East Anglia Offshore Wind

VATTENFALL

SCOTTISHPOWER RENEWABLES

East Anglia THREE

Chapter 11

Fish and Shellfish Ecology

Environmental Statement

Volume 1

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11.1	Fish and Shellfish Ecology Evidence Plan
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11 FISH AND SHELLFISH ECOLOGY

11.1 Introduction

1. This chapter describes the current fish and shellfish ecology baseline ('existing environment') in relation to the proposed East Anglia THREE project being developed by East Anglia THREE Limited (EATL). This chapter of the Environmental Statement (ES) has been prepared by Brown and May Marine Limited (BMML).

2. The chapter then presents an impact assessment evaluating the potential impacts of the proposed East Anglia THREE project on fish and shellfish receptors (e.g. the identified baseline) during the construction, decommissioning, and operational phases of the project.

3. Finally, potential for cumulative impacts arising from other offshore renewable developments and other marine developments and activities are also considered.

4. The assessment process has taken account of guidance provided in the National Policy Statement (NPS) for Renewable Energy Infrastructure (EN-3): Offshore Wind Farm Impacts – Fish and Shellfish.

5. The baseline description and subsequent impact assessment have been derived using data and information from a number of sources, including the relevant scientific literature, fisheries statistical datasets, and consultation undertaken with statutory and non-statutory stakeholders including the Marine Management Organisation (MMO) and Centre for Environment, Fisheries and Aquaculture Science (Cefas) and, where relevant, commercial fisheries organisations. In addition, site specific fish and shellfish community characterisation surveys were undertaken to build on the data sources outlined previously and ensure that the baseline and subsequent impact assessment were as accurate and robust as possible.

11.2 Consultation

6. Consultation undertaken to inform this Environmental Impact Assessment (EIA) is listed in *Table 11.1*. Consultation relevant to Fish and Shellfish ecology has been conducted through the following processes:

- Scoping opinion - which was sought from the relevant statutory consultees (The Planning Inspectorate 2012);
- Evidence Plan - consultation with key statutory consultees which was undertaken through the Evidence Plan process (for further details please refer

to *Appendix 11.1* and Chapter 6 Environmental Impact Assessment Methodology);

- East Anglia ONE - although undertaken specifically for the proposed East Anglia THREE project, relevant consultation of the now consented East Anglia ONE offshore windfarm has been taken into account within this chapter;
- Comments and advice received during the PEIR consultation period (May 2014 to July 2014) were also considered and addressed where appropriate; and
- No further comments or advice have been received during the Phase III consultation period (June 2015 to July 2015).

Table 11.1 Consultation Responses

Consultee	Date / Document	Comment	Response / where addressed in the PEI
East Anglia THREE			
Planning Inspectorate	East Anglia THREE Scoping Opinion (Planning Inspectorate 2012)	Main ICES rectangles for assessment 34F2 and 34F3. Offshore cable corridor crosses 34F2, 33F2, 33F1 and 32F1.	Section 11.3.1 and *Appendix 11.1*
		Dutch registered fishing vessels are responsible for the majority of fishing effort in 34F2 and 34F3, with French, Belgian and UK registered fishing vessels also operating in the area. The majority of fishing activity beyond the 12nm limit is principally vessels from the Netherlands and Belgium.	Chapter 14 Commercial Fisheries. Dutch and Belgian landings data are also reviewed in terms of species weight in section 11.5.5 of this chapter, and *Appendix 11.2.*
		It is noted that a methodology has been agreed in liaison with the MMO. Agreement should also be reached with JNCC and NE.	*Appendix 11.1*
		It is noted that the results of the noise monitoring would be used to inform the assessment on fish and shellfish. The SoS welcomes the consideration of inter-relationships within this assessment.	Section 11.6.1, Chapter 9 Underwater Noise and Electromagnetic Fields and 11.8
		The ES [Environmental Statement] must ensure that a robust assessment of all fish and shellfish ecology, whether commercially important or otherwise is presented within the ES. Where data sources are lacking, the Applicant could consider the use of primary data collection to enable a robust assessment.	Section 11.4.2 and *Appendix 11.2*. In addition to whether a receptor is of commercial importance in terms of landing weight, the assessment is considered against a baseline which includes species of non-commercial importance such as prey species and the wider ecosystem linkages. Data sources to inform the baseline are given with an indication of coverage and limitations.
Joint Nature Conservation	East Anglia THREE Scoping Opinion	EIA should consider the environment holistically, and not as a discrete set of individually sensitive receptors. Within the scoping report, EAOW have made a	Section 11.4.3.4 and *Appendix 11.2*.

Consultee	Date / Document	Comment	Response / where addressed in the PEI
Committee (JNCC)/ Natural England (NE)	(Planning Inspectorate 2012)	number of suggestions regarding assessment that could be undertaken to help us understand the ecosystem linkages between receptors, and to determine how impacts on one receptor may influence others, such as impacts to fish which may be important as prey species for birds and marine mammals. We consider that such inter-relationships are likely to be key in interpreting the environmental impacts of Round 3 development.	
		Recommend the developer engage with JNCC and NE in the pre-application stage of the PINS consenting regime, to deal with key environmental concerns prior to submission.	*Appendix 11.1*
		Recommends PEIR as a draft of the ES to allow time for areas of concern to be raised and resolved prior to submission of the final ES to PINS.	This suggested approach was taken to PEIR and comments incorporated into the ES
		Many of the issues pertinent to this application are likely to be similar to those in relation to the East Anglia ONE ES.	Throughout this chapter Responses and consultation comments on fish and shellfish (ecology and EIA) from East Anglia ONE which are also relevant to the proposed East Anglia THREE project are given below in the second part of this table (*Table 11.1*).
		Suggestion to communicate the confidence in the predictions on potential impacts.	Sections 11.6 to 11.9
		The development is constrained by the fixed limits of the zone and, therefore, mitigation is also restricted within this area i.e. the relocation of development away from sensitive areas is limited. Whilst appropriate mitigation measures may be identified in relation to project design, for some receptors more radical mitigation measures may require consideration such as the potential to reduce the number of wind turbines or to phase development to allow for uncertainties in data and impacts to be addressed.	Impacts to fish and shellfish ecology are not of a significance to warrant such radical mitigation measures
		Recommend PEI as a draft ES.	This suggested approach has been taken to

Consultee	Date / Document	Comment	Response / where addressed in the PEI
			PEIR
Marine Management Organisation (MMO)	East Anglia THREE Scoping Opinion (IPC 2012)	Impacts to demersal spawning species, sandeel and herring to be assessed. Recommend that spawning times of commercially important species - sole, plaice, cod are considered in EIA and mitigation proposed where appropriate.	Section 11.6 to 11.7
		The MMO recommends that non-commercially important species e.g. Sprat and Herring are considered within the ES. This is because of the importance of such species in supporting ecosystems in the North Sea and supporting commercial species.	Sprat, herring and non-commercial species are considered where relevant in section 11.6
		Data sources provided are appropriate and the MMO welcomes the inclusion of International Beam Trawl Survey (IBTS) data.	Section 11.5.4, and *Appendix 11.2*
		The MMO recommends a thorough baseline on key shellfish species is provided. Although the East Anglia (EA) zone as a whole is of little interest as a fishing ground for shellfish, to the best of our knowledge, the cable corridor may pass through some commercial shellfish grounds close inshore.	Section 11.5.and *Appendix 11.2*
		The MMO expects that the impact assessment for demersal spawning species, sandeel and herring will be addressed by the EIA process.	Section 11.5.6; and *Appendix 11.2*
		The creation of new habitat through installation of the wind turbines and associated scour protection should be noted as a modification of the existing habitat and not new habitat.	Section 11.6.2
		Offshore cable passes through the Outer Thames Estuary SPA. A number of SPA's and SACs are located in the vicinity of the offshore cable corridor. Offshore cable corridor also overlaps the Orford Inshore recommended MCZ. Include sites of Community Importance SCI in cumulative impact assessment.	Chapter 7 Marine Geology, Oceanography and Physical Processes and Chapter 10 Benthic Ecology.
		Noise and vibration impacts on possible spawning grounds of herring, plaice, sandeel, sprat and cod to be assessed and potential mitigation proposed.	Section 11.6.1.3 and 11.7.3. Herring, plaice, sandeel, sprat and cod are considered under

Consultee	Date / Document	Comment	Response / where addressed in the PEI
			the assessment for noise.
Evidence Plan Meeting	10th Sept. 2013 – Minutes of Meeting	Evidence Plan features sufficient data collection.	No response required
		Suggest inclusion of beam trawl data from benthic survey programme also.	Section 11.5
		Physical disturbance and habitat loss to be assessed as one impact.	Section 11.6
		Ellis and Coull et al data should not be used to do calculations (e.g. of % area loss of spawning grounds) as the areas are not well defined.	Section 11.4.2 and section 11.5.6.
		Methodology for Anglian dredging sites for assessing the impact for sandeel to be considered.	Section 11.6.
		Emerging whelk fishery in ICES rectangle 33F1.	Chapter 14 Commercial Fisheries and *Appendix 11.2*
		Key species to consider – plaice, cod and sandeel.	Section 11.5.8
Evidence Plan Meeting Physical Processes	13th Sept. 2013 – Minutes of Meeting	Agreed in principle that there is no need to model plume/sediment deposition, assessment will be expert judgement based upon knowledge of sites and available contextual information (in particular Zone and East Anglia ONE studies and modelling)	Section 11.6
		Cumulative assessment -Proportionate and high level assessment will suffice given the extensive work that has already been undertaken for Zone Cumulative Impacts and East Anglia One.	Section 11.7
JNCC – follow-up to Evidence Plan Meeting	October 2013 Email	With regard to the magnitude, sensitivity and cumulative impacts paper, Natural England is content with the definitions of sensitivity and magnitude to be used in assessment.	Section 11.4
Cefas – follow-up to Evidence Plan Meeting	7 October 2013 Email	Content with the definitions of magnitude and sensitivity for the assessment, with assumption that the definitions of major/moderate will be defined in the ES.	Section 11.4.3

Consultee	Date / Document	Comment	Response / where addressed in the PEI
		Multiple phases of different East Anglian wind farms at the same time is a concern. While we appreciate there is little we can advise concerning this at the present time, and all efforts to minimise effects/overlaps of impacts, suggest the cumulative impact assessment section assess the potential constructing EA 1, 3 and 4, at the same time.	Section 11.7. assesses the potential cumulative impacts of the construction of East Anglia THREE and other developments. However, there is no potential construction overlap with East Anglia ONE and insufficient data on future East Anglia Zone projects to allow inclusion in the cumulative impact assessment.
Natural England	July 2014 Consultation on PEIR	Impact 1: Physical disturbance and loss of sea bed habitat - total area of habitat loss during operation. It would be helpful to have all parameters listed, i.e. including the expected diameter of scour protection around each GBS foundation. Following discussions with Cefas it is confirmed that further clarification is required regarding this point.	This has been amended and values included in *Table 11.2* and Chapter 5 description of the Development section 5.5.9..
Natural England	July 2014 Consultation on PEIR	It is noted that "No recognised herring spawning grounds are overlapped by the 168dB contour modelled for pelagic fish species (Figure 11.59)". However, IHLS data does show presence of larvae within the 168dB contour (Figure 11.28, average 2003-2012). This should be acknowledged. Following further discussion with CEFAS it is agreed that the modelled noise contours should be applied to the IHLS data.	*Figure 11.59* has been updated and appropriate text added..
Natural England	July 2014 Consultation on PEIR	Section 197 It would be helpful to have percentage of area affected listed in this paragraph.	This has been addressed in section 11.6.2.1.2.
Natural England	July 2014 Consultation on PEIR	It is stated that "the proposed East Anglia THREE project does not overlap with spawning grounds as defined by Coull et al. (1998)." However, Figures 11.26-28 show IHLS data; at some stations within the array, larvae were present, which may indicate presence of spawning. This should be made clear in the	This has now been amended in section 11.6.1.1

Consultee	Date / Document	Comment	Response / where addressed in the PEI
		text. Kiorboe et al 1981 and Messieh et al 1981 are cited to mention that herring eggs may tolerate/hatch at concentrations up to 300/500 and 7000mg/l respectively. However, Griffin et al 2009 pointed out the limitations of these findings. This should be reflected in the text. They also showed that if eggs are exposed too SSC of 250mg/l during the first 2 hours development and survival may be impacted. It is stated that "Herring are demersal spawners requiring the presence of suitable substrate, therefore the sensitivity is medium. However, as the East Anglia THREE windfarm site or offshore cable corridor does not overlap defined herring spawning grounds". However, IHLS data does show presence of larvae within the array (Figure 11.28, average 2003-2012). This should be acknowledged. Following discussions with CEFAS it was agreed that further clarity (in line with the following) could be provided in order to qualify the position that EA3 is not on herring spawning grounds. CEFAS confirmed that the EA 3 boundary does not overlap with either herring spawning grounds defined by Coull et al (1998) or IHLS stations i.e. recorded herring larvae. The IHLS is considered by CEFAS to cover the recognised spawning grounds for the downs herring. Point 64 of Chapter 10 highlights that the EA 3 site is not likely to have substrate which is suitable for herring spawning "The sea bed across the East Anglia THREE site is homogeneous and is characterised predominantly by sand, with some muddy sand. "Figures 11.26-28 show that small larvae were only recorded in the IHLS data inside/proximal to EA 3 in 2003, 2005 and 2009. The abundance levels were also low i.e. 1-100 larvae per m^2. CEFAS also agreed that there are other information sources on impacts to herring eggs. There are several studies which have been undertaken that assess the effects of suspended sediment on herring eggs and larvae e.g. Boehlert and Morgan, 1985; Auld and Schubel, 1978; Johnston and Wildish,	

Consultee	Date / Document	Comment	Response / where addressed in the PEI
		1982; Kiørboe et al., 1981 and Wilber and Clarke, D. G. 2001. At sediment concentrations as low as 250 mg/l Griffin et al., (2009) suggest that the attachment of sediment particles on herring eggs may lead to retarded development and reduced larval survival rates (noting the above comment that it is thought unlikely that herring eggs will be present within EA 3, but further information to qualify this would be useful).	
Natural England	July 2014 Consultation on PEIR	For worst case considerations, minimal cable burial depth of 0.5m is assumed, Natural England would like to gain a better understanding how this may be affected if burial depth is reduced over time due to sediment movement. Following further discussion with Cefas it is agreed that further clarification is required regarding this point.	Addressed in section 11.6.1.2.
Natural England	July 2014 Consultation on PEIR	As noted above, IHLS data should be acknowledged with respect to herring spawning.	This has been addressed in Section 11.7.1.3
Natural England	July 2014 Consultation on PEIR	Further information is required as to the physical disturbance and loss/temporary loss of seabed; spawning ground overlap and impacts of increased suspended sediments.	This has been addressed in Section 11.6..1.2.5
Natural England	July 2014 Consultation on PEIR	It is mentioned that for spurdog, nursery grounds have been defined in the offshore cable corridor and the East Anglia THREE site. It would be useful to see relevant maps to estimate impacts; particularly as spurdog are benthic spawners (see point 58) with associated vulnerability to SSC and sediment re-deposition. Additionally, assessment of spurdog has been raised as an issue by Lowestoft Fishermen (Chapter 14, *Table 14.1*, p. 6). Following discussions with CEFAS it is agreed that sections 55 and 56 regarding spawning and nursery grounds for species needs reviewing as there appear to be errors with regards to the presence of certain species and intensity of spawning and nursery grounds.	This has now been amended in section 11.5.6

Consultee	Date / Document	Comment	Response / where addressed in the PEI
Natural England	July 2014 Consultation on PEIR	Impact 1 physical disturbance and temporary loss of sea bed habitat - no impact on pelagic eggs drifting in the water column: In point 78 it is stated that "...the only receptors with the potential to be impacted are herring and sandeels by virtue of their substrate specificity for benthic spawning and habitat preference." It should be made clear in the paragraph why lesser spotted dogfish, thornback ray and blonde ray have not been mentioned alongside herring and sandeels although they have been identified as laying eggs on benthic substrates under point 58 (p. 34). (See also comment to point 56.)	This has been addressed in section 11.6.1.1.1
Natural England	July 2014 Consultation on PEIR	Figure 11.58 does not show overlap of herring grounds with EA 3, but Lemon sole spawning area (Coull et al. 1998) 168db demersal noise contour at 3500kJ. Reference to the correct figures should be provided.	Figure 11.58 has been amended as appropriate
Natural England	July 2014 Consultation on PEIR	The text states the maximum volume of excavation per GBS/monopile foundation; however, to assess impacts on fish and shellfish receptors, it would be helpful to translate this number into a suspended sediment concentration under a worst case scenario. This has only been provided for jetting (i.e. point 96). Following discussions with CEFAS it is agreed that further clarification is required regarding this point.	Further detail has been included in Section 11.6.1.2
Natural England	July 2014 Consultation on PEIR	Natural England questions the conclusion made about lobsters with respect to escaping high concentrations of suspended sediment along the inshore cable section due to offshore migration for spawning. A report by CEFAS (Pawson 1995) states that "Lobsters do not appear to make extensive movements when berried, and hatching takes place in spring and early summer on the same grounds." It is further mentioned that "unlike the edible or spider crabs, lobsters do not undertake regular migrations, but simply make small random movements which could be prompted by local competition for food or by the need to change habitats as their size increases."	This has been addressed within section11.6.1.2

Consultee	Date / Document	Comment	Response / where addressed in the PEI
		Natural England therefore would like further clarification on suspended sediment concentrations that may affect berried lobsters. Physiological effects on shellfish species: it is stated that the ""as crabs and lobsters migrate offshore to spawn in deeper waters (Edwards 1979) and the area of habitat affected by the inshore section of the offshore export cable corridor is proportionally small". Natural England would welcome an indication of the size and proportion of the population/area considered to be affected in the inshore section, particularly as SSC may reach up to 400mg/l along inshore sections of the export cable (see point 96). Following discussions with CEFAS is agreed that lobsters do not carry out offshore migrations to spawn. Lobsters are territorial, usually living in crevices and will remain in the area to feed, mate and spawn. CEFAS also agree that lobsters in this area are likely to be more sensitive to SSC and settlement owing to the regionally limited available habitat, essentially limiting their ability to relocate away from any prolonged increases in SSC and sedimentation. CEFAS are in agreement that further clarification would be useful in this case as the information which informs the conclusion that lobsters can escape increased SSC, is incorrect. The proximity of the cable corridor to lobster habitat will of course be an important factor in the impact assessment. NE agrees with CEFAS that CEFAS that consultation with the fishing industry and local IFCA would be beneficial to ascertain the exact location of the potting effort in the area as the lobster fishery in the region of the inshore cable corridor is generally restricted to wrecks, with little other suitable habitat in the area. Some brown crab potting is known to occur in the vicinity of the inshore cable corridor but it the exact location and intensity is uncertain. From CEFAS' understanding the crab and lobster population in this region are only persecuted by the local fleet, with this fleet having a high reliance on the locally limited available crab and lobster ground.	

Consultee	Date / Document	Comment	Response / where addressed in the PEI
Natural England	July 2014 Consultation on PEIR	Low magnitude is assigned to herring eggs and exposure to increased SSC. Figure 11.28 (average 2003 – 2012) shows overlap with herring larvae, which may indicate presence of spawning; this should be acknowledged in the text. Following further discussions with CEFAS this issue is no longer of concern as it is agreed that the assessment of minor adverse as likelihood of exposure is low (see other comments on herring eggs).	No action required
Natural England	July 2014 Consultation on PEIR	Under point 116 it is stated that "sediment re-deposition is localised and the demersal spawning grounds of the Downs herring stock do not overlap with the proposed East Anglia THREE project, there is no potential for an impact to occur (i.e. no Impact). While herring grounds as defined by Coull et al. 1998 show no overlap with EA 3 array, Figure 11.28 (Average 2003-2012) shows overlap with stations where Herring larvae were detected indicating potential presence of spawning. Although abundance at these stations is low it is still possible that elevated SSC from construction activities overlap with herring spawning. It is further stated in Chapter 8, point 80, that "" There is a possibility that some of the finer sand and mud fractions could stay in suspension for longer,... these would fall to the sea bed in relatively close proximity (<1km) to its release within a short period of time"". Hence Natural England questions the conclusion of ""no impact"". Following further discussion with CEFAS it is agreed that the size of larvae recorded in the IHLS and used in Figures 11.26-28 does need to be qualified, for example: <11mm or >11mm or all size ranges recorded as <11m larvae is used as an indication of the presence of herring spawning grounds. There does not seem to be suitable spawning substrate within EA 3. The larvae would be susceptible to increased suspended sediment above background levels.	This has been addressed within section 11.6.1.2.4
Eastern Inshore Fisheries	July 2014 Consultation on	Whilst Eastern IFCA is comfortable that the applicant has utilised the best available evidence in chapter 11 with regards to disturbance of spawning and	This has been addressed in section 11.7

Consultee	Date / Document	Comment	Response / where addressed in the PEI
Conservation Association (EIFCA)	PEIR	nursery grounds from noise and vibrations we still have concerns over the potential for impacts to occur. Our primary concern is that in-combination with other wind farm developments and aggregate dredging activity, several successive spawning seasons of some species (for example, sole) may be impacted to the detriment of spawning productivity.	
MMO	July 2014 Consultation on PEIR	Although the cumulative sound exposure level criterion has not been applied to the outputs of the underwater noise modelling, fish injury and behaviour has been appropriately considered within the assessment.	No action required
MMO	July 2014 Consultation on PEIR	In general, the PEIR provides a comprehensive preliminary consideration of fish and shellfish resources. The data and information presented is from reputable sources and the fish surveys were undertaken in consultation with Cefas fisheries advisers.	No action required
MMO	July 2014 Consultation on PEIR	Information regarding spawning and nursery grounds needs to be reviewed for inaccuracies. For example, in Vol. 1, section 11.5.6 herring spawning grounds are stated to be present inside the EA3 site; however we do not believe this to be the case.	This has been amended within section 11.5.6
MMO	July 2014 Consultation on PEIR	Information regarding spawning and nursery grounds needs to be reviewed for inaccuracies. For example, in Vol. 1, section 11.5.6 herring spawning grounds are stated to be present inside the EA3 site; however we do not believe this to be the case.	This has been amended in section 11.5.6
MMO, Cefas, fisheries stakeholders.	July 2014 Consultation on PEIR	Vol. 1, section 11.5.5 and 14.2 – These sections need to be updated with the information from the Shark By-watch project report and any potential impacts identified and assessed within the ES.	A number of requests for shark by-watch data and the final report have been made to Cefas, including permission to reference the executive summary. No response has been forthcoming to date.

Consultee	Date / Document	Comment	Response / where addressed in the PEI
MMO.	July 2014 Consultation on PEIR	Vol. 1, section 11.6 – Whilst the Marine Life Information Network (MarLIN) sensitivity assessment is a useful source of information the limitations of these assessments should be considered and made clear in the text.	The limitations of this information source are acknowledged within section 11.4.3.3. and under relevant impacts.
MMO	July 2014 Consultation on PEIR	Vol. 1, section 11.6.1.2.2 – Further clarification is required on suspended sediment concentrations that may affect berried lobsters. Pawson, M.G. 1995 (Biogeographical identification of English Channel fish and shellfish stocks. Fisheries Research Technical Report (number 99), MAFF Direct Fisheries Research Lowestoft, England) states that “lobsters do not appear to make extensive movements when berried, and hatching takes place in spring and early summer on the same grounds” and that “unlike edible or spider crabs, lobsters do not undertake regular migrations, but simply make small random movements which could be prompted by local competition for food or by the need to change habitats as their size increases.”	This has been addressed in section 11.6.1.2
MMO	July 2014 Consultation on PEIR	Vol. 3, Appendices 10.4 and 11.2 – The surveys highlight that velvet swimming crabs were recorded in the 4m beam trawl surveys. However, it should be recognised that the otter trawl and 4m beam trawl gears are not effective at sampling macro-crustaceans.	This has been addressed in section 11.3.5.2
East Anglia ONE – comments relevant to East Anglia THREE			
Relevant consultation from Planning Inspectorate examination process for East Anglia ONE			
Planning Inspectorate	East Anglia ONE Scoping Opinion (IPC 2010)	The main potential issues identified include sediment impacts – including changes to the sediment regime and resultant impacts on ecology and fish, and ecological impacts, including loss or change to sea bed habitats, pollution and fragmentation of habitats; construction noise impacts, leading to disturbance to fish.	Throughout this chapter
Planning	East Anglia ONE	Many species of fish, including cod, whiting, plaice, mackerel and herring, have	Section 11.5.6

Consultee	Date / Document	Comment	Response / where addressed in the PEI
Inspectorate JNCC	Scoping Opinion (IPC 2010) East Anglia ONE (ERM 2012)	spawning or nursery grounds (or both) in the area of the southern North Sea which surrounds the proposed site.	
		The study of fish ecology should also cover all relevant shellfish species not just those that are '…of Commercial importance'	Shellfish species are reviewed on the basis of their presence from site specific surveys, benthic surveys, commercial landings and other data sources.
		The Commission does not agree that the effects of displacement of fish due to suspended sediments; changes to water quality and accidental release of contaminants for the operation phase of the proposed windfarm may be scoped out of the ES.	Section 11.6.2
		The potential environmental impacts of the decommissioning phase on marine mammals (and on fish) and how such impacts may be mitigated should be considered. For example, the use of any explosives to remove structures from the sea bed.	EATL have committed not to use explosives to remove structures from the sea bed.
		Consider the damage or potential mortality of fish at early life stages when piling. Any impacts at this stage could affect successive generations and as such could impact upon the population in this area.	Section 11.6. Potential effects of piling noise on fish at early life stages are assessed. Consultation undertaken with IMARES to improve the knowledge of the effect of piling noise on fish larvae (2012).
JNCC MMO	East Anglia ONE (ERM 2012) East Anglia ONE (ERM 2012)	Request methodology for targeted fish surveys agreed with Cefas and JNCC.	*Appendix 11.1*
		Recommended reference made to the indirect effects on prey. Impacts of spawning fish are a key concern.	Potential effects on key prey species and on spawning fish are assessed (section 11.6).
		Identification of fish spawning and nursery grounds in reports 1998 and 2010 differ in location and size of spawning grounds. Evidence which will be used to inform the ES should be comprehensive and up-to-date, and where there are	Section 11.4.2 and *Appendix 11.2*. Currently available up-to-date data in relation to the distribution of fish spawning grounds and

Consultee	Date / Document	Comment	Response / where addressed in the PEI
		uncertainties, the worst case scenario should be assessed.	nursery grounds are provided. This includes the distribution of nursery and spawning grounds as defined in Ellis et al. (2010) and Coull et al. (1998) and an indication of the recent temporal and spatial distribution of spawning, based on the results of monthly ichthyoplankton surveys carried out from April 2010 to March 2011 in the southern North Sea by Institute for Marine Resources and Ecosystem Studies (IMARES) (van Damme et al. 2011). The information is also supported by CHARM Consortium data with spatial patterns identified and described quantitatively using geostatistics from datasets including International Beam Trawl Data Survey data and Continuous Underway Fish Egg Sampler (CUFES) in the English Channel and the southern North Sea by L'Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) Carpentier et al. 2009).
		The fish ecology section of the ES should be cross-referenced with that of the commercial fisheries.	Section 11.5.5 and *Appendix 11.2*, and cross referenced where appropriate
		Sandeel should be referred to as Ammodytidae, since there are five species, with possibly three to four in the area.	This Chapter and *Appendix 11.2* Sandeels are referred to as Ammodytidae.
MMO IMARES	East Anglia ONE (ERM 2012)	In addition to the diadromous species, it should be acknowledged that some of the other species listed (eg demersal, pelagic and elasmobranch fish) will also undertake migrations (eg plaice will migrate from spawning to feeding	This Chapter, and *Appendix 11.2* The migratory and seasonal movement of relevant fish species (including non-

Consultee	Date / Document	Comment	Response / where addressed in the PEI
	East Anglia ONE (ERM 2012)	grounds) and so there may be seasonal differences in their habitat utilisation within the study area.	diadromous species) has been described
		The East Anglia ONE PEIR authors concluded there would be no cumulative effect of wind farm and nearby shipping route since the fish would be habituated to the higher sound levels of the shipping route. This conclusion cannot be followed since fish might already be displaced from habitats by the busy shipping route and are facing additional habitat loss due to noise especially during wind farm construction.	Section 11.6. The potential cumulative noise impacts of the wind farm together with existing shipping are discussed.
		Mitigation measures should be investigated as part of the EIA, e.g. restricting pile-driving activity during peak spawning periods.	Section 11.3.3
		Clarification is required on if the characterisation for elasmobranchs within the offshore cable corridor. The MMO would require an assessment of the potential impact to these species within the ES.	The distribution of the principal species of elasmobranchs found in the area and their ecology is described in *Appendix 11.2* The effect of Electromagnetic Fields (EMFs) on elasmobranchs is assessed in section 11.6.2.4
		Concern in relation to the effects of noise on eggs and larvae was expressed and the implication of substantial larval mortality to have potential to negatively affect other receptors such as breeding birds. The institute is heavily involved in a partnership with other Dutch researchers, in assessing indirect food web effects of wind farms. In addition, IMARES is working on experimental assessments of larval mortality as a result of piling noise.	Consultation was undertaken with IMARES researchers currently involved in a number of research projects to improve the knowledge of the effect of piling noise on fish larvae. The results of their findings have been included in this chapter. In addition, an indication of the recent temporal and spatial distribution of spawning, based on the results of monthly ichthyoplankton surveys carried out from April 2010 to March 2011 in the southern

Consultee	Date / Document	Comment	Response / where addressed in the PEI
			North Sea by IMARES (van Damme et al. 2011) has been used to inform the fish ecology baseline (*Appendix 11.2*)
RSPB	East Anglia ONE (ERM 2012)	Spawning and nursery grounds for a number of fish including herrings and sandeels, form important components of the diets of many seabirds. Recommends that the ES includes consideration of the potential for construction noise to kill early life stages that cannot disperse readily, and for spawning behaviour to be disrupted. An assessment should then be made of the potential for this effect (particularly in combination) to reduce recruitment to fish populations and therefore affect prey availability for species higher in the food chain, including seabirds, over a longer term than displacement of prey during construction alone.	The potential effects on key prey species and wider ecosystem linkages are assessed in section 11.5.8, (see also *Appendix 11.2*)
RSPB MMO and Cefas	East Anglia ONE (ERM 2012) East Anglia ONE (ERM 2012)	The RSPB welcomes the commitment to review the relationships between top predators and species such as herring, sprat and sandeels in an ecosystems section of the ES. We recommend this should include consideration of the possibility for longer term impacts to arise.	The potential effects on key prey species and wider ecosystem linkages are assessed in section 11.5.8, (see also *Appendix 11.2*
		Clarification should be provided in the final EIA to show that the development of the OWF is not expected to have a significant effect on water quality at any time, with the exception of the increase in suspended sediment concentrations (SSC) detailed.	Section 11.6 and Chapter 9 Underwater Noise and Electromagnetic Fields.
MMO and Cefas	East Anglia ONE (ERM 2012)	Requested evidence to support any estimates and ranges that noise disturbance to fish and shellfish will be experienced.	Section 11.6.2 Chapter 9 Underwater Noise and Electromagnetic Fields. Underwater noise modelling has been undertaken to support the assessment of construction noise on fish.

11.3 Scope

11.3.1 Study Areas

7. The principal study areas for the assessment of fish and shellfish ecology are shown in *Figure 14.1*. The proposed East Anglia THREE project is located within International Council for the Exploration of the Sea (ICES) Division IVc (Southern North Sea). Pressure stocks[1] are managed by ICES division and quota is also allocated at this scale. 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. ICES rectangles are the smallest spatial unit available for the collation of fisheries statistics and have therefore been used to underpin the study areas defined in this assessment. The study areas are:

- East Anglia THREE site –(primarily located within ICES rectangle 34F2);
- Offshore cable corridor (offshore)– (located within ICES rectangle 33F2; and
- Offshore cable corridor (inshore) – located within ICES rectangle 33F1.

8. Throughout this chapter the offshore cable corridor, which includes both the second and third bullet point above, is also referred to.

9. A small percentage of the proposed East Anglia THREE project is located outside these study areas. The north-eastern corner of the East Anglia THREE site is located within ICES rectangle 34F3 and a small section of the offshore cable corridor, close to the landfall location, is located in ICES rectangle 32F1 (*Figure 14.1*). Due to the small proportion of these rectangles occupied by the proposed East Anglia THREE project, annual and seasonal variation have not been described at the scale of individual ICES rectangles.

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

11.3.2 Worst Case

11. A realistic 'worst case' scenario for the potential impacts of the proposed East Anglia THREE project on fish and shellfish ecology has been identified by using the project design envelope parameters described in Chapter 5 Description of Development.

[1] Stocks identified as under pressure from fishing mortality (e.g. overfishing) and therefore requiring management at the EU level through a system of Total Allowable Catches (TACs) and Quota

12. EATL is currently considering constructing the project in either a Single Phase or in a Two Phased approach. Under the Single Phase approach the project would be constructed in one single build period and under a Two Phased approach the project would be constructed in two phases each consisting of up to 600MW each.

13. Under the Single Phase approach, it is expected that the construction period for the proposed East Anglia THREE project (offshore) would span approximately 41 months. Under a Two Phased approach the proposed East Anglia THREE project would be built in a staggered way, with the construction of Phase 2 commencing a maximum of 18 months after the start of onshore construction of Phase 1. The total offshore construction period would span 42 months. Indicative construction programmes for both Single and Two Phased approaches are displayed in Chapter 5 Description of the Development, *Table 5.34* and *Table 5.37*.

14. The design parameters which constitute the worst case scenario for fish and shellfish ecology are presented by impact in *Table 11.2.* For construction impacts, the worst case for both Single Phase and Two Phased approaches is presented, and for operational impacts, a single worst case scenario is presented which represents an overall worst case whether that would occur as a result of either the Single or the Two phased approach.

Table 11.2 Worst Case Assumptions (numbers are displayed to two decimal places therefore totals may not align exactly with individual elements)

Impact	Worst case parameter for assessment	Rationale
Construction		
Impact 1: Physical disturbance and temporary loss of sea bed habitat	**Single Phase approach** Under the Single Phase approach the maximum area of disturbance across the East Anglia THREE site and offshore cable corridor has been quantified based on the following: 1. Sea bed disturbance for 60m gravity base foundations and scour protection calculated as 25,500m^2 per foundation (see Chapter 5 description of the Development *Table 5.10*). Therefore, for 100 foundations (see rationale column) the maximum area of disturbance would be 2.55km^2. 2. Sea bed disturbance for offshore electrical platforms and accommodation platform foundations with associated scour protection would amount to 16,800m^2 each. Under a Single Phase approach there would be up to six such structures totalling 0.10km^2. 3. Sea bed disturbance for up to two meteorological masts and scour protection of 2,830m^2 each totalling an area of 0.01km^2. 4. Jack up barge sea bed footprint for 180 foundations (based on a jack up barge footprint of 1,200m^2 and three movements per foundation) the maximum disturbance would be 0.65km^2 5. Installation of up to 550km inter-array cables and 195km of platform link cables (with worst case trench width of 17.3m and 15m spoil width either side of that) of 35.2km^2. 6. Installation of anchors for up to 12 buoys (LiDAR, wave recording and guard) 48m^2. The Total maximum area of disturbance during construction within the East Anglia THREE site would be 38.87km^2 (12.74% of the East Anglia	**Single Phase approach** Only the largest wind turbines (12MW) would be installed on 60m diameter gravity base foundations and therefore the worst case would be 100 wind turbine foundations with their associated scour protection (a larger number (172) of the smaller (40m diameter) gravity base foundations and associated scour protection results in a smaller area of disturbance). If scour protection is applied it is likely to be in the form of rock, concrete mattresses, sand-filled geotextile bags, or similar. Under a Single Phase approach up to five foundations for converter and collector stations, and one accommodation platform would be installed and scour protection may be required (Calculations for the affected area are provided within Chapter 5 description of the development, *Table 5.16*). Up to two meteorological masts may be installed using gravity base foundations. There are a number of potential foundation types although the greatest disturbance would come from the use of gravity base structures and associated scour protection. The use of jack-up vessels may be required for the installation of wind turbines, offshore platforms and meteorological masts. Should this be the case the jack up legs will be placed on the seabed causing disturbance. A

Impact	Worst case parameter for assessment	Rationale
	THREE site) and would occur over a 33 month period (See Chapter 5 Description of the Development *Table 5.34*. 7. Installation of up to 380km of interconnector cables (between the East Anglia THREE site and East Anglia ONE) within 190km of trench would create a maximum area of disturbance of 8.99km^2 (3.78% of the interconnector cable corridor). The disturbance would occur over a 13 month period (See Chapter 5 Description of the Development *Table 5.34*). 8. Installation of up to 664km of export cable would result in a maximum disturbed area of 31.41km2 (6.92% of the offshore export cable corridor) and would occur over a 22 month period (See Chapter 5 Description of the Development *Table 5.34*). The overall total footprint of disturbance of the proposed East Anglia THREE project under a Single Phase approach is 79.26km^2 (9.04% of the proposed East Anglia THREE project) occurring over a 41 month period. **Two Phased approach** Under the Two Phased approach, there would be one additional offshore platform (16,800m^2) and up to 3 extra platform link cables therefore maximum disturbance across the East Anglia THREE site would be 41.02km^2 (13.45% of the East Anglia THREE site) with works taking place over a 42 month period. Within the offshore cable corridor there would be up to two additional trenches required for 190km of interconnector cable installation therefore the maximum disturbance across the cable corridor would be 49.38km^2 (8.64% of the offshore cable corridor) and would take 39	conservative assumption estimates that the jack up vessel would need to reposition three times for each installation. The jack-up barge would be present for a maximum of two days per foundation location. LiDAR buoys, wave recording buoys and guard buoys would be anchored to the sea bed by anchors that would have a footprint of 4m^2 per buoy. Up to 12 buoys would be installed. When installing cables the greatest area of disturbance to benthic habitat would be caused by excavating a trench large enough to bury the cables to up to 5m. To achieve this a trench would be required that would be 17.3m wide and would have 15m of spoil either side (See chapter 5 Description of the Development section 5.5.14.1.7) **Two Phased approach** Under the Two Phased approach to construction the area of disturbance would be largely the same as with the Single Phase approach with the addition of 1 electrical platform, 3 platform links and two trenches in which interconnector cables would be laid. The construction periods would also be extended (see Chapter 5 Description of the Development section 5.5.16). Under either approach much of this calculated area would be only temporarily disturbed (i.e. anything related to cable installation or Jack up vessels). It is anticipated that a small proportion of it (the physical footprint of the proposed project) would represent permanent habitat

Impact	Worst case parameter for assessment	Rationale
	month period (See Chapter 5 Description of the Development *Table 5.37*) The overall total footprint of disturbance of the proposed East Anglia THREE site and offshore cable corridor under a Two Phased approach is 90.40km^2 (10.32% of the proposed East Anglia THREE project) with impacts occurring over a 42 month period.	loss. Operation Impact 1 assesses the impact of permanent habitat loss. An overlap would occur where there is a temporary physical disturbance (for example with sea bed preparation) with an area which then suffers permanent habitat loss through infrastructure being placed on that location. By assessing the two impacts (Construction impact 1 and Operation impact 1) separately all possible impacts will be quantified although there would be a degree of "double counting". This is a precautionary approach but ensures a comprehensive assessment.
Impact 2: Increased Suspended Sediment Concentrations (SSCs) and Sediment Re-deposition	The worst case scenario would involve the maximum amount of sediment disturbance including: **Single Phase approach** 1. Sea bed preparation of 40m diameter gravity base foundations calculated as 17,500m^3 per foundation (see Chapter 7 Marine Geology, Oceanography and physical processes *Table 7.4*). Therefore for 172 foundations (see Rationale column) the maximum expected amount sediment released into the water column is 3,010,000m^3. 2. Sea bed preparation for installation of gravity base or jacket foundations for up to 2 meteorological masts. Therefore, the maximum possible amount of sediment released into the water column would be up to 20,750m^3. 3. Sea bed preparation to install Jacket foundations for up to six offshore platforms (see rationale) would result in a maximum sediment release into the water column of 439,350m^3. Combination of the values listed above would give a total volume of	Only the smallest wind turbines (7MW) would be installed on 40m diameter gravity base foundations and therefore the worst case would be 172 wind turbine foundations requiring 17,500m^3 of ground preparation per foundation under both Single and Two Phase approaches (see Chapter 7 Marine Geology, Oceanography and physical processes *Table 7.4*). Under either approach the worst case scenario for the installation of meteorological masts would be either gravity base or jackets. This would result in seabed preparation of 10, 375m^3 and therefore represent the maximum potential of re-suspended sediment. Under the Single Phase approach, the worst case for sediment disturbance would be the installation of foundations for up to five converter and collector stations, and one accommodation platform. The greatest amount of seabed preparation would occur if these offshore platforms were installed on jacket foundations, in which

<table>
<tr><th>Impact</th><th>Worst case parameter for assessment</th><th>Rationale</th></tr>
<tr><td></td><td>3,470,100m^3 excavated material for foundations
4. Sea bed preparation required for cable installation (see rationale column) within the East Anglia THREE site would be up to 136,000m^3.
5. Sea bed preparation required for cable installation within the offshore cable corridor would be up to 385,841m^3.
Therefore the total maximum excavated sediment required for sea bed preparation for cable installation within the proposed East Anglia THREE project would be up to 521,841m^3

6. Installation of 550km inter-array,195km of platform link, 190km of interconnector trenching and 664km of export cables (Total 1,599km) to a depth of 5m using the technique of jetting. The maximum realistic speed of cable installation if jetting is used is likely to be approximately 150-450 m/hr (See Chapter 5 Description of the development Table 5.34). The installation of cables would be spread across 26 months for the inter-array and platform link cables and across 13 months for the interconnector cables. (See Chapter 5 Description of the development Table 5.34).
The installation of cables and foundations would be spread across 33 months with a maximum of two sea bed preparations for foundations per day.

Two Phased approach
Under the Two Phased approach, sea bed preparation to install 1 extra Jacket foundation would result in a maximum sediment release into the water column of up to 3,543,325m^3.
The installation of foundations would extend across two distinct 7</td><td>case up to 73,225m^3 could be excavated.
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. The estimated maximum of material released into the water column would be 83,560m^3 (Chapter 5 Description of the development, section 5.5.4.1.3.
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 gravity base foundations (Chapter 7 Marine Geology, Oceanography and physical processes Table 7.5) and therefore overall it is considered that installation of gravity base foundations are the worst case scenario for re-suspension of sediments.
To allow efficient installation and protection of electrical cables there could be a requirement for sea bed excavation in areas where steep sided sand waves occur. A detailed explanation of how the calculations were made for the amount of material that may be excavated is provided in section 7.6.1.3 of Chapter 7 Marine Geology, Oceanography and Physical Processes and these calculations are deemed relevant to both the Single Phase and the Two Phased approaches.
With respect to actual electrical cable installation the worst case scenario for the suspension of sediment would arise from the use of jetting techniques. Other techniques are being considered (Chapter 5 Description of the</td></tr>
</table>

Impact	Worst case parameter for assessment	Rationale
	month periods (See Chapter 5 Description of the Development *Table 5.36* and *Table 5.37*). Under the Two Phased approach, three extra platform link cables, and two extra trenches would be required for interconnector cables would be required, therefore the total length of installed cable would be 1,834km. The installation of cables and foundations would extend across 42 months (See Chapter 5 Description of the Development *Table 5.37*) with a maximum of two sea bed preparations for foundations per day.	Development, section 5.5.14). In reality, jetting is only likely to be used for a small proportion of electrical cable installation. **Two Phased approach** Under the Two Phased approach, much of the worst case scenario would be identical to that of the Single Phase, with the addition of one offshore electrical platforms three platform link cables and two interconnector cable trenches installed over a longer construction period (42 months as opposed to 33)
Impact 3: Underwater noise	For both Single and Two Phased approaches, the worst case for the assessment of construction noise is based on the use of a 3,500kJ hammer **Single Phase approach** 1. Up to two concurrent piling events 12m diameter piles 3,500kJ hammer 2. Total piling duration of 8 months The Single Phase effectively represents the worst case in a spatial context. **Two Phased approach** 1. No concurrent piling 2. Duration of pile driving within each phase of 5 months separated by 10 months (Chapter 5 Description of Development, *Table 5.34*) The Two Phased Approach effectively represents the worst case in a temporal context	The greatest potential impacts on fish and shellfish as a result of underwater would originate from the installation of 12m monopile foundations. Installation of these piles using the maximum hammer energy of 3,500 kJ would result in the greatest spatial extent of the impact. **Single Phase approach** Concurrent piling (two piles being used at the same time) would increase the spatial arera of impact. **Two Phased approach** As pile driving would not occur simultaneously the spatial extent of the impact would be reduced. However, overall piling time would be increased by two months.

Impact	Worst case parameter for assessment	Rationale
Operation		
Impact 1: Physical disturbance and loss of sea bed habitat	The maximum possible sea bed footprint of the project including scour protection. The scour assessment *Appendix 7.3* shows that the maximum scour holes would be smaller than the maximum area of scour protection as specified in Chapter 5 Description of the Development. Under the worst case scenario the Two Phased approach would have the size of footprint is based on the following: **Two Phased approach** 1. 60m gravity base foundations and scour protection calculated as 25,500m^2 per foundation (see Chapter 7 Marine Geology, Oceanography and physical processes Table 7.4). Therefore for 111 foundations (see Rationale column) the maximum area of disturbance would be 2.55km^2. 2. Gravity base foundations for offshore electrical platform and accommodation platform foundations with associated scour protection would amount to a footprint of 16,800m^2 each. Under a Single Phase approach there would be up to 6 such structures totalling 0.10km^2 3. The gravity base foundation and scour protection footprint for two meteorological masts would be 0.01km^2. 4. Cable protection due to inability to bury for up to 10% of 550km inter-array cable would result in a footprint of up to 0.17km^2 5. Cable protection for up to 10% of 195km of Platform link cable would result in a footprint of up to 0.06 km^2. 6. Cable protection associated with cable crossing for platform link cables would result in a footprint of up to 0.01 Km^2. Total footprint during operation within the East Anglia THREE site which	Represents the greatest calculated area of permanent seabed habitat loss. The areas occupied by cable protection, are based on calculations displayed in *Table 5.25* and *Table 5.27* in Chapter 5 Description of the Development. It is expected that any requirement for cable protection would be considerably reduced following further detailed design studies. **Two Phased approach** Under the Two Phased approach, much of the worst case scenario would be identical to that of the Single Phase, with the exception of offshore electrical platforms platform link cables and interconnector cables. Under the worst case scenario for the Two Phased approach there would be one additional electrical platform and three additional platform link cables, and two additional interconnector cable trenches to protect. All of which would result in a greater amount of material placed on the seabed to protect the infrastructure.

Impact	Worst case parameter for assessment	Rationale
	could be subject to permanent habitat loss is therefore 2.92km^2 (0.95% of the East Anglia THREE site area). 7. Cable protection due to an inability to bury interconnector cables (between East Anglia THREE and East Anglia ONE) would result in a footprint of up to 0.11km^2. 8. Protection associated with cable crossing for interconnector cables would result in a footprint of up to 0.02km^2. Total footprint during operation of the interconnector cables is therefore 0.14km^2 (0.06% of the Interconnector cable corridor area). 9. Cable protection due to an inability to bury export cables would result in a footprint of up to 0.20km^2. 10. Protection associated with cable crossing for export cables would result in a footprint of up to 0.03km^2. Total footprint which could be subject to permanent habitat loss during operation of the export cables is therefore 0.23km^2 (0.05% of the export cable corridor area). Total footprint which could be subject to permanent habitat loss during operation of the export cables is therefore 0.23km^2 (0.05% of the export cable corridor area). Under the Two Phased approach, the overall total footprint which could be subject to permanent habitat loss would therefore be 3.23km^2 (0.37% of the overall project area).	
Impact 2: Introduction of hard substrate	The introduction of new hard structures with a maximum surface area provided by the following project infrastructure: 1. Gravity base foundations for wind turbines 2. Gravity base foundations for offshore platforms and meteorological masts,	It is not possible to accurately calculate the surface area that would be available for colonisation. It would however be greater than the figure presented for "footprint" in operation Impact 1 (above) as the former is a 3-D metric, whilst the latter is 2-D.

Impact	Worst case parameter for assessment	Rationale
	3. Inter-array cable protection and crossings, 4. cable protection of High Voltage Alternating Current (HVAC) or Low Frequency Alternating Current (LFAC) export cables and between offshore electrical platforms Cable protection of HVDC or LFAC export cable	
Impact 3: Operational noise	**Both Single Phase and Two Phased approach** 172 wind turbines (7MW) with minimum spacing (675m x 900m) Maximum number of operation and maintenance works over the proposed East Anglia THREE project lifetime (25 years) which would include up to 4,000 two way trips to site per annum.	The largest number of wind turbines with the closest spacing results in the generation of the greatest levels of underwater noise. The maximum number of vessel movements would create the greatest period of underwater noise.
Impact 4: EMFs	The greatest impact from EMF would occur if cables are buried to the shallowest depth of 0.5m and the maximum amount of cable laid is based on: **Two Phased approach** 3. The maximum length of inter-array (up to 75kV of alternating current) cables would be up to 550km 4. The maximum length of platform link cables would be up to 240km of up to 400kV direct current cables under the HVDC solution or up to 45km of 600kV alternating current cables under the LFAC solution. 5. The maximum length of interconnector cables (up to 600kV) would be 380km (up to 600kV). 6. The maximum length of export cable (up to 600kV) would be 664km. The total length of cable laid under the Two Phased approach would be up to 1,834km.	The scenario described would result in the greatest area of impact. Note that a Two Phased approach would result in the greatest amount of installed cable (1834km compared to 1789km). (See Chapter 9 Underwater Noise and Electromagnetic Fields).

Impact	Worst case parameter for assessment	Rationale
Decommissioning		
In the absence of detailed methodologies and schedules, the worst case scenarios for decommissioning activities and associated implications for fish and shellfish are considered analogous with those assessed fort the construction phase.		
Cumulative effects		
Outcome of the cumulative impact assessment would be greatest when the greatest number of other schemes, present or planned, are considered.		

11.3.3 Embedded Mitigation Specific to Fish and Shellfish Ecology

15. Where relevant, mitigation measures are incorporated as part of the project design process and are referred to as "Embedded mitigation". In order to minimise the potential impacts of the proposed East Anglia THREE project on fish ecology, EATL has committed to the following:

- The majority of the inter-array, platform link cables (between offshore electrical platforms), interconnector cables and export cables would be armoured, and buried in the sea bed at a depth of between 0.5m and 5m..
- Appropriate cable protection methods would be used where burial is not possible, however this would be limited to 10% of the cable length.
- The preferred method of cable protection would be mattresses (see Chapter 5 Description of the Development, section 5.5.14.2) which would have the smallest ecological footprint of any cable protection method.
- 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 East Anglia THREE site.
- Soft start pile driving would be implemented to allow mobile species to move away from the area of highest noise impact.

11.4 Assessment Methodology

11.4.1 Legislation, Policy and Guidance

16. 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 THREE project are as follows:

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

17. The specific NPS (EN-3) assessment guidance relevant to fish and shellfish ecology is summarised in *Appendix 11.2*

18. 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 are able to support strong, biodiverse biological communities and the functioning of healthy, resilient and adaptable marine ecosystems.
- Our oceans support viable populations of representative, rare, vulnerable, and valued species.

19. 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 to do with the Marine Strategy Framework Directive and the Water Framework Directive (WFD) (see Chapter 3 Policy and Legislative Context and Chapter 8 Marine Water and Sediment Quality for more details) , as well as other environmental, social and economic considerations.

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

- Review of Cefas monitoring programmes;
- Guidelines for ecological impact assessment in Britain and Ireland: Marine and coastal. (Chartered) Institute of Ecology and Environmental Management (IEEM) (2010);
- Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2012) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Contract report: ME5403, May 2012;
- Marine Licensing requirements (replacing Section 5 Part II of the Food and Environment Protection Act (FEPA) 1985 and Section 34 of the Coast Protection Act (CPA) 1949);

- 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 FEPA and CPA requirements, Version 2;
- Strategic Review of Offshore Windfarm Monitoring Data Associated with FEPA Licence Conditions (Cefas 2010);
- 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 - 2nd Report of the Technical Subgroup on Underwater noise (TSG Noise). Part II Monitoring Guidance Specifications. Interim Guidance Report. (2013);
- 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
- East Anglia THREE Windfarm IPC Scoping responses.

11.4.2 Data sources

21. The key data sources and limitations of this data used to characterise the baseline and assess the potential impacts of the proposed East Anglia THREE project on fish and shellfish receptors are discussed in detail in section 11.3 of *Appendix 11.2.* Fish and shellfish characterisation surveys using otter and beam trawls were undertaken in February and May 2013 within the proposed East Anglia THREE project area to provide information on fish and shellfish assemblages (further detail is provided with *Appendix 11.2*).

22. The following resources were also accessed:

- Cefas publications and International Council for Exploration of the Sea (ICES) publications;
- COWRIE reports;
- Results of monitoring programmes undertaken in operational wind farms in the UK and other European countries;
- East Coast Regional Environmental Characterisation (REC) (Limpenny 2011)
- Draft East Marine Plan documents, July 2013 (MMO 2013)

- MCZ recommendations – Net Gain and Natural England; and
- Other relevant research publications and stock assessments.

23. In light of potential inter-relationships between impacts the following Environmental Statement (ES) chapters have been used to inform the assessment where appropriate:

- Chapter 7 Marine Geology, Oceanography and Physical Processes;
- Chapter 9 Underwater Noise and Electromagnetic Fields;
- Chapter 10 Benthic Ecology;
- Chapter 12 Marine Mammal Ecology; and
- Chapter 14 Commercial Fisheries

11.4.3 Data Limitations and Gaps

24. All data sources listed under section 11.4.2 are subject to certain sensitivities and limitations, which are described in more detail in *Appendix 11.2.*

11.4.4 Impact Assessment Methodology

25. The approach to assessment of potential impacts on fish and shellfish ecology has been agreed in consultation with Natural England and Cefas and is described further in *Appendix 11.1*.

26. The potential impacts of the proposed East Anglia THREE project on fish and shellfish are as specified in the Cefas and MCEU (2004) guidelines for offshore wind developments. Potential impacts on the following ecological aspects are taken forward for assessment:

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

- Commercial importance.

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

28. Cumulative impacts relevant to fish and shellfish ecology arising from other marine developments are discussed in section 11.7 and interrelationships with other receptor groups are described in section 11.8.

11.4.4.1 Assessment Limitations

29. 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. Further uncertainties relate to the distribution of some species and the degree to which they access the proposed East Anglia THREE project during key life history phases such as during spawning or migration.

11.4.4.2 Significance Criteria

30. 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 to some extent qualitative and reliant on professional experience and judgement.

11.4.4.3 Sensitivity

31. 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. vulnerability)

32. 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 11.3*.

33. 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. (2006) and Carlson et al. (2007) in terms of injury, while behavioural criteria were devised following the work of McCauley et al. (2000) and Pearson et al. (1992). Consideration has also been given to work by Mueller-Blenkle et al. (2010) and Halvorsen et al (2012).

Table 11.3 Definitions of Receptor Sensitivity

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

11.4.4.4 Ecological value

34. 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 *Table11.4*.

Table 11.4 Definition of Value

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

11.4.4.5 Magnitude

35. The magnitude of an effect is considered for each predicted impact on a given receptor and is defined geographically, temporally and in terms of the likelihood of

occurrence. The definitions of terms relating to the magnitude of a potential impact on fish and shellfish ecology are provided in *Table 11.5.*

36. With respect to duration of potential impacts, those associated with construction are considered to be short term, occurring over a maximum of 2 years. Impacts associated with operation are longer term, occurring over the operational lifetime of the proposed East Anglia THREE project.

Table 11.5 Definitions of Magnitude of Effect

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the particular receptors character or distinctiveness.
Medium	Considerable, permanent / irreversible changes, over the majority of the receptor, and / or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Low	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
No Impact	No loss of extent or alteration to characteristics, features or elements.

11.4.4.6 Impact significance

37. *Table 11.6* applies the significance criteria 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 results in a minor significance. Those effects which are moderate or major are considered significant with respect to EIA assessments.

38. 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 11.6 Impact Significance Matrix

Sensitivity	Magnitude				
	High	Medium	Low	Negligible	No change
High	Major	Major	Moderate	Minor	No impact
Medium	Major	Moderate	Minor	Negligible	No impact
Low	Moderate	Minor	Minor	Negligible	No impact
Negligible	Minor	Negligible	Negligible	Negligible	No impact

39. Through use of this matrix, an assessment of the significance of an impact can be made in accordance with the definitions in *Table 10.7*.

Table 11.7 Impact Significance Definitions

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

11.4.5 Cumulative Impact Assessment

40. With regards to cumulative impacts, already installed infrastructure, practiced licenced activities and implemented measures have been assumed to constitute part of the existing environment to which receptors have adapted. There is also a paucity of information on a number of planned offshore developments which hinder a comprehensive assessment. The developments, activities and measures taken forward for cumulative assessment have been selected to be taken forward on the basis on the availability of information, probability and spatial overlap where relevant.

11.4.6 Trans-boundary Impact Assessment

41. The distribution of fish and shellfish species is independent of national geographical boundaries. The East Anglia THREE specific impact assessment has therefore been

undertaken taking account of the distribution of fish stocks and populations irrespective of political limits. As a result, it is considered that a specific assessment of trans-boundary effects is unnecessary.

11.5 Existing Environment

11.5.1 Fish and Shellfish distribution in the Southern North Sea (ICES Area IVc)

42. An overview of fish and shellfish distribution in ICES Area IV (including areas IVa, IVb, IVc) is provided in *Appendix 11.2*. Within this chapter, fish and shellfish species are described in the relevant sections in terms of their commercial importance, location of spawning and nursery grounds, and conservation importance. With respect to species of conservation importance, information is provided on the conservation status of a given species, including diadromous and elasmobranch species, as well as those that play fundamental roles in North Sea food webs.

11.5.2 Site Specific Surveys

43. In order to inform the EIA, site specific fish and shellfish characterisation surveys were conducted in February and May 2013. In both surveys, fish and shellfish assemblages were sampled using a commercial demersal otter trawl and four metre commercial beam trawl gear. Survey methodology and results are described in detail within *Appendix 11.2*.

44. As part of the benthic ecology work package, epi-benthic communities were characterised using a two metre scientific beam trawl at nine stations along the export cable corridor and within the East Anglia THREE site; a description of the survey methodology and results is provided in *Appendix 10.4,* results are summarised in *Table 11.10,* section 11.5.3.3.

11.5.2.1 Otter Trawl Sampling

45. A total of eighteen species were caught by the demersal otter trawl sampling. Species richness was higher within samples from the East Anglia THREE site (18 species) compared to controls (eight species). The highest catch rates (Catch Per Unit Effort (CPUE) measured as number of individuals per hour) were recorded for dab *Limanda limanda* followed by plaice *Pleuronectes platessa* and whiting *Merlangius merlangus*. Other species were less abundant. A summary of the results of demersal otter trawl sampling is provided in *Table 11.8*.

Table 11.8 Summary Results of the Demersal Otter Trawl Sampling (February and May 2013)

Common Name	Latin Name	CPUE (number of individuals per hour)			
		Control		East Anglia THREE site	
		Feb 2013	May 2013	Feb 2013	May 2013
Dab	*Limanda limanda*	72.8	9.0	60.5	12.8
Plaice	*Pleuronectes platessa*	33.9	7.5	31.3	16.6
Whiting	*Merlangius merlangus*	3.0	32.8	34.8	11.0
Lesser spotted dogfish	*Scyliorhinus canicula*	-	13.5	-	3.8
Grey Gurnard	*Eutrigla gurnardus*	4.0	-	3.0	2.1
Herring	*Clupea harengus*	-	-	6.9	-
Flounder	*Platichthys flesus*	3.0	-	2.0	-
Lesser Weever	*Echiichthys vipera*	2.0	1.2	-	0.9
Cod	*Gadus morhua*	1.0	-	2.0	-
Bullrout	*Myoxocephalus scorpius*	-	-	-	1.8
Sprat	*Sprattus sprattus*	-	-	1.5	-
Bib	*Trisopterus luscus*	-	-	1.0	-
Cuttlefish	*Sepia officinalis*	-	-	0.5	-
Common Dragonet	*Callionymus lyra*	-	-	-	0.5
Squid indet.	*Alloteuthis* spp.	-	-	-	0.5
Horse Mackerel	*Trachurus trachurus*	-	-	-	0.5
Sprat	*Sprattus sprattus*	-	-	-	0.4
Lemon Sole	*Microstomus kitt*	-	-	-	0.4

11.5.2.2 Beam Trawl Sampling

46. A total of twenty-three species of fish and shellfish were present in 4 metre beam trawl samples. As with otter trawls, species richness was highest in samples from the East Anglia THREE windfarm site (19 species) compared to controls (17 species) although the difference was less marked. Similar to otter trawl samples, plaice and dab were the most abundant species encountered. Whelk *Buccinum undatum* were not caught in the East Anglia THREE site but were present in relatively high numbers at control stations during the May 2013 survey. Remaining species were generally lower in abundance. It should be noted that whilst species such as velvet swimming crabs were recorded in 4 metre beam trawl samples, this method is not designed to sample macro-invertebrates. The numbers reported may therefore underrepresent the underlying population. A summary of the results of the beam trawl sampling is provided in *Table 11.9.*

Table 11.9 Summary Results of 4m Beam Trawl sampling in the study area (February and May 2013)

Common Name	Latin Name	CPUE (number of individuals per hour)			
		Control		East Anglia THREE site	
		Feb 2013	May 2013	Feb 2013	May 2013
Plaice	*Pleuronectes platessa*	37.6	29.2	86.2	36.0
Dab	*Limanda limanda*	29.0	15.0	68.1	16.5
Whelk	*Buccinum undatum*	0.7	27.0	-	-
Solenette	*Buglossidium luteum*	0.7	3.0	5.2	6.8
Velvet Crab	*Necora puber*	0.7	3.0	5.1	-
Lesser spotted dogfish	*Scyliorhinus canicula*	-	5.2	1.5	0.7
Cuttlefish	*Sepia officinalis*	1.5	-	5.2	-
Bullrout	*Myoxocephalus scorpius*	-	-	5.2	1.5
Scaldfish	*Arnoglossus laterna*	1.5	1.5	3.0	-
Common dragonet	*Callionymus lyra*	-	2.2	0.7	1.5
Grey gurnard	*Eutrigla gurnardus*	0.7	1.5	1.5	-
Lesser weever	*Echiichthys vipera*	-	0.7	-	1.5
Dover Sole	*Solea solea*	-	0.7	-	0.8
Pogge	*Agonus cataphractus*	-	0.7	-	0.7
Whiting	*Merlangius merlangus*	-	0.7	0.7	-
Turbot	*Psetta maxima*	-	-	-	0.8
John Dory	*Zeus faber*	-	-	-	0.7
Sea Scorpion	*Taurulus bubalis*	-	-	-	0.7
Mackerel	*Scomber scombrus*	-	-	-	0.7
Goby indet.	Gobidae	0.7	-	-	-
Sprat	*Sprattus sprattus*	0.7	-	-	-
Brill	*Scophthalmus rhombus*	-	-	0.7	-
Thornback Ray	*Raja clavata*	0.7	-	-	-

11.5.2.3 Epibenthic surveys

47. A total of 42 fish and invertebrate species occurred in samples using the 2m scientific beam trawl. Although species composition was broadly consistent with otter and beam trawl surveys the most abundant fish were small bodied non-commercial species such as solenette, sand goby and lesser weever. This difference is largely attributable to the use of the smaller meshed cod end used on the scientific 2m beam trawl.

48. Abundance of epi-benthic invertebrates was generally relatively low, with brown shrimp[2] *Crangon allmanni* and *Crangon crangon* representing the most abundant species, followed by hermit crab *Pagurus bernhardus*. Results from the survey are

[2] Both species occur in commercial catches where they are marketed under the common name of 'brown shrimp'

described in further detail within Chapter 10 Benthic Ecology and summarised in *Table 11.10.*

Table 11.10 Summary of the results (No. individuals caught per hour) of the 2m Scientific Beam Trawl survey in the study area (May 2013)

Common Name	Latin Name	CPUE (individuals per hour)	
		Offshore cable corridor	East Anglia THREE site
Solenette	*Buglossidium luteum*	6.51	5.49
Sand goby	*Pomatoschistus minutus*	2.08	5.83
Brown shrimp	*Crangon allmanni*	4.65	1.10
Lesser weever	*Echiichthys vipera*	1.28	0.94
Scaldfish	*Arnoglossus laterna*	0.51	0.79
Brown shrimp	*Crangon crangon*	0.55	0.35
Common hermit crab	*Pagurus bernhardus*	0.45	0.22
Dab	*Limanda limanda*	0.31	0.24
Common dragonet	*Callionymus lyra*	0.22	0.17
Swimming crab	*Liocarcinus holsatus*	0.24	0.13
Dragonet indet.	*Callionymus* spp.	0.01	0.33
Little cuttlefish	*Sepiola atlantica*	0.27	0.06
Pogge	*Agonus cataphractus*	0.19	0.13
Pink shrimp	*Pandalus montagui*	0.22	0.06
Greater sandeel	*Hyperoplus lanceolatus*	0.11	0.06
Plaice	*Pleuronectes platessa*	0.04	0.15
Sandy swimming crab	*Liocarcinus depurator*	0.04	0.14
Sandeel indet.	*Ammodytidae*	0.08	0.06
Reticulated dragonet	*Callionymus reticulatus*	0.06	0.07
Smooth sandeel	*Gymnammodytes semisquamatus*	0.01	0.11
Sprat	*Sprattus sprattus*	0.11	0.00
Spider crab indet.	*Macropodia parva/rostrata*	0.11	0.00
Whiting	*Merlangius merlangus*	0.05	0.06
Marbled swimming crab	*Liocarcinus marmoreus*	0.08	0.03
Dover sole	*Solea solea*	0.06	0.04
Four bearded rockling	*Enchelyopus cimbrius*	0.04	0.04
Grey gurnard	*Eutrigla gurnardus*	0.02	0.06
Velvet crab	*Necora puber*	0.00	0.06
Masked Crab	*Corystes cassivelaunus*	0.04	0.02
Lesser sandeel	*Ammodytes tobianus*	0.03	0.02
Greater pipefish	*Syngnathus acus*	0.05	0.00
Goby indet.	*Pomatoschistus* spp.	0.01	0.02
Five bearded rockling	*Ciliata mustela*	0.01	0.02
Lesser spotted dogfish	*Scyliorhinus canicula*	0.03	-
Shrimp indet.	*Pandalus* spp.	0.03	-
Shrimp indet.	*Crangon* spp.	0.03	-
Whelk	*Buccinum undatum*	0.02	-
Goby indet.	*Gobiidae*	0.02	-
Herring/Sprat	*Clupeidae*	0.01	-
Spotted ray	*Raja montagui*	0.01	-

Common Name	Latin Name	CPUE (individuals per hour)	
		Offshore cable corridor	East Anglia THREE site
Slender spider crab	*Macropodia tenuirostris*	0.01	-
Squat lobster	*Galathea intermedia*	0.01	-

11.5.3 International Beam Trawl Surveys (IBTS)

49. The 50 most common species present in the East Anglia THREE specific study areas *(Figure 11.1),* expressed as their average relative abundance (CPUE) in IBT surveys (spring, summer, autumn, winter) for the years 2004-2013 is given in *Table 11.11.* For all species, data are mean values from combined quarterly surveys (spring, summer, autumn, winter) from 2004-2013.

50. High CPUEs were recorded for sprat in the offshore cable corridor and the East Anglia THREE site. Sand goby CPUE was highest in the offshore cable corridor. Herring CPUE was highest within the East Anglia THREE site, but low in the offshore cable corridor. Relatively high CPUEs were also recorded for greater sandeel *Hyperoplus lanceolatus* in the offshore cable corridor.

Table 11.11 Average CPUE for principle species recorded in the IBTS in the local study area (2004-2013) (DATRAS 2013)

Common Name	Latin Name	CPUE (individuals per hour)		
		33F1	33F2	34F2
Sprat	*Sprattus sprattus*	301.20	69.52	843.42
Sand Goby	*Pomatoschistus* spp.	0.00	1234.80	177.10
Whiting	*Merlangius merlangus*	132.60	145.20	406.40
Greater sandeel	*Hyperoplus lanceolatus*	0.00	239.45	4.27
Lesser weever fish	*Echiichthys vipera*	3.30	120.34	90.43
Poor cod	*Trisopterus esmarkii*	7.30	330.76	7.72
Herring	*Clupea harengus*	8.40	31.51	270.86
Dab	*Limanda limanda*	54.40	17.88	98.70
Mackerel	*Scomber scombrus*	1.40	7.85	64.50
Lesser sandeel	*Ammodytes tobianus*	0.00	0.00	5.80
Horse mackerel	*Trachurus trachurus*	2.20	10.36	31.38
Bib	*Trisopterus luscus*	1.00	18.64	6.70
Pogge	*Agonus cataphractus*	1.40	21.85	2.94
Red mullet	*Mullus barbatus*	0.00	0.70	1.40
Squid spp.	*Loliginidae* spp.	0.00	0.00	17.80
Lesser sandeel	*Ammodytes marinus*	0.00	3.56	2.79
Plaice	*Pleuronectes platessa*	0.50	5.86	3.38
Lesser spotted dogfish	*Scyliorhinus canicula*	9.00	3.28	3.33
Striped red mullet	*Mullus surmuletus*	1.80	0.81	2.90
European common squid	*Alloteuthis subulata*	0.00	1.86	3.50

Common Name	Latin Name	CPUE (individuals per hour)		
		33F1	33F2	34F2
Solenette	*Buglossidium luteum*	0.00	0.85	6.00
Long-finned squid	*Loligo forbesii*	0.00	0.60	0.10
Common squid	*Loligo subulata*	0.00	0.00	4.47
Grey gurnard	*Eutrigla gurnardus*	0.00	2.31	2.52
Cuttlefish	*Sepiidae*	0.00	0.00	0.20
Scaldfish	*Arnoglossus laterna*	0.00	0.30	4.94
Goby indet.	*Gobiidae*	0.00	0.00	1.20
Dover sole	*Solea solea*	0.30	1.10	0.20
Red gurnard	*Chelidonichthys cuculus*	0.00	0.80	0.73
Sandeel indet.	*Ammodytidae*	0.00	0.60	0.00
Smooth sandeel	*Gymnammodytes semisquamatus*	0.00	4.80	0.20
Lemon sole	*Microstomus kitt*	2.00	0.66	2.11
Common dragonet	*Callionymus lyra*	0.20	0.52	0.93
Cod	*Gadus morhua*	0.40	2.04	0.88
Starry smoothhound	*Mustelus asterias*	1.30	0.26	0.34
Blonde ray	*Raja brachyura*	0.00	3.10	0.40
Common smoothhound	*Mustelus mustelus*	0.00	1.73	0.29
Flounder	*Platichthys flesus*	0.00	0.00	0.00
European anchovy	*Engraulis encrasicolus*	0.00	0.2	0.86
Atlantic bobtail	*Sepiola atlantica*	0.00	0.00	0.20
Sea lamprey	*Petromyzon marinus*	0.00	0.80	0.00
Thornback ray	*Raja clavata*	0.20	0.20	0.23
European eel	*Anguilla anguilla*	0.00	0.00	0.00
Pilchard	*Sardina pilchardus*	0.00	0.00	0.00

11.5.4 Commercial Fish and Shellfish Species

51. It is important to consider that commercial fisheries data does 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 14 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. For example, recent ICES reports indicate that the abundance of North Sea of cod, haddock and plaice are increasing (The Scottish Government 2015). However, the TAC and associated quota for these species would only ever reflect this in subsequent years and resulting increases are unlikely to represent a direct reflection in abundance.

52. 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 not present in 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.

53. MMO data has therefore been used to provide an indication only of the commercial species present. This has been presented by ICES rectangle and analysed in order to identify those species to be taken forward for the impact assessment in sections 11.6 and 11.7.

11.5.4.1 Principal Commercial Species

11.5.4.1.1 UK MMO Landings Statistics

54. Annual landings weights (average 2004-2013) of the principal commercial species targeted in ICES rectangles relevant to the proposed East Anglia THREE project (33F1, 33F2 and 34F2) are shown in *Table 11.12*. The fish species landed in the highest volumes are sprat, plaice, cod, sole, skates and rays, thornback rays and horse mackerel. Landings of plaice were highest in offshore rectangles, representing approximately half of total landings of the offshore cable corridor (offshore) and a third of landings in the East Anglia THREE site, but were negligible in the offshore cable corridor (inshore). Sprat landings were an order of magnitude higher in the offshore cable corridor (inshore) compared to the offshore cable corridor (offshore) and the East Anglia THREE site. Horse mackerel landings are constrained almost entirely to the offshore cable corridor (offshore). Landings weights of sole, cod, skates and rays and thornback rays were all highest from the offshore cable corridor (inshore) area compared to the East Anglia THREE site.

55. With respect to shellfish, almost all landings are from the offshore cable corridor (inshore). By weight, whelks constituted the highest landings, whilst those of edible crab and lobster, (*Homarus gammarus*), were considerably lower.

56. Annual and seasonal variations in landings from UK registered vessels in the ICES rectangles occupied by the proposed East Anglia THREE project are shown in *Figure 11.2* to *Figure 11.5* in *Appendix 11.2.* With respect to seasonal variability in the East Anglia THREE site, plaice landings peak during the winter (November to February), corresponding to the high intensity spawning period defined by Coull et al. (1998) and Ellis et al. (2010). The highest cod landings from the East Anglia THREE site also

corroborate the spawning period defined by Coull et al. (1998) and Ellis et al. (2010) (December to April).

57. In those rectangles relevant to the offshore cable corridor, seasonal landings of cod are also highest during the spawning period (e.g. January to April). Although sole are landed throughout the year, seasonally the highest weights are recorded from April to August, overlapping partially with spring spawning. Herring landings are considerably higher during the tail end of the winter spawning period (January) compared to other months.

Table 11.12 Average weight (tonnes) and percentage contribution of the principal commercial species (MMO landings data 2004-2013) within each ICES rectangle relevant to the East Anglia THREE Wind Farm site and the Offshore Cable Corridor

Species	33F1 (offshore cable corridor (inshore)		33F2 (Offshore cable corridor (offshore)		34F2 (East Anglia THREE site)	
	Average Landings (tonnes)	Average contribution to total landings in 33F1 (%)	Average Landings (tonnes)	Average contribution to total landings in 33F2 (%)	Average Landings (tonnes)	Average contribution to total landings in 34F2 (%)
Sprat	133.9039	30.95%	57.526	15.00%	34.225	26.94%
Plaice	2.01389	0.47%	174.3154	45.47%	45.04076	35.46%
Sole	69.35468	16.03%	43.67373	11.39%	19.05274	15.00%
Cod	79.23073	18.31%	20.84125	5.44%	9.66258	7.61%
Skates and Rays	37.74711	8.72%	6.11023	1.59%	2.62124	2.06%
Whelks	32.52077	7.52%	2.29862	0.60%	0.70437	0.55%
Horse Mackerel	0.09573	0.02%	31.47378	8.21%	0.01029	0.01%
Thornback Ray	22.0964	5.11%	2.50123	0.65%	1.45031	1.14%
Flounder or Flukes	6.8168	1.58%	4.82326	1.26%	1.21828	0.96%
Dabs	1.3921	0.32%	7.67828	2.00%	2.60041	2.05%
Herring	6.31707	1.46%	4.76439	1.24%	0	0.00%
Brill	1.44719	0.33%	5.90903	1.54%	1.89307	1.49%
Bass	5.94981	1.38%	0.62031	0.16%	0.11845	0.09%
Edible Crabs	6.35022	1.47%	0.07605	0.02%	0.09446	0.07%
Turbot	0.20484	0.05%	4.34837	1.13%	1.7965	1.41%
Whiting	0.86587	0.20%	4.51059	1.18%	0.55835	0.44%
Spurdog	3.86022	0.89%	0.20621	0.05%	1.7005	1.34%

Species	33F1 (offshore cable corridor (inshore)		33F2 (Offshore cable corridor (offshore)		34F2 (East Anglia THREE site)	
	Average Landings (tonnes)	Average contribution to total landings in 33F1 (%)	Average Landings (tonnes)	Average contribution to total landings in 33F2 (%)	Average Landings (tonnes)	Average contribution to total landings in 34F2 (%)
Lobsters	4.93737	1.14%	0.07527	0.02%	0.02214	0.02%
Smoothhound	4.7051	1.09%	0.12876	0.03%	0.02859	0.02%
Brown Shrimps	4.364	1.01%	0	0.00%	0.004	0.00%
Blonde Ray	1.4645	0.34%	1.08149	0.28%	1.50934	1.19%
Lesser Spotted Dog	3.0316	0.70%	0.353	0.09%	0.248	0.20%
Black Seabream	0.0004	0.00%	2.74421	0.72%	0	0.00%
Pouting	0.26769	0.06%	1.69384	0.44%	0.15209	0.12%
Other Species	3.70933	0.86%	5.64899	1.47%	2.32466	1.83%

11.5.4.1.2 Dutch landings Statistics

58. It is important to note that the majority of quota held by the Dutch fishing fleet in area IVc is for sole and plaice, with small by catch quota for turbot and brill. Landings therefore directly reflect available quota as opposed to providing any indication of species present in the area (see paragraphs 42 -44).

59. Landings statistics from the Dutch fleet have been provided on an annual as opposed to seasonal basis. These data are shown in *Figure 11.6* and *Figure 11.7* in *Appendix 11.2*. As the Netherlands do not hold historic access rights within UK territorial waters (see Chapter 14 Commercial Fisheries) and only a very small proportion of 33F1 is located outside this boundary, almost all landings must originate from the area which includes the East Anglia THREE site and cable corridor (offshore). In the East Anglia THREE site landings of plaice and sole have remained relatively consistent. For both sole and plaice peak weights were recorded during 2013 (947 tonnes and 1,447 tonnes, respectively).

60. With reference to the ICES rectangles occupied by the offshore cable corridor, landings of both sole and plaice have been relatively consistent from 2009-2013. For both species the highest landings were recorded in 2011 (sole, 473 tonnes; plaice, 1,390 tonnes).

11.5.4.1.3 Belgian ILVO Landings statistics

61. Belgian annual landings statistics have only been provided for the years 2006-2010 by ILVO (*Figure 11.8* and *Figure 11.9* in *Appendix 11.2*). Belgian fishing activity is relatively low within the East Anglia THREE site with higher activity within the offshore cable corridor. *Figure 11.8* and *Figure 11.9* in *Appendix 11.2* show that less than a tonne has been recorded annually for each species between 2006 and 2010, with sole being the highest landed species.

11.5.5 Spawning and Nursery Grounds

62. The location of spawning grounds and associated spawning intensity have been defined based on Coull et al (1998), and Ellis et al (2010; 2012). As outlined in section 11.5.5 *Appendix 11.2* these papers are based on review of published data, and as such 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 THREE project, use of these data sources can be considered to represent conservative (maximum) estimates.

63. Spawning and nursery grounds which overlap with the proposed East Anglia THREE project are shown in *Table 11.13.*

64. Spawning grounds for cod, sandeel, plaice, whiting, sole, lemon sole, sandeel, sprat and tope have all been defined within the East Anglia THREE site. Summer spawning grounds of pilchard, a species not included in Coull et al. (1998) and Ellis et al (2010), have also been defined in the area of the East Anglia THREE site (Pawson 1995).

65. Nursery grounds for all of the above species with the addition of herring have been defined within the East Anglia THREE site, with the exception of sole, lemon sole and plaice for which nursery grounds overlap the offshore cable corridor only. In addition, nursery grounds have been defined in the East Anglia THREE site and the offshore cable corridor for thornback ray and tope.

66. In the case of thornback ray, tope and spurdog, there is currently insufficient data on the occurrence of egg-cases or egg-bearing females in the spawning season with which to delineate spawning grounds. However, it is considered that these are likely to broadly overlap with nursery grounds (Ellis et al. 2012).

67. Most of the species with defined spawning grounds in the area of the proposed East Anglia THREE project are pelagic spawners, which release their eggs in the water column. The exceptions to this are herring and sandeel (Ammodytidae) which are demersal spawners, as well as some elasmobranch species including lesser spotted dogfish, thornback ray and blonde ray which also lay eggs on benthic substrates (Serena 2005; Compagno 2001).

68. Detailed information on the distribution of spawning and nursery grounds of the species described above, together with information relating to their ecology, is provided in section 11.5.5*, Appendix 11.2*.

Table 11.13 Spawning seasonality and intensity in East Anglia THREE and the offshore cable corridor for species with defined spawning periods (based on Coull *et al.* 1998 and Ellis *et al.* 2010).

Species	Spawning seasonality and intensity in East Anglia THREE and the offshore cable corridor												Nursery Grounds		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	East Anglia THREE site	Offshore Cable Corridor	
Cod		●	●												
Plaice	●	●											n/a		n/a
Sole				●									n/a		
Whiting															
Lemon Sole													n/a		n/a
Herring	n/a														
Mackerel					●	●	●								
Sprat					●	●									
Sandeel															
Thornback Ray	n/a														
Tope	Gravid females present year round														
Spurdog	Gravid females present year round														

Spawning times and Intensity colour key: red= 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

11.5.6 Species of Conservation Importance

69. A summary of the fish and shellfish species with recognised conservation status which have the potential to be present within the sea area occupied by the proposed East Anglia THREE project is provided below. Information regarding species-specific ecology and how this relates to potential site-use is described in section 11.5.6, *Appendix 11.2.*

11.5.6.1 Diadromous Species

70. Diadromous species with the potential to access the proposed East Anglia THREE project during the marine migration phase of their life cycle are listed in *Table 11.14*. None of these species was encountered during sampling for the site specific fish and shellfish or epi-benthic surveys. The presence of certain species, however, (e.g. sea trout, European eel, smelt and river lamprey) is well documented in the proposed East Anglia THREE project (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 11.14 Conservation Status of Diadromous Migratory Species relevant to the proposed East Anglia THREE Project

Common Name	Latin Name	Conservation Status							
		UK BAP[3]	OSPAR[4]	NERC[5] 2006	IUCN Red List[6]	Bern Convention	CITES	W&C 1981[7]	Habitats Directive
European eel	*Anguilla anguilla*	✓	✓	✓	Critically Endangered	-	✓	-	-
Allis shad	*Alosa alosa*	✓	✓	✓	Least Concern	✓	-	✓	✓
Twaite shad	*Alosa fallax*	✓	✓	✓	Least Concern	✓	-	✓	✓
Sea lamprey	*Petromyzon marinus*	✓	✓	✓	Least Concern	✓	-	-	✓
River lamprey	*Lampetra fluviatilis*	✓	✓	✓	Least Concern	✓	-	-	✓
Sea trout	*Salmo trutta*	✓	✓	✓	Least Concern	-	-	-	-
Smelt	*Osmerus esperlanus*	✓	✓	✓	Least Concern	-	-	-	-

[3] OSPAR - Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic – Threatened or declining species
[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 Conservation Act 1981

11.5.6.2 Elasmobranch species (Sharks and Rays)

71. 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 11.15.* Of the species listed below only thornback ray were recorded during site specific surveys. During the PEIR section 42 consultation stage, Cefas and local fisheries stakeholders suggested the inclusion of results from the Shark By-watch project. Shark By-watch is a collaborative programme between Cefas, Blue Lobster and the European Science Foundation, funded through the European Fisheries Fund (EFF). Fishermen and scientists work together to gain a better understanding of local sharks and rays stocks to inform management plans for the benefit of both the fishery and fishers. However, this data is not yet publicly available, and therefore has not been included within the assessment.

Table 11.15 Conservation status of elasmobranch species of relevance to East Anglia THREE and the offshore cable corridor

Common Name	Latin Name	Conservation Status							
		ICUN Red List	UK BAP	NERC 2006	OSPAR	Bern Convention	CITES	W&C 1981	Habitats Directive
Sharks									
Basking shark	*Cetorhinus maximus*	Vulnerable	✓	✓	✓	✓	✓	✓	-
Starry smoothhound	*Mustelus asterias*	Vulnerable	-	-	-	-	-	-	-
Smoothhound	*M. mustelus*	Least concern	-	-	-	-	-	-	-
Spurdog	*Squalus acanthias*	Vulnerable	-	-	✓	-	-	-	-
Thresher shark	*Alopias vulpinus*	Vulnerable	-	-	-	-	-	-	-
Tope	*Galeorhinus galeus*	Vulnerable	-	✓	-	-	-	-	-
Skates and Rays									
Blonde ray	*Raja brachyura*	Near Threatened	-	-	-	-	-	-	-
Cuckoo ray	*Leucoraja naevus*	Least concern	-	-	-	-	-	-	-
Common Skate Complex[8]	*Dipturus intermedia/ Dipturus flossada*	Critically endangered	✓	✓	✓	-	-	-	-
Spotted ray	*Raja montagui*	Least concern	-	-	✓	-	-	-	-
Thornback ray	*Raja clavata*	Near Threatened	-	-	✓	-	-	-	-
Undulate ray[9]	*Raja undulata*	Endangered	✓	✓	-	-	-	-	-
White skate	*Rostroraja alba*	Endangered	✓	✓	✓	-	-	-	-

8 A recent study by Iglésias 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 (Iglésias 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).

11.5.6.3 Other Species of Conservation Importance

72. Other fish and shellfish species which have designated conservation status and are present (or potentially present) in the proposed East Anglia THREE project are listed in *Table 11.16.* An indication of presence or absence in site-specific fish and shellfish and epi-benthic surveys is also provided. It should be noted that a number of the species listed are targeted commercially in East Anglia THREE project.

Table 11.16 Conservation Status of Fish Species relevant to the proposed East Anglia THREE Project

Common Name	Latin Name	Present in Surveys (Y/N)	Conservation Status							
			ICUN Red List	UK BAP	NERC 2006	OSPAR	Bern Convention	CITES	W&C 1981	Habitats Directive
Demersal Species										
Cod	*Gadus morhua*	✓	Vulnerable	✓	✓	✓	-	-	-	-
Plaice	*Pleuronectes platessa*	✓	Least concern	✓	✓	-	-	-	-	-
Gobiidae: Sand goby, common goby	*Pomatoschistus minutus, Pomatoschistus microps*	✓	Least concern	-	-	-	✓	-		-
Lesser sandeel	*Ammodytes marinus*	✓	-	✓	✓	-	-	-	-	-
Common sole	*Solea solea*	✓	-	✓	✓	-	-	-	-	-
Whiting	*Merlangius merlangus*	✓	-	✓	✓	-	-	-	-	-
Ling	*Molva molva*	N	-	✓	✓	-	-	-	-	-
European Hake	*Merluccius merluccius*	N	-	✓	✓	-	-	-	-	-
Pelagic Species										
Herring	*Clupea harengus*	✓	Least concern	✓	✓	-	-	-	-	-
Horse mackerel	*Trachurus trachurus*	N	-	✓	✓	-	-	-	-	-
Mackerel	*Scomber scombrus*	✓	Least concern	✓	✓	-	-	-	-	-
Shellfish										
Horse mussel	*Modiolus modiolus*	N	-	-	-	✓	-	-	-	-
Blue mussel	*Mytilus edulis*	N	-	✓	-	✓	-	-	-	✓
Dog whelk	*Nucella lapillus*	N	-	-	-	✓	-	-	-	-
Crawfish	*Palinurus elephas*	N	-	✓	✓	-	-	-	-	-
Fan mussel	*Atrina fragilis*	N	-	✓	✓	-	-	-	✓	-
Ocean quahog	*Arctica islandica*	N	-	-	-	✓	-	-	-	-
Native oyster	*Ostrea edulis*	N	-	✓	✓	✓	-	-	-	-

11.5.6.4 Prey Species and Food Web Linkages

73. 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. As described in *Appendix.11.2*, the distribution of both these species groups overlap with the proposed East Anglia THREE 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 THREE project (*Table 11.11*). Species from both families were present in site-specific surveys, albeit in relatively low abundances (*Table 11.8* and *Table11.9*).

74. 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 & Bailey 1993; Furness 1999; Wanless et al. 1998; Wanless et al. 2005).

75. The ecology of these species is described in further detail within *Appendix 11.2*, section 11.5.9

11.5.7 Species taken Forward for Assessment

76. To reach agreement regarding which potential impacts and species would be taken forward for the East Anglia THREE EIA on fish and shellfish ecology, an evidence plan was produced and consultation undertaken with Cefas and Natural England (Evidence Plan meeting, 10th September 2013, and *Appendix 11.1*). Impacts to be assessed were decided based on species distribution, with reference to the proposed East Anglia THREE project, and associated sensitivities to a range of potential impacts that may occur from the construction, operation and decommissioning phases.

77. Consequently, the following key impacts, species and groups to be taken forward were identified as:

- Impacts of physical disturbance and increased suspended sediment concentrations / sediment re-deposition upon fish egg, larvae, juvenile and adult fish species;
- Impacts of constructional and operational noise upon herring, cod and sandeel;
- Impacts of physical disturbance and permanent loss of habitat upon fish and shellfish species;
- Impacts of the introduction of hard substrate into the marine environment upon commercial fish and shellfish species;
- Impacts of electromagnetic fields upon elasmobranchs and electroreceptive species; and
- Temporary and Permanent loss of habitat through the installation of foundations and sub-sea cables.

78. Other key species outlined by Cefas and Natural England for assessment during the Evidence Plan meeting were as follows:

- Plaice;
- Sole; and
- Whelk

79. Species and the rationale for their inclusion within the assessment are provided in *Table 11.17.* Note that for some impacts scenarios species are not considered on an individual basis but by functional group (e.g. demersal or pelagic). Further information regarding the ecology of these species is provided within section *11.5.7, Appendix 11.1.*

Table 11.17 Key fish and shellfish species taken forward for assessment of the potential impacts from the proposed East Anglia THREE Project

Relevant Fish and Shellfish Species	Rationale
Commercial demersal fish species	
Sole	• Abundant throughout the study area • UK BAP species. • Commercially important species in the study area • Low/high intensity nursery areas in the inshore and offshore cable corridor
Plaice	• Abundant throughout the study area. • UK BAP listed species.

Relevant Fish and Shellfish Species	Rationale
	• Low/High intensity spawning areas in the study area • Commercially important species in the study area • Low intensity nursery areas in the study area
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 study area • Low/high intensity nursery areas in the study area
Whiting	• Abundant throughout the study area. • UK BAP listed species. • Extensive spawning grounds around the UK including in the the study area
Lemon sole	• Present throughout the study area • Extensive North Sea spawning grounds including in the study area • Low intensity nursery areas in the offshore cable corridor
Commercial pelagic fish species	
Herring	• Present in the study area. • UK BAP listed species • Low/high intensity nursery habitats within the cable analysis study areas. • Key prey species for fish, birds and marine mammals. • Demersal spawner • Hearing specialist (potentially sensitive to underwater noise)
Sprat	• Abundant in the proposed East Anglia THREE project • 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 study area
Ammodytidae (Sandeels)	
Greater sandeel Lesser sandeel Smooth sandeel Small sandeel	• UK BAP listed species • Spawning areas within the proposed East Anglia THREE project • Low intensity nursery areas occurs within the proposed East Anglia THREE project and offshore cable corridor • Prey species for fish, birds and marine mammals. • Demersal spawner
Elasmobranchs	
Rays, Skates and Sharks	• Present in the study 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 study area is situated within low intensity nursery area for tope and undefined/low for thornback ray
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 in some East Anglian rivers • UK BAP listed species • Feeding grounds located in the proposed East Anglia THREE project • May transit/feed in the study 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 proposed East Anglia THREE project 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 • 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	• UK BAP listed species • Potential (rarely) transit/feed in the study area during marine migration
Non commercial fish species	
Includes grey gurnard, lesser weever fish and solenette (characterising species of the fish assemblage), and small demersal species Gobiidae spp.	• Present/ abundant throughout the study area • Possible prey items for fish, bird and marine mammal species • Sand Goby protected under the Bern convention
Shellfish species	
Brown (edible) crab	• Present in the offshore cable corridor • Commercially important species • May overwinter within the regional area
Lobster	• Present in the export cable corridor • Commercially important species in the proposed East Anglia THREE project
Brown and pink shrimp	• Present in the study area • Important prey species for fish • Commercially important species in the study area
Whelk	• Of increasing commercial importance in the regional area

11.6 Potential Impacts

80. The potential impacts of the proposed East Anglia THREE project on the fish and shellfish receptors described in *section 11.5* above are assessed in the following sections.

81. A summary of the potential impacts is given in *Table 11.18* which has been derived from literature review, experiences gained from other operational windfarms and through consultation with MMO, Natural England, Cefas and stakeholders.

Table 11.18 Potential Impacts on Fish and Shellfish Receptors

East Anglia THREE Project Phase	Potential Impact
Construction and Decommissioning	• Physical disturbance and temporary loss of sea bed habitat • Increased suspended sediment concentrations and sediment re-deposition • Underwater noise
Operation	• Physical disturbance and loss of sea bed habitat • Introduction of hard substrate • Operational noise • EMFs
Cumulative Impacts	• Increased suspended sediment concentrations • Physical disturbance and loss of sea bed habitat • Introduction of hard substrate • Operational noise • EMFs

82. 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 wind farm related infrastructure is installed. Since it is expected that the full 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 11.6.2.

11.6.1 Potential Impacts during Construction

83. The following assessment details the potential impacts associated with the construction phase of the proposed East Anglia THREE project on fish and shellfish receptors. Throughout, a separate assessments are given for the Single Phase and Two Phased approaches.

11.6.1.1 Impact 1: Physical disturbance and temporary loss of sea bed habitat

84. Physical disturbance resulting from inter-array, platform link, interconnector and offshore export cable installation and sea bed preparation for foundations could, in theory, affect fish and shellfish, particularly species of limited mobility.

Single Phase

85. A maximum area 38.87km^2 of sea bed habitat within the proposed East Anglia THREE site would be temporarily disturbed or lost during the construction phase (*Table 11.2*). During the construction period, potential disturbance would occur as a result of the installation of foundations, inter-array and platform link cables, offshore electrical platforms, met masts and accommodation platforms. This disturbance is expected to be localised, of relatively short duration, reversible and occurring over a maximum of 33 months (See Chapter 5 Description of the development *Table 5.34*.). Considering the availability of similar suitable habitat both in the proposed East Anglia Project and in the wider context of the southern North Sea together with and the intermittent and reversible nature of the effect, the magnitude of temporary sea bed disturbance during construction activities for the East Anglia THREE site is considered to be low.

86. During the foundation installation phase, temporary loss of habitat would be progressive leading up to that assessed for the operational phase in section 11.6.2.1 resulting in a magnitude which would be at worst, low.

87. In the case of interconnector and offshore export cable installation, the proportional loss of habitat would be considerably less than that associated with the East Anglia THREE site, temporary in duration (35 months in total) and for the most part habitats would be expected to recover to pre-installation condition. This would occur as a result of the installation of up to four export cables over a total distance of 664km and the installation of up to four interconnector cables in two trenches totalling 190km (*Table 11.2*). The combined area of disturbance along the entire length of the offshore cable corridor would therefore be 40.39km^2. This is equivalent to 7.07% of the offshore cable corridor. The installation of cable protection and cable crossings is regarded as permanent habitat loss and are considered under the operational phase (Impact 1). In light of these considerations, the magnitude of effect for physical disturbance and temporary loss of habitat are considered to be low.

11.6.1.1.1 Impacts on Fish, Shellfish, Eggs and larvae

88. 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 habitat preference (as shown in *Table 11.17*).

89. In the case of herring, as shown by *Figure 11.59* the proposed East Anglia THREE project does not overlap with spawning grounds as defined by Coull et al. (1998). However, it can be seen from *Figure 11.26* to *Figure 11.28* that herring larvae have been recorded within the proposed East Anglia THREE project albeit at low abundances (2003, 2005, 2009: 1-100 larvae per m^2). Chapter 7 Marine Geology, Oceanography and Physical Processes shows the sea bed across the East Anglia THREE site is homogeneous and is characterised predominantly by sand, with some muddy sand, and therefore does not represent suitable habitat for herring spawning. Furthermore, 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). In light of these considerations, it is likely that herring larvae sampled within the East Anglia THREE site have drifted from spawning grounds located elsewhere (e.g. spawning grounds of the Downs stock).

90. The proposed East Anglia Zone overlaps a minimal proportion of the sandeel grounds (as shown in black in *Figure 11.56)* within the SA1 (yellow in *Figure 11.56*) and SA2 (red in *Figure 11.56*) assessment areas. However, there is no overlap between the depicted sandeel grounds and the proposed East Anglia THREE project. 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 medium sensitivity has also been assigned.

91. Therefore for both herring and sandeels an impact of **negligible** 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 THREE site.

92. The eggs of the principal shellfish species in the East Anglia Zone, 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).

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 (egg-bearing) 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*Two Phased*

93. The area of physical disturbance resulting from a Two Phased approach to construction would be slightly greater than that of a Single Phase approach both spatially (90.07km^2 compared with 79.26km^2) and temporally (42 months as opposed to 33). Despite the increased area of potential impact, the activities would be staggered (Chapter 5 Description of the development *Table 5.37*) and therefore the magnitude of impact under the Two Phased approach is also considered to be low. The sensitivity of the receptors would remain the same as previously assessed for the Single Phase approach. Therefore, the impact of physical disturbance during construction under a Two Phased approach would not be expected to exceed **minor adverse** significance.

Table 11.19 Impact of physical disturbance and temporary loss of sea bed habitat under Single Phase and Two Phased approaches.

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Herring and Sandeel	Medium	Low	Negligible to minor adverse
Shellfish	Medium	Low	Minor

11.6.1.2 Impact 2: Increased Suspended Sediment Concentrations and Sediment Re-deposition

94. The results of modelling suspended sediment concentrations and sediment re-deposition across the East Anglia THREE site are described fully in Chapter 7 Marine Geology, Oceanography and Physical Processes.

95. The magnitude of the effect of increased suspended sediment concentrations and sediment re-deposition for the following construction activities is discussed separately for;

- Gravity base structures foundation preparation and installation;
- Drilling operations;
- Inter-array and platform Link cable Installation; and
- Export cable and Interconnector cable installation.

96. Receptor sensitivity is then considered as follows;

- Physiological Effects on Fish Species;
- Physiological Effects on Shellfish Species;
- Physiological Effects on Sandeels; and
- Changes to Composition of Demersal Spawning Grounds.

11.6.1.2.1 Gravity Base Structures Foundation Preparation and Installation

97. As reported in Chapter 7 Marine Geology, Oceanography and Physical Processes, measurements of suspended particulate matter (SPM) within the proposed East Anglia THREE site as part of the metocean survey showed naturally occurring concentrations of 3 - 13.5mg/l throughout the winter of 2012/13. As expected, suspended sediment concentrations increase considerably closer to the coast, with levels up to 170mg/l recorded in the vicinity of Great Yarmouth (ABPmer 2012).

98. For the installation of gravity base structures foundations the worst case scenario involves excavation of the sea bed to level an area of sand waves up to 5m in height, with a maximum volume of excavation of 26,000m^3 per foundation.

99. For the preparation of the sea bed for gravity base foundations in the initial dynamic phase of the sediment plume, the dispersal of the sediment in suspension from construction activities will be localised and in close proximity to the location of each activity. The majority of the sediment present within the East Anglia THREE site is composed of medium sands with a much smaller fractions of finer sands and muds (Chapter 7 Marine Geology, Oceanography and Physical Processes). The heavier fraction of medium sands will fall out of suspension rapidly and in close proximity to the point of disturbance.

100. As a result of their lower mass, finer sand and muds will remain in suspension forming a passive plume which would be advected from source by tidal currents. The resultant plume would likely exist as a notable plume for less than half a tidal cycle and sediments would be re-deposited within 1km of the area where dredging is occurring. Modelling undertaken for the East Anglia ONE project predicted that the

deposited sediment layer across the wider seabed would be less than 0.2mm and not exceed 2mm in any location. The principle orientation of plumes is expected to be north-south with the tide (Chapter 7 Marine Geology, Oceanography and Physical Processes).

101. The same modelling further predicted that SSCs would remain high (orders of magnitude in excess of natural background levels) for a very short duration (minutes to hours) as the dynamic plume settles to the seabed. Elevations in suspended sediment concentration above background levels within the passive plume are expected to less than 10mg/l which is within the range of natural variability.

102. Modelling undertaken for sandwave clearance via dredging predicts a maximum deposition of less than that for the dredging preparations of the gravity base foundations. Sediment would be re-suspended and transported away from the dredge site on subsequent tides (Chapter 7 Marine Geology, Oceanography and Physical Processes).

103. It is assumed that 90% of all sediment released at the water surface from a dredger would be deposited from the dynamic plume over a small area. This material will be similar to that on the existing sea bed and therefore there would be no significant change in sediment type (Chapter 7 Marine Geology, Oceanography and Physical Processes). Considering the relatively short duration and limited spatial extent of the effect, the magnitude of any impacts is assessed as low.

11.6.1.2.2 Drilling Operations

104. During the installation of monopile foundations drilling may be necessary if ground conditions are found to be unfavourable. The disposal of drill cuttings would result in increased SSCs where operations are being undertaken.

105. The worst case scenario assumes that a 12m diameter monopile foundation would be drilled from the sea bed surface to a depth of 40m below the sea bed surface, releasing 4,524m^3 of sediment into the water column.

106. Drill cutting disposal would result in the disposal of larger grain size fractions close to where installation preparations occur, i.e. within a few hundred metres. Finer grain size material that is deposited during the plume phase would be deposited over a much wider area in the range of tens of kilometres in a much thinner layer (less than 0.025 and not exceeding 2mm) compared to the larger grain size.

107. Assessments and modelling undertaken have shown that levels of SSC associated with drill cutting disposal during monopile installation would be elevated above natural background levels by no more than 5 mg/l at a distance of 5km.

108. Considering the relatively short duration and restricted spatial extent of the effect, the magnitude of any impacts is assessed as low.

11.6.1.2.3 Inter-Array and Platform Link Cable Installation

109. Detail of inter-array and platform link cabling will be determined during post-consent construction design. However, current estimates for the total length of cabling required for these two aspects could be up to 745km (550km inter-array and 195km platform link cables). The installation technique which would represent the worst case scenario in terms of increased SSCs would be levelling with a dredge and installation of the cable by jetting.

110. Inter-array cable installation has the potential to disturb sediments from the sea bed to shallow depths of up to 5m. The magnitude of effect that could result is assessed in Chapter 7 Marine Geology, Oceanography and Physical Processes. The magnitude would be considerably lower than that created by the installation of foundations as the overall sediment release volumes would be lower and confined to near the sea bed (rather than higher in the water column) along the alignment of the inter-array cables. Therefore, the magnitude of the impact from inter-array cable installation can be considered as low.

11.6.1.2.4 Export Cable and Interconnector Cable Installation

111. It is estimated that up to 664km of export cables would be installed during construction of the proposed East Anglia THREE project. In addition, up to four 95km long interconnector cables (380km in total) between the proposed East Anglia THREE project and East Anglia ONE would be installed. The interconnector cables would be installed as bundled pairs in a single cable trench, resulting in a length of 190km being installed in trenches (Chapter 5 Description of the Development). The installation of the offshore cabling has the potential to disturb sediments from the sea bed surface to depths of up to 5m over the length of export and interconnector cabling which totals 854km over a width of up to 17.3m. As for inter-array and platform link cabling, the worst case scenario for the suspension of sediment would be the use of jetting techniques. Other techniques are also under consideration (Chapter 5 Description of the Development, section 5.5.14) and in reality, jetting is only likely to be used for a small proportion of total installation.

112. Overall sediment release volumes are predicted to be low, occurring close to the sea bed (rather than higher in the water column) and along the alignment of the offshore export cables. The rate at which the sediment is released into the water column from the jetting process would be relatively slow. Sand sized particles would settle out within 1km of the jetting operations whereas mud particles would be advected a greater distance and persist in the water column from hours to days.

113. In water depths greater than 20m Lowest Astronomical Tide (LAT), peak suspended sediment concentrations would be typically less than 100mg/l, except in the immediate vicinity of the area where jetting is occurring. However, in shallower waters of less than 5m LAT concentrations could potentially approach 400mg/l which is in excess of the maximum naturally occurring concentrations recorded during metocean surveys (170mg/l).

114. On the basis of the information provided in chapter 7, Marine Geology, Oceanography and Physical Processes it is appropriate to consider the magnitude of the effect in terms of offshore and inshore sections of the export cable. The magnitude of the impact of increased SSCs and sediment re-deposition through ploughing, jetting, trenching, or mass flow excavation is classified as low for near field effects in the offshore areas of the export cable and negligible to medium for far field and near field effects respectively when considering shallower water.

Single Phased

115. Under the Single Phase approach the installation of export and interconnector cables would take a maximum of 35 months. This does not include a six month gap which would occur between the installation of export and interconnector cables (e.g. the total construction time of 41 months).

11.6.1.2.5 Physiological Effects on Fish Species

116. 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, they would be able to move to adjacent, undisturbed areas within their normal habitat range.

117. Eggs and early larval stages of fish and shellfish do not however have the same capacity to avoid increased SSCs and areas affected by the re-deposition of sediment as adult and juvenile fish as they are either passively drifting in the water column or present on 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.

118. 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.

119. 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).

120. 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).

121. 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.

122. Herring eggs and larvae are considered to be the most sensitive to increased SSCs. 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 eggs and larvae is taken as medium. Taking the low magnitude, the impact of increased SSCs on fish eggs and larvae is assessed to be of **minor adverse** significance.

11.6.1.2.6 Physiological Effects on Shellfish Species

123. Eggs and larvae are considered to be less tolerant to increased suspended sediment concentrations 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. Eggs of berried crustaceans are likely to be more vulnerable to smothering, as they require regular aeration. However, as females of these species are ovigerous the potential for eggs to be impacted by increased SCCs / sediment re-deposition would be partially influenced by the response/tolerance of the adult to these impacts.

124. According to MarLIN (Neal and Wilson 2008), edible crab are considered to have a low sensitivity to increased suspended sediment concentrations (i.e. a change of 100

mg/l 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. This assessment is based on crabs being able to escape from under silt and migrate away from an area, and consequently, smothering is not expected to result in mortality.

125. Migration of berried lobsters appears to be less extensive than that of edible crab, 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^{-1} (considerably higher than those generated by construction activity associated with the installation of the offshore export cable).

126. There is no MarLIN benchmark assessment for lobster. Lobster do however belong to the same taxonomic family as the spiny lobster (Nephropidae) for which there is a benchmark assessment, thus providing a relevant comparison. The MarLIN conclude 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. In addition, 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. Taking a precautionary approach, a medium sensitivity has been assigned for shellfish as a whole, including whelks.

127. As stated above, the magnitude of effect for the installation of the East Anglia THREE windfarm site and the offshore section of the offshore export cables is considered to be low. The magnitude of effect for the installation of the offshore export cables in waters of depths below 5m is considered to be medium in the near field where jetting is used for cable burial. However, based on consultation with local commercial fishermen, it is understood that much of the suitable lobster habitat is formed by wrecks. Most wrecks within close proximity of the offshore export cable occur outside of the 10m contour line, therefore it is not expected that the majority of the lobster population within the offshore export cable will be subjected to the higher SSCs of 400 mg/l occurring within waters shallower than 5m LAT. In addition, crab and lobster are considered to be tolerant to increased SSCs and due to the localised and temporary nature of the impact, the area of habitat affected by the installation of inshore section of the offshore export cable corridor is proportionally small, the magnitude in relation to 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).

128. 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.

11.6.1.2.7 Physiological Effects on Sandeels

129. 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.

130. 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 (Hassel et al*.* 2004).

131. In a feeding study of larval assemblages in the southern North Sea, Pérez-Domínguez and Vogel (2010) found that the presence of larval sandeel was correlated with high levels of suspended particulate matter, including silt. The absence of silt in their stomach contents indicated that sandeel larvae were able to successfully target prey items in turbid environments.

132. Research by Behrens et al. (2007) on the oxygenation in the burrows of sandeel *Ammodytes tobianus* 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 to form an inverted cone of porewater with 93% oxygen saturation.

133. From the above, it is apparent that sandeel eggs, larvae and 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.

134. As shown by *Figure 11.56*, the area of the proposed East Anglia THREE project does not overlap the main sandeel habitats (shown as black areas in *Figure 11.56*) depicted by Jensen et al. (2011). As discussed above, in view of the minimal spatial

overlap and the short duration of the effect, the magnitude is assessed as low, giving an impact of **minor adverse** significance.

11.6.1.2.8 Changes to Composition of Demersal Spawning Grounds

135. 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.

136. Other than sandeels, (discussed above), herring are the only demersal spawning species within the proposed East Anglia THREE project. The East Anglia THREE project however does not overlap with defined herring spawning grounds (*Figure 11.58*).

137. 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. 2003, 2005, 2009: 1-100 larvae per m^2) within the East Anglia THREE site. Based on the lack of suitable substrate for herring spawning within the East Anglia THREE site and the potential for herring larvae to potentially drift hundreds of kilometres following hatching (Dicky-Collas et al., 2009), it is likely that these larvae originate from spawning grounds located elsewhere (e.g. spawning grounds of the Downs stock). As sediment re-deposition is localised and there is no suitable spawning substrate within the proposed East Anglia THREE project, 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, **minor adverse**).

11.6.1.2.9 Increased SSCs in Pelagic Spawning Areas

138. A limited number of spawning areas of pelagic spawning species overlap with the proposed East Anglia THREE project (*Table 11.20*). 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 proposed East Anglia THREE project. These species do not however have the same level of spatial dependency on a specific substrate unlike herring. 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 is low, giving a significance of a **minor adverse** impact.

Table 11.20 East Anglia THREE project overlap with pelagic spawning areas

Species	Total Spawning Area (km^2)	Discrete Spawning Area (km^2)	Area of East Anglia THREE project within Discrete Spawning Area (km^2)	Percent overlap of Total Spawning Area	Percent overlap of Discrete Spawning Area
Plaice	142,748	84,325	721	0.51%	0.85%
Cod	128,741	9,550	0.03	0.0000%	0.0003%
Whiting	120,436	14,544	704	0.58%	4.84%
Sandeel	251,257	40,383	657	0.26%	1.63%

Two Phased

139. Under a Two Phased approach there would be a relatively minor increase in the quantity of sediment released as a result of sea bed preparation for the installation of foundations (3,543,325m^3 as opposed to 3,470,100m^3 (see *Table 11.2*)). This would, however, occur over a 28 month period with an eight month gap between phases (Chapter 5 Description of the Development, *Table 5.37*). This extended time scale would therefore allow sediment to settle out of suspension between phases. The spatial extent of the impact (e.g. the distance over which settlement would occur) would be similar to that previously described for the Single Phase approach. In light of these considerations, the magnitude of the impact would not be expected to exceed that as previously assessed for the Single Phase approach (e.g. low) and in reality would likely be less.

140. The amount of sediment disturbed as a result of cable installation would also be greater under a Two Phased approach (1,834km of cables trenched as opposed to 1,599km). Despite this increase there will be no overlap between of each type of cable installation (inter-array, platform link, interconnector and export) across the two phases (Chapter 5 Description of the Development *Table 5.37*). Therefore, although the amount of sediment disturbance is greater than for the Single Phase approach, activity would be staggered and therefore less intense allowing for settlement of suspended sediment. As previously described, the spatial extent of the impact would be relatively limited. As a result the magnitude of the effect would not be expected to exceed that previously assessed (e.g. low).

As the sensitivity of the receptors remains as assessed previously, the impact of increased SSCs is expected to be of **minor adverse** significance.

141. *Table 11.20* summarises the potential impacts of increased SSCs and sediment re-deposition for both the Single Phase and Two Phased approaches.

Table 11.21 Impacts of increased SSCs and sediment re-deposition under Single Phase and Two Phased approaches)

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Physiological Effects on Fish species	Medium	Low	Minor
Physiological Effects on Shellfish species	Low	Low	Minor
Physiological Effects on Sandeels	Medium	Low	Minor
Changes to Composition of Demersal Spawning Grounds	N/A	No Impact	No impact
Increased SSCs Pelagic in Spawning Areas	Low	Low	Minor

11.6.1.3 Impact 3: Underwater Noise

142. The following assessment considers the potential for underwater noise generated by construction activities to impact fish and shellfish receptors. Noise levels generated by decommissioning activities are not anticipated to exceed those for the construction phase.

143. When considering how vibration travels through the sea bed it should be noted that very little relevant data exists for either the effect on sea bed-dwelling marine fauna or on the levels generated during marine impact piling. However, vibration generated from piling in the seabed would be expected to decay more rapidly than the acoustic pressure component in the water, which is regarded as the prevalent component when considering the impact of piling related underwater noise on marine life. This would particularly be the case for the North Sea, where attenuation in sediments has been shown to be much higher than in water (Lurton 2002).

144. Potential sources of underwater noise and vibration include piling, vessel traffic, sea bed preparation, rock dumping and cable installation. Of these, piling (particularly in relation to the installation of monopiles) is considered to produce the highest levels of underwater noise and therefore has the worst case potential to result in adverse impacts on fish and shellfish receptors (Nedwell et al. 2007 Lindeboom et al. 2011). For this reason, focus has been placed on piling noise. The following assessment is based on the outputs of the noise modelling undertaken by National Physical Laboratory (NPL) and should be read with reference to *Appendix 9.1* and Chapter 9 Underwater Noise and Electromagnetic Fields.

145. Underwater noise modelling was undertaken for a number of locations within and around the windfarm boundary and the likely effects have been assessed on the

basis of risk of instantaneous injury (hearing damage) and behavioural disturbance. This modelling is presented in detail in *Appendix 9.1.*

146. A 'soft-start' (a period at the onset of piling when the hammer strike energy would be gradually increased) would take place at all piling locations. Whilst full hammer energy (3,500kJ) may not be used for every piling sequence and at the onset of piling, it may be required in certain instances to install foundations to full design penetration and is therefore considered to be the worst case under both Single Phase and Two Phased approaches.

147. Under both approaches the worst case scenario for the propagation of underwater noise is assumed to arise from the installation of monopile foundations using a 3,500kJ hammer blow energy. (see *Table 11.2*).

148. Under the Single Phase approach, there is the potential for simultaneous piling to occur during installation which would result in the greatest potential spatial extent being impacted by piling noise. Under this scenario, it is expected that this piling could last for up to eight months, (Chapter 5 Description of Development, *Table 5.34*).

149. Under the Two Phased approach the use of simultaneous piling would not occur. Therefore, the spatial extent of the impact would be reduced compared to the Single Phase approach. Indicative time scales for the installation of monopiles are approximately five months in each of the two phases (*Table 5.36*, Chapter 5 Description of Development), which would be separated by ten months. Therefore, although the spatial extent of the impact would be reduced compared to the Single Phase approach, the total duration would be extended by two months. For these reasons the Two Phased Approach is considered to be comparable to the Single Phase approach in terms of worst case.

150. For the reasons outlined above, it is not expected that there will be any material difference in terms of the magnitude for each impact assessed regardless of whether the Single Phase or Two Phase approach is selected for the final construction plan. Therefore, in the case of all noise related impacts magnitude and receptor sensitivity are remain the same for each impact and the two approaches are not assessed separately.

151. The use of soft start and ramp up procedures would reduce the potential for mobile fish receptors to be exposed to instantaneous injury or permanent loss of hearing sensitivity (Permanent Threshold Shift (PTS)).

152. There have been few studies of the effects of anthropogenic noise on the behaviour of fish and shellfish with data lacking on the behavioural effects on fish in close proximity to noise sources. Similarly, there is little information on the long-term effects of exposure to sound on fish behaviour or about cumulative effects.

153. The majority of behavioural experiments have been conducted on captive fish and do not reflect conditions in the natural environment.

154. When assessing noise impacts on fish, species have previously been characterised as either hearing generalists or specialists (Underwater Noise Modelling, *Appendix 9.1*). In general, hearing generalists were described as fish species having hearing capabilities over relatively narrow frequency ranges from 50Hz or below to 1,000Hz-1,500Hz, although this varies considerably between species. Hearing specialists were considered to have improved sensitivity over the same range as hearing generalists but also sensitivity to sound at higher frequencies extending above 3,000Hz.

155. These differences in hearing ability were related primarily to physiological differences; hearing specialists have a structure linking the swim bladder and ears, whereas hearing generalists do not usually have this connection (Webb et al. 2008).

156. For the purpose of this assessment, these categorisations may not be strictly relevant as piling operations generate acoustic energy of 100 to 400Hz. Therefore, this higher frequency capability is of little relevance with regards to piling noise. The approach of categorising hearing specialists and hearing generalists is therefore no longer advocated by its originators (Underwater Noise Modelling, *Appendix 9.1*).

157. Extrapolation of hearing capabilities between different species, and especially those which are taxonomically distant requires cautious interpretation (Hastings and Popper 2005). There is also insufficient evidence in the peer reviewed literature for species specific impact ranges. In light of the above, generic (non-species specific) criteria have been used to model the ranges at which injury and behavioural impacts are expected to occur in fish.

158. The impact criteria are based on those proposed by the Fisheries Hydroacoustic Working Group (FHWG) that has been adopted by several states in the USA (Popper et al. 2006; Carlson et al. 2007), whilst for assessment of behavioural impacts an indicative two-level behavioural influence criteria based on observational studies (McCauley et al. 2000; Pearson et al. 1992) has been used. As part of the study by McCauley et al. (2000), these levels were compared against other findings in the literature and found to be comparable. The threshold values were also confirmed in

a more recent publication (Fewtrell and McCauley 2011). It should be noted that the criteria are based on a limited amount of information and do not account for variation between fish species, size, age and sex and life-history stage.

159. Due to the nature of sound propagation and the generally lower sound pressures near the sea bed, the behavioural impact from piling noise on fish has been modelled in terms of fish in mid-water column (pelagic) and fish that dwell near or on the sea bed (demersal). The impact ranges for demersal fish also extend to any fish which may temporarily move closer to the sea bed in response to the sound.

160. The threshold noise levels used for the assessment of impacts on fish are summarised below in *Table 11.21* and *Table* 11.22. The use of the term 'peak SPL' follows the definition provided by Southall et al. (2007) i.e. peak SPL represents the zero-to-peak pressure level of the pulse, which for a symmetrical pulse can be assumed to be 6dB less than the peak-to-peak pressure level.

161. Underwater sound propagation modelling for the proposed East Anglia THREE project was undertaken assuming a worst case 3,500kJ hammer strike energy, as well as, a number of smaller hammer strike energies including 1,400kJ, 2,000kJ, 2,300kJ and 3,000kJ. The lowest hammer energy is 40% of the full hammer energy, which may be considered sufficiently high to encompass the hammer strike energy at the onset of piling (assumed to be around 10 to 20% of the full hammer strike energy) (further information is provided in Chapter 9 Underwater Noise and Electromagnetic Fields).

Table 11.22 Summary of impact distances for fish near the sea bed (demersal fish), estimated for pile driving during construction of the proposed East Anglia THREE project for different hammer energies.[10]

Impact Criterion	Estimated impact distance for fish near the sea bed				
	1,400 kJ hammer energy	2,000 kJ hammer energy	2,300 kJ hammer energy	3,000 kJ hammer energy	3,500 kJ hammer energy
Instantaneous injury/PTS (peak pressure level 206 dB re 1 µPa) (Popper et al. 2006 and Carlson et al. 2007) *Applicable to all fish species with a mass of over 2g.	<100m	<150m	<150m	<200m	<250m
Startle response (peak pressure level 200 dB re 1 µPa) (Pearson et al. 1992)	<350m	<500m	<500m	<1.0km	<1.0km
Behavioural disturbance (peak pressure level 168 - 173 dB re 1 µPa) (McCauley et al. 2000) *These levels have been established from seismic airgun surveys and should therefore only be applied for impulsive sound sources for fish that are sensitive to sound below around 500Hz	~7 to 20†km (maximum of ~22km)	~9 to 23†km (maximum of ~26km)	~10 to 24†km (maximum of ~27km)	~10 to 27†km (maximum of ~30km)	~11 to 30†km (maximum of ~34km)

†95th percentile impact range.

[10] Behavioural disturbance of area is stated as the minimum to the 95th percentile impact distance, where the actual impact distance within this range will depend on the transect and piling location. Larger impact distances may occur along limited transects for some locations (their approximate extent is indicated in brackets). Impact ranges are rounded up to the nearest 50m for distance of 500m and less, up to the nearest 500m for distances of 3km and less, and up to the nearest 1km for distances greater than 3km (Source: *Appendix 9.1 Underwater Noise Modelling*).

Table 11.23 Summary of impact distances for fish around mid-water column (pelagic fish), estimated for pile driving during construction of the proposed East Anglia THREE project for different hammer energies.

Impact Criterion	Estimated impact distance for fish around mid-water column				
	1,400 kJ hammer energy	2,000 kJ hammer energy	2,300 kJ hammer energy	3,000 kJ hammer energy	3,500 kJ hammer energy
Instantaneous injury/PTS (peak pressure level 206 dB re 1 µPa)	<100m	<150m	<150m	<200m	<250m
Startle response (peak pressure level 200 dB re 1 µPa)	<350m	<500m	<500m	<1.0km	<1.0km
Behavioural disturbance (peak pressure level 168 - 173 dB re 1 µPa)	~10 to 25[†]km (maximum of ~28km)	~12 to 30[†]km (maximum of ~39km)	~12 to 32[†]km (maximum of ~41km)	~14 to 37[†]km (maximum of ~47km)	~16 to 40[†]km (maximum of ~49km)

†95th percentile impact range.

11.6.1.3.1 Instantaneous Injury (mortality, physical injury and auditory injury)

162. As previously stated, there is limited species specific research into instantaneous injury caused by anthropogenic noise. Furthermore, the noise modelling undertaken for the proposed East Anglia THREE project only differentiates between demersal and pelagic species. The following assessment of the risks of instantaneous injury categorises life stages / species in terms of their mobility.

Mobile Life Stages/ Species

163. Teleost and elasmobranch adults and juveniles are for the purposes of this assessment considered as mobile.

164. As shown in *Table 11.21* and *Table 11.22*, instantaneous injury is expected to occur within 250m of the monopile when using a 3,500kJ hammer energy for both demersal and pelagic species. Cumulative exposure could increase this range, although it should be emphasised that the implementation of soft-start procedures would result in many fish being displaced from the area of effect before noise levels reach the levels predicted for injury and mortality.

165. Taking the extent of the area where noise-related death or injury from piling noise may potentially occur, in addition to the short term and intermittent nature of piling activity, the magnitude of this effect is judged to be negligible as the death or injury of individuals has little potential to create impacts on the size and structure of the stocks of species in the North Sea.

166. The sensitivity of mobile adult and juvenile fish is taken to be low, since they are expected to vacate the area in which the impact could occur with the onset of 'soft start' piling. With respect to instantaneous injury due to piling noise, the impact is therefore, assessed to be of **negligible** significance.

Early Life Stages and Species of Limited Mobility

Early Life stages

167. Early life stages such as larvae would not be able to flee the vicinity of the foundations during piling, however prolonged exposure could be reduced by any drift of larvae due to water currents which may reduce the risk of mortality.

168. Bolle et al. (2011) did not find significant impacts at a cumulative SEL of 206 dB on sole larvae and suggested that the assumption of 100% mortality within a radius of 1000m around a piling site (used in the Appropriate Assessment of Dutch offshore windfarms) is too precautionary in the case of sole larvae. It was stated that the results should not be extrapolated to fish larvae in general, as inter-specific

differences in vulnerability to sound exposure may occur. Furthermore, this study was focused on the potential lethal effects of sound exposure and not on any physiological, behavioural or morphological effects or on determining the likelihood of survival in the long term. The results do however, suggest that previous assumptions in relation to the lethal impact of noise on larvae and the injury criteria are likely to be over-precautionary and should be revised.

169. Taking the relatively small areas around each piling operation where larval mortality may potentially occur and the short term and intermittent nature of piling, the magnitude of the effect is considered to be low. The distribution of larvae of a given species extends over wide areas at a given time. Whilst 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 larval mortality associated with piling in relation to the natural mortality rates during this life stage should be noted. Taking the above into account, larval stages are considered of medium sensitivity and instantaneous injury impact is therefore assessed to be of **minor adverse** significance.

Species of Limited Mobility- Gobies

170. As identified in site specific epibenthic surveys and IBTS data, sand gobies are expected to be present in the area of the East Anglia THREE site. Sand gobies have limited mobility and may therefore have limited capacity to escape areas impacted by piling noise. Given the short term, intermittent and localised nature of piling, however, the magnitude of the effect is considered to be low.

171. Sand gobies are prey for a number of species and are protected under the Bern Convention. They are abundant over wide areas of the North Sea therefore any noise effects would impact only a small proportion of the population. Furthermore, given the relatively short life cycle of this species (Teal et al. 2009) they are expected to recover quickly if subject to localised lethal or injury impacts associated with piling. Taking the above into account, they are considered to be receptors of medium sensitivity, the significance of the impact is assessed to be of **minor adverse**.

Species of Limited Mobility- Sandeels

172. *Figure 11.56* depicts Sandeel grounds as defined by Jensen et al. (2011). As is apparent, these are extensive throughout the Southern and Central North Sea, and any overlap with the East Anglia THREE site would be minimal when compared to other areas available in the sandeel assessment areas SA1 and SA2. Furthermore, the absence of any concerted sandeel fishery in the area implies that the densities of sandeel in the East Anglia THREE site are substantially lower than in other areas in the North Sea where high levels of fishing activity occur. Taking the minimal spatial

extent of the effect and its temporary and intermittent nature, the magnitude of effect is considered to be negligible.

173. Whilst sandeels have 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, with the result that an impact of **negligible** significance is predicted.

Species of Limited Mobility- Shellfish

174. 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), although some avoidance behaviour may occur (Payne et al. 2007). This should not however interfere with normal behaviour as mobile species would be likely to return to the areas soon after cessation of the piling activity. Furthermore, other marine bivalves (e.g. mussels *Mytilus edulis* and periwinkles *Littorina spp*) exposed to a single airgun at a distance of 0.5m also have shown no effects after exposure (Kosheleva 1992). As such no impacts on sedentary macro-invertebrates are to be expected.

175. The magnitude of the effect of underwater noise to shellfish with limited mobility and sedentary shellfish is therefore, considered to be negligible. The sensitivity of these species is considered to be low, therefore an impact of **negligible** significance is predicted.

176. *Table 11.23* summarises the potential impact of mortality, physical injury and auditory injury as a result of construction noise, for both Single Phase and Two Phase approaches.

Table 1 1.24 Impact of instantaneous injury as a result of construction noise for both Single and Two Phased approaches

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Mobile life stages/ Species	Low	Negligible	Negligible
Early Life Stages	Medium	Low	Minor
Species of Limited Mobility- Gobies	Medium	Low	Minor
Species of Limited Mobility- Sandeels	Medium	Negligible	Negligible
Species of Limited Mobility- Shellfish	Low	Negligible	Negligible

11.6.1.3.2 Behavioural Disturbance

177. Behavioural responses to underwater noise could result in decreased feeding activity, the potential avoidance of spawning grounds, and as a potential barrier to migration.

178. Impacts on feeding activity are unlikely to cause long term, larger scale effects on fish populations given the wider availability of suitable feeding grounds in the region. There is concern however that behavioural responses could have an adverse impact on spawning behaviour and migration of certain species.

179. Assessment of behavioural responses to underwater noise has been undertaken for the following species on the basis of overlap of the 168dB contour with spawning grounds (3,500kJ hammer energy), the commercial importance of a species, species conservation status and specific concerns raised during consultation with Cefas and Natural England (10/09/2013). As given in *Table 11.21* and *Table 11.22* startle response ranges are substantially smaller than those modelled for behavioural disturbance and are therefore encompassed within the ranges modelled for behavioural disturbance.

- Sole;
- Plaice;
- Cod;
- Whiting;
- Lemon sole;
- Herring;
- Sprat;
- Sandeels;
- Elasmobranchs; and
- Diadromous species;

Sole, plaice and cod

180. As shown by *Figure 11.53- Figure 11.55*, the spawning grounds defined for sole, plaice and cod are overlapped by the 168dB contour giving rise to some potential for juvenile and spawning sole, plaice and cod to be affected by piling noise during the

construction phase. However, in all cases the proportion of defined spawning ground overlapped is small relative to the total area.

181. These species are pelagic spawners and not dependent on spawning grounds with specific sea bed characteristics. As shown by *Figures 11.54 and 11.55*, cod and plaice spawning grounds occur across large areas of the North Sea, therefore the displacement of adults from relatively small areas of sea during the respective spawning seasons is not expected to affect the overall spawning success of these species. The magnitude of the effect is therefore considered to be low.

182. In the case of sole, as shown by *Figure 11.53*, although their spawning grounds cover substantial areas of the Southern North Sea and the English Channel, they are not as extensive as cod and plaice. Whilst only a very small proportion of sole spawning grounds are encompassed by the 168dB contour, taking a precautionary approach a medium magnitude of effect has been assumed.

183. Sole, cod and plaice are not substrate specific spawners and have low spatial dependency in respect of spawning areas. Furthermore, as shown by *Figure 11.53* to *Figure 11.55* for each of these species there is minimal overlap of spawning areas by the 168dB contour, and as such at population levels, very low receptor-effect interactions are expected to occur. Consequently, low sensitivities have been assumed for sole, cod and plaice giving impacts of **minor adverse** significance for these species.

Whiting

184. Construction noise from East Anglia THREE may potentially impact on the spawning behaviour of the sub-population of whiting in the southern North Sea. The 168dB contour partially overlaps a spawning ground for whiting (Coull et al. 1998) (*Figure 11.57*). Given the spatial extent of the overlap and the availability of suitable spawning areas which are not impacted by noise, the magnitude of the effect is low. The absence of specific information on the behavioural responses of whiting to noise necessitates the adoption of a precautionary approach to the assessment of this species, therefore the sensitivity of spawning whiting is assessed as medium. The corresponding impact is therefore likely to be of **minor adverse** significance.

Lemon Sole

185. Whilst Ellis et al. (2012) does not provide spawning grounds for lemon sole, Coull et al. (1998) does. As shown by *Figure 11.58* the spawning grounds of lemon sole are extensive covering wide areas of the North Sea. From *Figure 11.58* it is apparent that a negligible proportion of the defined lemon sole spawning grounds are overlapped by the 168dB contour, giving a negligible magnitude of effect.

186. Coull et al. (1998) states that flat fish species such as lemon sole are not thought to be affected by noise generated by seismic surveys and that they are not included in seismic survey restriction maps. Furthermore, lemon sole are not substrate specific spawners and show minimal spatial dependency in respect of spawning grounds, their sensitivity is considered to be low, giving an impact of **negligible** significance.

Herring

187. Blaxter and Hoss (1981) found startle responses at received levels between 122–138dB re 1µPa and observed that the response depended on the size of the herring. Skaret et al. (2005) found that herring spawning close to the sea bed did not show any sign of a reaction towards a survey vessel passing at a standard survey speed (10–11 knots) at a distance of 8–40m at sound pressure levels ranging from 70-150 dB re 1 µPa 1 Hz. In a seismic study on adult herring involving sound exposure levels (SEL) ranging from 125 to 155 dB re 1 µPa2, Peña et al. (2013) found that no changes were observed in swimming speed, swimming direction, or school size. The lack of a response to the seismic survey was interpreted as a combination of a strong motivation to spawn, and a progressively increased level of tolerance over time.

188. Herring generally adopt low-risk behavioural strategies (Fernö et al. 1998; Axelsen et al. 2000), but at times predator avoidance must be balanced with other activities that affect vigilance. During the feeding season, the reaction towards vessels is low compared with the wintering period (Misund 1994) and the act of reproduction during the spawning season takes precedence over avoidance reactions that are evident at other times of the year (Nøttestad et al. 1996, Skaret et al. 2003). Mohr (1971) observed that ripe herring swimming close to the sea bed showed no avoidance reactions to a moving trawl, consistent with high reaction thresholds during spawning.

189. No recognised herring spawning grounds are overlapped by the 168dB contour modelled for pelagic fish species (*Figure 11.59*) although, low abundances of herring larvae have been recorded by the IHLS in some years (e.g. 2003, 2005, 2009: 1-100 larvae per m^2). Based on the lack of suitable substrate for herring spawning within the East Anglia THREE site and the potential for herring larvae to drift hundreds of kilometres following hatching (Dicky-Collas et al., 2009), it is likely that these larvae originate from spawning grounds located elsewhere (e.g. spawning grounds of the Downs stock).

190. There is the possibility of low level interaction with adults migrating through the East Anglia Zone from feeding grounds in the North Sea to the Downs sub stock main spawning grounds in the Eastern Channel.

191. ICES (2013) also advises that the North Sea herring stock is currently at full reproductive capacity and it is harvested sustainably with increases of over 95 per cent in the Total Allowable Catch (TAC) for 2012.

192. Any temporary noise effects resulting from piling are therefore not expected to contribute to changes in spawning activity or an increase in mortality that would be detrimental to the Downs sub-population or to the North Sea herring stock as a whole and therefore the magnitude is expected to be low.

193. As spawning activity is highly variable year on year, driven largely by environmental variables (Hufnagl and Peck 2011), and as herring are a highly mobile species any avoidance of the noise impact area during piling is not expected to result in exclusion of individuals from the wider available spawning locations and so a low sensitivity has been assumed. This is further supported by the fact that herring have been reported to relocate to alternative spawning locations between generations (Schmidt et al. 2009).

194. In view of the above, an impact of **minor adverse** significance is expected to occur.

Sprat

195. With respect to potential impacts on spawning aggregations, sprat utilise coastal and offshore waters during spawning and release their eggs into the water column (Whitehead 1986). As a result spawning grounds are widespread around the North Sea and not limited to areas with specific characteristics (*Figure 11.60*). The magnitude of any effect is considered to be low with a receptor sensitivity equivalent to that of herring i.e. low. The predicted significance of the impact of piling noise causing behavioural effects in sprat is therefore assessed as being of **minor adverse** significance.

Sandeels

196. Monitoring of lesser sandeels during seismic surveys showed some behavioural reactions to source levels equivalent to 210 dB at 1 mPa (Hassel et al. 2004). After the seismic shooting had ceased however, normal behaviour resumed (Hassel et al. 2004).

197. As no increase in mortality or injurious effects were observed in treatment groups (exposed to seismic shooting) over control groups (not exposed to seismic activity), and no reduction in sandeel abundance in grab surveys was observed after the seismic activity had ceased (Hassel et al. 2004). The results of this study indicate that effects of such noise levels on sandeel are likely to be short term, localised and constrained to behavioural level effects, with no longer term effects likely.

198. *Figure 11.56* depicts Sandeel grounds (Jensen et al. 2011), showing a very small overlap with the modelled 168dB contour when compared to other areas available in the Sandeel assessment areas SA1 and SA2. As such, underwater noise on sandeel is considered to be of low magnitude in the context of behavioural responses. Due to the ecological and conservation status of sandeels, they are considered to be of medium sensitivity, with the result that an impact of **minor adverse** significance is predicted.

Elasmobranchs

199. Elasmobranchs are thought to be sensitive to the particle displacement component of sounds within the range of 20–1000 Hz (Casper and Mann 2006, 2010), although laboratory studies have raised questions over sharks' capability of detecting sounds in the acoustic far field (Casper and Mann 2006).

200. Elasmobranchs have a wide distribution throughout the North Sea and the level of effect-receptor interaction between elasmobranchs and piling noise is expected to be minimal. The magnitude of the effect of noise on behavioural responses of elasmobranchs is low. Their sensitivity to underwater noise is considered to be low, resulting in an impact of **minor adverse** significance impact.

Diadromous species

201. Diadromous migratory species are only likely to occur occasionally in the area of the East Anglia THREE site (see *Appendix 11.2*, section 11.5.12). Given the distance of the East Anglia THREE site from the coast, it is not expected that diadromous species would be subjected to a noise impact that would result in a behavioural response. In addition, diadromous species are considered to be highly mobile with the ability to escape from impact areas where noise levels are sufficiently high to trigger avoidance reactions. The magnitude of the impact is anticipated to be low.

202. Diadromous migratory species are considered to have low sensitivity to piling noise but considering the high conservation value of these species the sensitivity level has been modified to medium. Taking the above into account, the impact of piling noise on the migration of diadromous species is considered to be of **minor adverse** significance.

203. *Table 11.24* summarises potential behavioural responses as a result of underwater noise during the construction phase for both the Single Phase and Two Phased approaches.

Table 11.25 Impact of behavioural responses as a result of underwater noise during the construction phase under both the Single Phase and Two Phased approaches.

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Plaice	Low	Low	Minor adverse
Cod	Low	Low	Minor adverse
Sole	Medium	Low	Minor adverse
Whiting	Medium	Low	Minor adverse
Lemon Sole	Low	Negligible	Negligible
Herring	Low	Low	Minor adverse
Sprat	Low	Low	Minor adverse
Sandeels	Medium	Low	Minor adverse
Elasmobranchs	Low	Low	Minor adverse
Diandromous Species	Medium	Low	Minor adverse

11.6.1.3.3 Changes to Prey Species or Feeding Behaviour

204. The majority of fish species present in the area of the East Anglia THREE site feed on a combination of invertebrate and fish prey. As indicated in Chapter 10 Benthic Ecology, impacts predicted to occur during the construction phase of the proposed East Anglia THREE project on benthic species are assessed as not significant. Both the benthic community and the fish assemblages are relatively homogenous across the windfarm site and adjacent areas. If fish species are displaced through piling noise they would be able to find suitable prey in adjacent areas and therefore the magnitude of effect is negligible. Taking the maximum sensitivity as high, the impact of piling noise on prey and feeding behaviour of the majority of fish species is assessed to be of **minor adverse** significance.

11.6.2 Potential Impacts during Operation

205. Potential impacts during operation are not assessed separately for Single and Two Phased approaches. Alternatively, the approach that represents the worst case is described in isolation. The following potential impacts associated with the operational phase are assessed below:

- Physical disturbance and loss of sea bed habitat;
- Introduction of hard substrate / permanent loss of habitat;
- Operational noise; and
- Electromagnetic fields (EMFs).

206. Of the potential effects listed above, in the particular case of the offshore cable corridor only EMF and loss of habitat related effects are considered relevant during the operational phase.

11.6.2.1 Impact 1: Physical disturbance and permanent loss of habitat

11.6.2.1.1 Physical disturbance

207. There would be no difference between Single of Two Phased approaches for the impact of physical disturbance. Therefore, the impact is considered generically in this instance. Should jack up barges be required for maintenance operations, the feet of the barge could penetrate the sea bed disturbing benthic habitats and affecting the organisms within the footprint. The worst case estimate in terms of jack up barge visits to the East Anglia THREE site per day is not expected to exceed two. This could result in a footprint of disturbance of up to 1,200m^2, equivalent to a total annual area of up to 0.88km^2 (the equivalent of 0.2% of the East Anglia THREE site).

208. The duration of the effect would be temporary, therefore it is unlikely that the physical disturbance of jack-up barge feet would overlap with critical life-stages. Furthermore, it is considered likely that mobile organisms such as fish would flee the immediate area around the feet and therefore avoid injury/mortality. Therefore, the impact is likely to be limited to less mobile fish species and shellfish. Whilst individuals directly within the footprint may not recover, the numbers concerned would be low with no long lasting effects on the wider population and therefore the population would be able to tolerate the impact. In addition, the duration of the impact would be of temporary, short term duration. Taking this into account, the magnitude would be negligible.

209. With respect to maintenance of both cables installed within the East Anglia THREE site (inter-array and platform link cables) and those within the Offshore Cable Corridor (export and interconnector cables) this could constitute up to three visits each per year by a jack up barge (e.g. a combined total of six). The magnitude of this physical disturbance is expected to be so small as to constitute no change.

210. As receptor sensitivities would remain the same as assessed for the construction phase, the resultant impact significance would be at worst, **negligible**, for the East Anglia THREE site and there would be **no change** with regard to maintenance associated with either the inter-array or platform cables.

211. *Table 11.25* summarises the potential impacts associated with physical disturbance during the operational phase.

Table 11.26 Impact of physical disturbance to fish and shellfish species during the operational phase,

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
As assessed for construction phase Impact 1	As assessed for construction phase impact 1 (medium)	No impact - Negligible	No impact - Negligible

11.6.2.1.2 Introduction of hard substrate/permanent loss of habitat

212. The worst case scenario in terms of permanent loss of habitat during the operational phase would occur if the proposed East Anglia THREE project was constructed using a Two Phase approach. The presence of wind turbine foundations, cable protection and any required scour protection would result in worst case permanent net habitat loss of approximately 3.23km^2 (which is approximately 0.3% of the area within the offshore redline boundary for the proposed East Anglia THREE project). The worst-case scenario is based on gravity base structures (GBS) and scour protection for foundations and cable protection (*Table 11.2*).

213. The fish and shellfish receptors described as present in the proposed East Anglia THREE project have comparatively large areas for spawning grounds, nursery grounds (as described in section 11.5) and foraging, and many have wide distribution ranges; all of which may be spatially and temporally variable.

214. The loss of habitat resulting from the installation of gravity base structures foundations and scour materials (2.55km^2), and any associated loss of habitat would be constant throughout the duration of the operational phase (>25 years). Given the small spatial extent of any installed infrastructure, any effects are considered to be of a low magnitude**.** The fish species taken forward for assessment (see section 11.5.8) are unlikely to be affected by loss of habitat during the operation phase. They are therefore expected to remain unaffected by the relatively small predicted loss of sea bed area. The majority of species in the study area are considered to be of **low** sensitivity to loss of habitat during the operational phase. The species with the potential to be impacted by permanent loss of habitat as a result of the proposed East Anglia THREE project are demersal spawners such as sandeels and herring. Impacts on these species are therefore considered separately below.

Sandeels

215. 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, *Figure 11.56*). 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 one of the top five species

present during the IBTS (average 2004-2013) within the East Anglia THREE specific study areas with a moderate CPUE in the offshore cable corridor (offshore).

216. Sandeels are not targeted commercially on the East Anglia THREE site by the Danish fishing fleet, in contrast to the Dogger Bank and the surrounding area. Therefore, considering 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.

Herring

217. Herring are demersal spawners requiring the presence of specific substrate, therefore they are considered to be receptors of medium sensitivity. However, as the East Anglia THREE windfarm site or offshore cable corridor do not overlap defined herring spawning grounds (*Figure 11.25*), 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.

Shellfish

218. The loss of sea bed habitat associated with the presence of the export and interconnector 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.**

219. Shellfish species are of low abundance within the East Anglia THREE 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 wind farms 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 and Barrow offshore windfarms 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. Sensitivity is therefore categorised as low.

220. 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 THREE project on shellfish species is assessed to be of **minor adverse** significance.

Two Phased

221. *Table 11.26* summarises the potential for permanent loss of habitat during the operational phase of the proposed East Anglia THREE project built employing either a Two Phased approach.

Table 11.27 impact of permanent loss of habitat during the operational phase of the proposed East Anglia THREE project built using a Two Phased approach.

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Sandeels	Medium	Low	Minor adverse
Herring	Medium	Negligible	Negligible
Shellfish	Low	Low	Minor adverse

11.6.2.2 Impact 2: Introduction of hard substrate

222. The worst case scenario for the introduction of hard substrate would occur if the proposed East Anglia THREE project was built under the Two Phased approach. This would require an additional foundation and an increase of up to 2.5% of cable protection compared to the Single Phase approach.

223. The introduction of sub-surface infrastructure associated with the proposed East Anglia THREE project has the potential to alter the structure of benthic habitats and associated faunal assemblages. As described in Chapter 10 Benthic Ecology, this represents a potential change from the existing environmental baseline and as such, is not considered to be beneficial.

224. Substrates across both the offshore cable corridor and the East Anglia THREE site are 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.

225. 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 (Chapter 10 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).

226. Hard substrates introduced by the project would include foundations and scour protection for wind turbines, offshore collector stations, offshore convertor stations, accommodation platform, 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 the 3.15km^2. 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.

227. Lindeboom et al. (2011) found that new hard substrate introduced by the construction of the Dutch OWEZ windfarm acted as a new habitat type with a higher biodiversity of marine organisms.

228. The expected increase in diversity and productivity of sea bed communities may have an impact on fish, resulting in either attraction, increased productivity or changes in species composition (Hoffman et al. 2000). The potential for marine subsea structure, whether man-made or natural, to attract and concentrate fish is well documented (Sayer et al. 2005; Bohnsack 1989; Bohnsack & Sutherland 1985; Jørgensen et al. 2002).

229. 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).

230. 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 Öhman 2010; Bohnsack 1989).

231. The Horns Rev Offshore Wind Farm monitoring follow-up report recently published (Stenberg et al. 2011) examined the changes in the fish community seven years after construction. This report suggests that the introduction of hard substrate has resulted in minor changes in the fish community and species diversity. Fish community changes were observed due to changes in densities of the most commonly occurring fish, whiting and dab. However, this reflected the general trend of these fish populations in the North Sea.

232. The introduction of hard substrate was, however, found to result in higher species diversity close to each turbine with a clear (horizontal) distribution, which was most pronounced in the autumn, when most species occurred. New reef habitat fish such as goldsinny wrasse, viviparous eelpout *Zoarces viviparous* and lumpsucker *Cyclopterus lumpus* were found to establish themselves on the introduced reef area.

233. A review of the short term ecological effects of the offshore wind farm Egmond aan Zee (OWEZ) in the Netherlands, based on two year post-construction monitoring (Lindeboom et al. 2011) found minor effects upon fish assemblages, especially near the monopiles. It was suggested that species such as cod may find shelter within the wind farm. A similar study conducted in the Belgian part of the North Sea (Bligh Bank wind farm; 55 monopile foundations) found that there was a decrease in overall demersal fish densities within the windfarm compared to control sites. However, for a number of commercially important species (turbot, sole and plaice), higher densities/increases in length distribution were observed (Vandendriessche et al., 2012). It was not possible to determine whether this was attributable to a refuge effect (commercial fishing is excluded from Belgian windfarms), changes in epibenthic fauna (e.g. prey) or substrate composition, or any combination of all three of these variables. 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).

234. 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 being constructed (Cefas 2009).

235. 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 wind farm 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).

236. It is anticipated that any hard substrate associated with of the installation of GBS foundations and scour protection, other windfarm associated infrastructure and inter-array, inter platform cabling and interconnector and 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.

237. 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 proposed East Anglia THREE project 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 negligible magnitude and the low to medium sensitivity of the receptors, the impact is expected to be of **minor adverse** significance.

238. *Table 11.27* summarises the potential impact of introduction of hard substrate during the operational phase.

Table 11.28 impact of introduction of hard substrate during the operational phase of the proposed East Anglia THREE project using Two Phased approach

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Fish and Shellfish	Low to Medium	Low	Minor adverse

11.6.2.3 Impact 3: Operational noise

239. There would be no difference between Single of Two Phased approaches for the impact of operational noise. Therefore, the impact is considered generically in this instance.

240. Sources of operational noise would include wind turbine vibration, the contact of waves with offshore structures and maintenance vessel engines. It is likely that these would increase noise levels above existing baseline levels (i.e. pre-construction).

241. 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. 2007a 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).

242. A review of monitoring data from operational UK offshore wind farms 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 wind farm 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).

243. 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).

244. In view of the above, the sensitivity of fish and shellfish species to operational noise is considered to be low and the magnitude of effect negligible, resulting in an impact of **negligible** significance.

245. *Table 11.28* summarises the impacts of operational noise on fish and shellfish species for the impact of underwater noise during the operational phase of the proposed East Anglia THREE project

Table 11.29 Impact of underwater noise during the operational phase of the proposed East Anglia THREE project

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Fish and Shellfish Species	Low	Negligible	Negligible

11.6.2.4 Impact 4: EMFs

246. As stated in the section describing embedded mitigation (section 11.3.3) Inter- array, platform link, inter-connector and export cables would be buried to a target depth of between 0.5 and 5m. Where substrate conditions prevent burial, and at cable crossings additional cable protection would be deployed. The potential protection methods under consideration include, rock placement, concrete mattressing, fronded concrete mattressing, bridging or positioning of gravel bags.

247. Predictions of the EMF and induced EMF from the cable options proposed for the proposed East Anglia THREE project are summarised in Chapter 9 Underwater Noise and Electromagnetic Fields and described in further detail in *Appendix 9.1.*

248. In terms of the worst case scenario for EMF related impacts on potentially sensitive fish and shellfish receptors, this would result from the minimal cable burial depth of 0.5m, the maximum length of installed cable and the highest power rating. As shown in *Table 11.2*, there is little difference in terms of power ratings between the

HVDC and LFAC cabling solution. However, in terms of total cable installed this could be up to 348km greater under the HVDC solution and under the Two Phased approach (*Table 5.20*; Chapter 5, Description of the Development). Therefore, the HVDC option is considered to represent the theoretical worst case scenario for the assessment of potential EMF related impacts.

249. 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. In substrates such as clay, where re-exposure is less likely, shallower burial depths will be adequate to ensure the cable remains buried.

250. During the operational phase AC cables (inter-array and 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 cables and export cables during the operational phase.

251. Information on the predicted magnetic (B) and induced electric fields (Ei) from the range of cable types proposed for the project has been summarised in Chapter 9 Underwater Noise and Electromagnetic Fields, and is described in further detail in *Appendix 9.1.*

252. For the purposes of impact assessment it is appropriate to adopt a worst case approach. However, it is of note that EN- 3 guidance (paragraphs 2.6.75 and 2.6.76) states that "*EMF during operation may be mitigated by use of armoured cable for interarray and export cables which should be buried at a sufficient depth. Some research has shown that where cables are buried at depths greater than 1.5m below the sea bed impacts are likely to be negligible (CMACS, 2004)"* Therefore, once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement.

253. Normandeau et al. (2011) modelled expected magnetic fields using design characteristics taken from 24 undersea cable projects. Of the 10 AC and DC 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 11.29*). The averaged modelled values of the magnetic field strengths from AC and DC cables assumed a 1m burial depth.

Table 11.30 Averaged magnetic field strength values from AC and DC cables buried 1m (Normandeau et al. 2011)

Distance (m) above sea bed	Magnetic Fields Strength (µT) Horizontal distance (m) from cable					
	0m AC	0m DC	4m AC	4m DC	10m AC	10m DC
0	7.85	78.27	1.47	5.97	0.22	1.02
5	0.35	2.73	0.29	1.92	0.14	0.75
10	0.13	0.83	0.12	0.74	0.08	0.46

254. The areas affected by EMFs generated by the worst case scenario cabling associated with the proposed East Anglia THREE project are expected to be small, being limited to the area of the East Anglia THREE windfarm site and the offshore cable corridor, 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.

255. 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 (Gill & Taylor 2001; Gill et al. 2005). 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.

256. The first group are those species that are electro-receptive, the majority of which are elasmobranchs (sharks, skates and rays), although it also includes holocephalans (chimaeras, e.g. ratfish) and agnathans (i.e. lampreys). 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.

257. The second group are believed to use magnetic particles (magnetite) within their own tissues in magnetic field detection (Kirshvink 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 THREE 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).

258. The sensitivity of the main receptors found in the local 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.

11.6.2.4.1 Elasmobranchs

259. 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).

260. 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), or to tens of centimetres should burial be to a depth of 0.5m.

261. Similarly, for HVDC cabling, iE at which avoidance in elasmobranchs could occur are only expected within a few tens of centimetres (bundled) or 1m (separated) of 320kV cables. Avoidance behaviour would be expected at only slightly greater distances from 500 kV cables (0.5m if bundled and 1 - 2m if separated). Again, burial would reduce these small avoidance zones completely for bundled cables even at 0.5m burial depth and at 0.5m and 0.5 - 1.5m if separated for 320 kV and 500kV HVDC cables respectively. For 600 kV cables the distances would be expected to be only slightly further than those presented above for 320 and 500 kV cables.

262. 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 & Sisneros 2004; Kimber et al. 2011). Recent 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). Experiments by Gill et al. (2009) provided the first evidence of electrically sensitive fish response to AC EMF emissions from sub-sea, electricity cables of the type used by the offshore renewable energy industry. This research found lesser spotted dogfish were more likely to be found within the zone of EMF emissions, and some thornback rays showed increased movement around the cable when the cable was switched on. Responses were unpredictable however, did not always occur, and appeared to be species dependent and individual specific.

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

264. The recently published: Review of environmental data associated with post-consent monitoring of licence conditions of offshore wind farms (MMO April 2014) states:

"*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."

265. 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 THREE 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.

11.6.2.4.2 Lamprey

266. 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 proposed East Anglia THREE project; 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 THREE project is considered to be low, resulting in an impact of **minor adverse** significance.

11.6.2.4.3 Salmon and Sea trout

267. As indicated in section *11.5.12* of *Appendix 11.2*, there are no salmon rivers in the vicinity of East Anglia THREE 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 area of the offshore cable corridor and the East Anglia THREE site during migration and as part of their foraging activity.

268. Swedpower (2003) found no measurable impact when subjecting salmon and sea trout to magnetic fields twice the magnitude of the geomagnetic field. Furthermore, Atlantic salmon migration in and out of the Baltic Sea over a number of operational

sub-sea HVDC cables was observed to continue apparently unaffected by EMFs produced by the cables (Walker 2001).

269. 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.

270. 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.

271. 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.

11.6.2.4.4 European Eel

272. European eel may transit the offshore cable corridor and the East Anglia THREE windfarm site. It has been shown that a B-Field from the cable connecting the windfarm at Nysted, to the mainland at around 5 µT (Eltra 2000) resulted in some deviation in the swimming direction of european eel. However, this result was found to be statistically insignificant Westerberg (1994). 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.

11.6.2.4.5 Crustaceans

273. 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 (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.

274. 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). Indirect evidence from post construction monitoring programmes undertaken in operational wind farms does not suggest that crustaceans or molluscs have been affected by the presence of submarine power cables.

275. 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.

276. 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.

277. European lobster belong to the same taxonomic family as the spiny lobster (Nephropidae) but is not known to undertake significant long distance migrations. 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 (Ueno et al. 1986; Normandeau et al. 2011).

278. Based on the research available, the sensitivity of crustaceans to EMFs is considered to be **negligible**, resulting in an impact of **negligible** significance.

279. *Table 11.30* summarises the potential impacts of EMFs during the operational phase of the proposed East Anglia THREE project built using either a Single or Two Phased approach

Table 11.31 Impact of EMFs on fish and shellfish receptors of the proposed East Anglia THREE project built using either a Single or Two Phased approach

Receptor Group	Receptor sensitivity	Magnitude of Effect	Impact Significance
Elasmobranchs	Medium	Low	Minor adverse
Lamprey	Low	Low	Minor adverse
Salmon	Negligible	Low	Negligible
Sea Trout	Low	Low	Minor adverse
European Eel	Medium	Low	Minor adverse
Crustaceans	Negligible	Low	Negligible

11.6.3 Potential Impacts during Decommissioning

280. On expiry of the lease for the proposed East Anglia THREE project, EATL would remove all structures, except cables and pin piles deeper than 1 to 2m, and return the sea bed to a usable state in accordance with the Department of Energy and Climate Change (DECC) decommissioning guidance (DECC 2011).

281. 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.

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

- Impact 1: Physical Disturbance;
- Impact 2: Increased Suspended Sediment Concentrations;
- Impact 4: Underwater Noise; and
- Impact 3: Re-mobilisation of Contaminated Sediments

283. 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 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.

11.7 Cumulative Impacts

284. As discussed in section 11.4.4, the development activities and measures taken forward for cumulative assessment have been selected on the basis of availability and quality of information and the probability of a cumulative impact occurring, including, where relevant, spatial overlap.

285. Already installed infrastructure, practiced licenced activities and implemented measures have been assumed part of the existing environment to which receptors have already adapted.

286. The approach to screening both the impacts and the types of plans or projects to be included within the CIA were discussed with Cefas, Natural England and the MMO during a meeting held on 10th September 2013 meeting (*Appendix 11.2*).

287. It was agreed that, in respect of fish ecology, apart from underwater noise and regional impacts of increased SSCs and sediment re-deposition on sandeels, all other impacts can be assessed collectively under a single generic assessment.

288. The CIA therefore considers the following impacts in detail:

- Increases in SSCs and sediment re-deposition during construction and decommissioning, particularly in relation to sandeels; and
- Increases in underwater noise during construction and decommissioning.

289. In addition to the above, the following impacts as agreed, have been considered in a single generic assessment:

- Physical disturbance and permanent habitat loss;
- Introduction of hard substrate; and
- EMFs.

290. Only projects with anticipated construction periods that are likely to overlap with that of the proposed East Anglia THREE project and which are at sufficient distance for zones of impact on fish and shellfish to overlap spatially are assessed. The proposed construction period for East Anglia THREE is from 2020 to 2025. As shown by *Table 11.31* temporal overlap of the construction phases would only occur with Hornsea 2, Triton Knoll[11] and the four Dogger Bank projects[12].

291. At present there is no publicly available information that there will be any major oil and gas installation activities which would either spatially or temporally overlap with the construction phase of the proposed East Anglia THREE project. Whilst it is understood that over the longer term, there may be decommissioning and removal of offshore oil and gas infrastructure in the North Sea, the time frames involved are currently unknown and may well occur after construction of the proposed East Anglia THREE project has been constructed. Therefore oil and gas infrastructure is not considered further for cumulative assessment.

[11] Triton Knoll awaiting cable consent, but has been included from a precautionary standpoint
[12] Although there is potential for all four Dogger Bank projects to construct at the same time as the proposed East Anglia THREE project, this is considered highly unlikely

Table 11.32 Summary of infrastructure projects and aggregate extraction taken forward for cumulative impact assessment for fish and shellfish

Project	Status	Estimated Construction period	Distance from EA THREE site (km)	Likely overlap of construction with East Anglia THREE
East Anglia THREE	Full draft ES	2020-2025		-
Offshore Windfarms				
East Anglia ONE	Consented June 14	2018-2019	22	No
Hornsea Project ONE	Consented	2018-2020	96	No
Hornsea Project Two	Examination / Determination	2016-2021	120	Yes+
Triton Knoll phase 1-3	Windfarm consented, cable in examination	2016-2021	137	Yes
Dogger Bank Creyke Beck A	Consented	2016-2028	218	Yes+
Dogger Bank Creyke Beck B	Consented	2016-2028	242	No+
Dogger Bank Teesside A	Consented	2016 - 2028	231	No+
Dogger Bank Teesside B	Consented	2016-2028	245	No+
Rampion	Consented	2016 -2018	295	No
Aggregate extraction				
Humber 5 (483)	Application	Undetermined	96	Unknown
Humber 3 (484)	Application	Undetermined	91	Unknown
Sole Pit (492)	Application	Undetermined	117	Unknown
Outer Dowsing (441)	Application	Undetermined	127-136	Unknown

Project	Status	Estimated Construction period	Distance from EA THREE site (km)	Likely overlap of construction with East Anglia THREE
Cross Sands (242/361)	Application	Undetermined	45-46	Unknown
North Cross Sands (494)	Application	Undetermined	50	Unknown
Off Great Yarmouth/Yarmouth (328/254))	Application	Undetermined	40-53	Unknown
Off Great Yarmouth Extension (240)	Application	Undetermined	52	Unknown
TBC (511-513)	Application	Undetermined	47-57	Unknown
North Inner Gabbard (498)	Pre-application	Undetermined	78	Unknown
Cutline (466 - 477)	Application	Undetermined	97-109	Unknown
North Falls East (504)	Pre-application	Undetermined	89	Unknown

[#] Shortest distance between the considered project and The proposed East Anglia THREE project unless otherwise stated– unless specified otherwise.

[+] The most likely potential for overlap of construction has been assessed based on known piling scenarios and what would be achievable. It is highly unlikely that all four Dogger Bank projects would be piling at the same time and concurrent piling would take place at the site, therefore only one project has been included as potentially overlapping with East Anglia THREE. .

11.7.1.1 Physical disturbance and habitat loss, introduction of hard substrate and EMFs

292. Given the distances to other activities in the region (e.g. other offshore windfarms, aggregate extraction, a minimum distance of 38km) and the localised nature of the impacts there is no pathway for interaction between impacts cumulatively.

293. Whilst it is recognised that across the East Anglia Zone or regional area 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.

11.7.1.2 Increased SSCs and sediment re-deposition

294. There is a potential for cumulative increased SSCs and sediment re-deposition impacts to occur on the fish and shellfish receptors identified in the proposed East Anglia THREE project if all of the other potential developments, regulated activities and conservation areas listed in *Table 11.31* and shown in *Figures 11.64* are implemented.

295. As shown in *Table 11.31* there is scope for a temporal overlap with the construction phases of other projects and therefore potential for cumulative impact from increased suspended sediment and sediment re-deposition (section 11.7.1). Due to the distances between East Anglia THREE and other windfarm sites, the rapid plume dispersion and the localised nature of sediment re-deposition, the cumulative impact associated with East Anglia THREE and other windfarm developments is predicted to be **no impact**.

296. *Figure 11.61* illustrates that licenced aggregate dredging sites are located some distance away from the East Anglia THREE site and offshore cable corridor (a minimum of 38km). Furthermore, as stated above, the rapid plume dispersion and the localised nature of sediment re-deposition associated with East Anglia THREE will lead to a minimal contribution to any cumulative effects. As such, the magnitude of the effect is expected to be negligible.

297. As stated above, during the Evidence Plan meetings, sandeels were identified by the MMO, Natural England and Cefas as being the species of concern in relation to the regional cumulative effects of SSCs and sediment re-deposition. As discussed in section 11.6.2, it is considered that sandeels and their eggs and larvae have high

tolerances to SSCs and sediment re-deposition. In view of their limited mobility and substrate dependence, however, their sensitivity is considered to be medium.

298. As the magnitude of effect with aggregate dredging is expected to be negligible, the cumulative impact of increased SSCs and sediment re-deposition associated with East Anglia THREE on sandeels is expected to be of **negligible** significance. Whist concern was not raised in the respect of other species during consultation, it is assumed that impacts on other species will be no greater than those assessed for sandeels.

11.7.1.3 Underwater noise

299. Any cumulative effect associated with underwater noise would be the result of either spatial or temporal effects, or a combination of both. As discussed above, the primary concern is the effect of piling noise on fish spawning behaviour, particularly herring and cod.

300. *Figure 11.62* illustrates the modelled 168dB noise contour of East Anglia ONE and East Anglia THREE and the approximate behavioural noise ranges of other relevant developments within the Southern and Central North Sea in relation to the herring spawning grounds as identified by Coull et al. (1998). These ranges have been estimated at an average 30km radius, with the exception of East Anglia ONE where the design envelope includes only small pin piles and so a 9km radius has been used.

301. As previously discussed, the herring spawning stock relevant to East Anglia THREE is the Downs stock. From *Figure 11.62* it is apparent that unlike other projects, the behavioural noise contour for East Anglia THREE does not overlap with any currently defined herring spawning grounds, although herring larvae have been recorded within the proposed East Anglia THREE project in low abundances (2003, 2005, 2009: 1-100 larvae per m^2). Chapter 7 Marine Geology, Oceanography and Physical Processes, shows the sea bed across the East Anglia THREE site is homogeneous and is characterised predominantly by sand, with some muddy sand, and therefore does not represent suitable habitat for herring spawning. Furthermore, 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). In light of these considerations, it is likely that herring larvae sampled within the East Anglia THREE site have drifted from spawning grounds located elsewhere (e.g. spawning grounds of the Downs stock). As such, in the case of herring there is no potential for the proposed East Anglia THREE project to make a contribution to any cumulative effect associated with underwater noise (i.e. **no impact**).

302. *Figure 11.63* provides the same information in relation to cod spawning grounds. With regard to cumulative effects on cod spawning, and as discussed in section 11.6.1.5, there is some overlap with East Anglia THREE 168dB contours and those estimated for other windfarm developments with low intensity cod spawning grounds. Spawning grounds of the species are extensive and the highest intensity is considered by Ellis et al. (2010) to occur in the northern North Sea, some considerable distance from the proposed East Anglia THREE project. The contribution of East Anglia THREE site to the cumulative effect of underwater noise on cod spawning will therefore be of **negligible** significance.

11.8 Inter-relationships

303. The assessment of the impacts arising from construction, operation and decommissioning of the proposed East Anglia THREE project given above, indicates that impacts on receptors addressed in other ES chapters may potentially further contribute to the impacts assessed on fish and shellfish species and vice versa.

304. The principal linkages identified are summarised in *Table 11.32* below. No inter-relationships have been identified where an accumulation of residual impacts on fish and shellfish ecology gives rise to a need for additional mitigation.

Table 11.33 Chapter topic inter-relationships

Topic and description	Related Chapter	Where addressed in this Chapter
Underwater Noise	9	Section 11.6.3
Benthic Ecology	10	Section 11.7.1
Commercial Fisheries	14	Section 11.5.5
Physical Processes	7	Section 11.7.2
Marine Mammals	12	Section 11.7.5.4
Ornithology	13	Section 11.7.5.4

11.9 Transboundary

305. As previously stated, the distribution of fish and shellfish species is independent of national geographical boundaries. The East Anglia THREE specific impact assessment has therefore been undertaken taking account of the distribution of fish stocks and populations irrespective of political limits. As a result, it is considered that a specific assessment of trans-boundary effects is unnecessary.

11.10 Summary

306. Numerous existing data sources, as well as site-specific surveys, have been used to characterise the species of fish and shellfish that could be impacted by the proposed East Anglia THREE 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.

307. The receptors that have been identified in specific relation to fish and shellfish ecology include a number of species of interest due to ecosystem value and the value to commercial fishermen. Other species such as salmon and lamprey were taken forward for assessment due to their conservation value.

308. The construction, operation and decommissioning phases of the proposed East Anglia THREE project would cause a range of effects to fish and shellfish ecology which are summarised in *Table 11.33*. 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.

309. 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 11.34 Summary of Impacts on Fish and Shellfish Species for the Construction, Operation and Decommissioning phase of the proposed East Anglia THREE project

Receptor Group	Receptor Sensitivity	Magnitude of Effect	Impact Significance
Construction Phase			
Physical disturbance and temporary loss of sea bed habitat			
Herring and Sandeel	Medium	low	Negligible to minor adverse
Shellfish	Medium	low	Minor adverse
Increased Suspended Sediment Concentrations and Sediment Re-deposition			
Physiological Effects on Fish species	Medium	Low	Minor adverse
Physiological Effects on Shellfish species	Medium	Low	Minor adverse
Physiological Effects on Sandeels	Medium	Low	Minor adverse
Changes to Composition of Demersal Spawning Grounds	N/A	No impact	No Impact
Increased SSCs Pelagic in Spawning Areas	Low	Low	Minor adverse
Underwater Noise			
Instantaneous Injury			
Mobile life stages/ Species	Low	Negligible	Negligible
Early Life Stages	Medium	Low	Minor adverse
Species of Limited Mobility- Gobies	Medium	Low	Minor adverse
Species of Limited Mobility- Sandeels	Medium	Negligible	Negligible
Species of Limited Mobility- Shellfish	Low	Negligible	Negligible
Behavioural Disturbance			

Receptor Group	Receptor Sensitivity	Magnitude of Effect	Impact Significance
Sole plaice and cod	Low	Medium	Minor adverse
Whiting	Medium	Low	Minor adverse
Lemon Sole	Low	Negligible	Negligible
Herring	Low	Low	Minor adverse
Sprat	Low	Low	Minor adverse
Sandeels	Medium	Low	Minor adverse
Elasmobranchs	Low	Low	Minor adverse
Diandromous Species	Medium	Low	Minor adverse
Operational Phase			
Physical Disturbance			
Fish and Shellfish	Negligible	No change	No impact
Permanent Loss of Habitat			
Sandeels	Medium	Low	Minor adverse
Herring	Medium	Negligible	Negligible
Shellfish	Low	Low	Minor adverse
Introduction of Hard Substrate			
Fish and Shellfish	Low	low to medium	Minor adverse
Operational Noise			
Fish and Shellfish Species	Low	Negligible	Negligible
Electromagnetic Fields (EMFs)			

Receptor Group	Receptor Sensitivity	Magnitude of Effect	Impact Significance
Elasmobranchs	Medium	Low	Minor adverse
Lamprey	Low	Low	Minor adverse
Salmon	Negligible	Low	Negligible
Sea Trout	Low	Low	Minor adverse
European Eel	Medium	Low	Minor adverse
Crustaceans	Negligible	Low	Negligible
Decommissioning Phase			
In the absence of detailed methodologies and schedules, the worst case scenarios for decommissioning activities and associated implications for fish and shellfish are considered analogous with those assessed fort the construction phase.			
Cumulative impacts			
Physical disturbance and habitat loss, introduction of hard substrate and EMFs			
Fish and Shellfish species	N/A	Negligible	Negligible to minor adverse
Increased SSCs and sediment re-deposition			
Sandeels	Medium	Negligible	Negligible
Underwater Noise			
Herring and Cod	Low	Negligible	Negligible

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Chapter 11 Ends Here