W.H. (2004). Sound detection and production in the American lobster, *Homarus americanus*: Sensitivity range and behavioural implications. Journal of the Acoustical Society of America 115 : 2486

Renewable UK (2013) Cumulative impact assessment guidelines, guiding principles for cumulative impacts assessments in offshore wind farms; 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 [Accessed 20/05/19]

Richardson, D., Hare, J., Fogarty, M., Link, J. (2011) Role of egg predation by haddock in the decline of an Atlantic herring population, Proceedings of the National Academy of Sciences, vol. 108, pp. 13606

Roach, M., Cohen, M., Forster, R., Revill, A. S., and Johnson, M. 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.

Santos, M. and Pierce, G. (2003).The diet of harbour porpoise (*Phocoena phocoena*) in the Northeast Atlantic. Oceanography and Marine Biology: an Annual Review, vol. 41, pp. 355–390.

Santos, M., and Pierce, G. (2004) Variability in the diet of harbor porpoises (*Phocoena phocoena*) in Scottish waters 1992–2003. Marine Mammal Science, vol. 20(1), pp. 1-27.

Sayer, M., Magill, S., Pitcher, T., Morisette, L. and Ainsworth, C. (2005). Simulation-based investigations of fishery changes as affected by the scale and design of artificial habitats. Journal of Fish Biology, vol. 67 (Supplement B), pp. 218–243.

ScottishPower Renewables (2017) East Anglia TWO Scoping Report.

ScottishPower Renewables (2019) East Anglia TWO Preliminary Environmental Information Report.

Sell, A. F. and I. Kröncke (2013). "Correlations between benthic habitats and demersal fish assemblages — A case study on the Dogger Bank (North Sea)." Journal of Sea Research 80: 12-24.

Shark Trust (2010) An Illustrated Compendium of Sharks, Skates, Rays and Chimaera. Chapter 1: The British Isles and Northeast Atlantic. Part 2: Sharks.

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.

Smith, S., Au, D. and Show, C. (1998) Intrinsic rebound potentials of 26 species of Pacific sharks. Marine and Freshwater Research, vol. 49, pp. 663-678.

Snoek, R., de Swart, R., Didderen, K,m Lengkeek, W., and Teunis, M. (2016) Potential effects of electromagnetic fields in the Dutch North sea. Phase 1 Desk Study., Marine Consultancy & Research BV. and Bureau Waardenburg BV. For Rijkwaterstaat. WP2016_1031.

Statoil (2014) Hywind turbine. Marine noise inputs. Technical Note on Underwater Noise. Available online at: https://www.statoil.com/content/dam/statoil/documents/impact-assessment/Hywind/Statoil-Underwater%20noise%20technical%20assessment.pdf. [Accessed 20/05/19]

Stenberg, C., van Deurs, M., Stottrup, J., Mosegaard, H, Grome, T., Dinesen, G., Christensen, A., Jensen, H, Kaspersen, M., Berg, C.W., Leonhard, S.B., Skov, H., Pedersen, J., Hvidt, C.B. and Kaustrup, M. (2011). Effect of the Hors Rev 1 Offshore Wind Farm on Fish Communities. Follow-up Seven Years after Construction. DTU Aqua Report NO 246-2011

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

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.R. (2011) The North Sea fish community: past, present and future. Background document for the 2011 National Nature Outlook. Wageningen, Wettelijke Onderzoekstaken Natuur and Milieu, WOtwerkdocument 256, pp.64.

Tingley, G., Ives, M. and Russell, C. (1997) The occurrence of lice on sea trout (Salmo trutta L.) captured in the sea off the East Anglian coast of England. ICES Journal of Marine Science, vol. 54, pp. 1120-1128.

Tricas, T.C. and J.A. Sisneros. (2004). Ecological functions and adaptations of the elasmobranch electrosense, pp. 308-329. In: G. von der Emde, J. Mogdans & B.G. Kapoor (eds.), The Senses of Fish: Adaptations for the Reception of Natural Stimuli, Narosa Publishing House, New Delhi

Tingley, G., Ives, M. and Russell, C. (1997) The occurrence of lice on sea trout (Salmo trutta L.) captured in the sea off the East Anglian coast of England. ICES Journal of Marine Science, vol. 54, pp. 1120-1128. Ueno, S., Lövsund, P. and Åke Öberg, P. (1986) Effect of time-varying magnetic fields on the action potential in lobster giant axon. Medical and Biological Engineering and Computing vol. 24(5), pp. 521-526

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

van Damme, C.J.G., Hoek, R., Beare, D., Bolle, L.J., Bakker, C., van Barneveld, E., Lohman, M., os-Koomen, E., Nijssen, P., Pennock, I. and Tribuhl, S. (2011) Shortlist Master plan Wind Monitoring fish eggs and larvae in the Southern North Sea; Final Report . Report number C098/11

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

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

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 offshore wind farm, Scotland (operational year 3) technical report. Report produced by Natural Power on behalf of E.ON Climate & Renewables, [Online], http://www.gov.scot/Resource/0046/00463654.pdf [Accessed 20/05/19]

Wanless, S., Harris, M., Greenstreet, S. (1998). Summer sandeel consumption by seabirds breeding in the Firth of Forth, south-east Scotland. ICES Journal of Marine Science, vol. 55, pp. 1141-1151.

Wanless, S., Wright, P.J., Harris, M.P. and Elston, D. A. (2005). Evidence for decrease in size of lesser sandeels *Ammodytes marinus* in a North Sea aggregation over a 30-yr period. Marine Ecology Progress Series, vol. 279, pp. 237–246.

Westerberg, 1994. Fiskeriundersøgninger vid havbaseret vindkraftverk 1990-1993. Fiskeriverkets Utredningskontoret Jønkøbing. Rapport 5-1994. Gøteborgfilialen.

Wilber, D.H. and Clarke, D.G. (2001). Biological Effects of Suspended Sediments: A review of Suspended Sediment Impacts on Fish and Shellfish with Relation to Dredging Activities in Estuaries. North American Journal of Fisheries Management. 21: 855-875.

Wilhelmsson, D., Malm, T., Ohman, M., (2006) The influence of offshore windpower on demersal fish. ICES Journal of Marine Science, vol. 63, pp. 775-784

Winslade, P. (1971) Behavioural and embryological studies on the lesser sandeel *Ammodytes marinus* (Raitt). PhD thesis, Univ. East Anglia. pp. 174.

Wright, P. J., and M. C. Bailey., (1993). Biology of sandeels in the vicinity of seabird colonies at Shetland. Fisheries Research Report No. 15/93. SOAFD Marine Laboratory, Aberdeen, Scotland.