East Anglia Offshore Wind

VATTENFALL

SCOTTISHPOWER RENEWABLES

East Anglia THREE

Chapter 9

Underwater Noise and Electromagnetic Fields

Environmental Statement

Volume 1

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9 UNDERWATER NOISE AND ELECTROMAGNETIC FIELDS

9.1 Introduction

1. This chapter first describes the underwater noise modelling carried out by the National Physical Laboratory (NPL) for the proposed East Anglia THREE project. Comprehensive details are provided in *Appendix 9.1*. The chapter then describes the potential effects of electromagnetic fields (EMF) of the proposed East Anglia THREE project with reference to work undertaken by the Centre for Marine and Coastal Studies Ltd (CMACS). The original CMACS report is presented as *Appendix 9.2* and was commissioned for the East Anglia ONE project., It is reproduced here as it is a review of current knowledge and relevant to this assessment.

2. The underwater noise modelling was conducted to provide technical information in support of the fish and marine mammal impact assessments (Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammal Ecology, respectively). The model describes how noise would propagate in the marine environment and the extent to which this is predicted for the proposed East Anglia THREE project.

3. The EMF assessment considers the impacts of the operational phase of the proposed East Anglia THREE project only. Information on predicted fields from cables for the proposed East Anglia THREE project, background fields, electromagnetic field detection and potential impacts are presented. This technical information is then utilised in the benthic ecology, and fish and shellfish, impact assessments (Chapter 10 Benthic Ecology, and Chapter 11 Fish and Shellfish Ecology respectively).

9.2 Consultation

4. Consultation relating to the impact of underwater noise and EMF on benthic ecology, fish and shellfish and marine mammals is reported in Chapter 10 Benthic Ecology, Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammal Ecology. EMF impacts on marine mammals have not been taken forward for assessment in the EIA, as agreed by Natural England in the first marine mammal evidence plan meeting held on the 13th September 2013 (*Appendix 12.1*).

5. *Table 9.1* summarises comments specifically related to underwater noise and EMF raised during the formal consultation on the Preliminary Environmental Information Report (PEIR) (East Anglia THREE Limited (EATL) 2014) consultation and other informal consultation and advice.

Table 9.1 Consultation Responses

Consultee	Date /Document	Comment	Response / where addressed in the ES
PEIR consultation			
MMO	May 2014	A thorough literature review has been conducted to obtain and summarise the most relevant, up-to-date and internationally accepted impact criteria from peer-reviewed literature in order to assess the impact of underwater noise on marine mammals and fish. Potential impacts are comprehensively listed and appropriately considered for marine mammals; injury and behavioural criteria according to the standard are detailed and modelled for a range of hammer energies.	The review of the literature is included in Chapter 12 Marine Mammal Ecology and Chapter 11 Fish and Shellfish Ecology for marine mammals and fish, respectively, with the underwater noise modelling further detailed in *Appendix 9.1* Underwater Noise Modelling, Environmental Statement Volume 3.
MMO	May 2014	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.	Modelling has been completed for an illustrative example for cumulative sound exposure level in Appendix 9.1 Underwater Noise Modelling, Environmental Statement Volume 3, however, the caveats associated with this type of modelling should be understood and are detailed in 9.4.1.1.2 of Appendix 9.1 Underwater Noise Modelling, Environmental Statement Volume 3.
Natural England	May 2014	Natural England would welcome further consideration given to impacts of EMF despite the lack of knowledge around this subject. Natural England supports the proposal of burying cables as this will increase the physical separation of mammals and fish from the cables and reduce the impact of EMF. If cable burial is not an option, or effective then some form of armouring should be employed. This would however have a knock-on effect to the surrounding habitat and we would like to draw attention to the advice regarding linear cable	The effect of cable protection measures (with regard to the worst case scenario) is described in Chapter 7 Marine Geology, Oceanography and Physical Processes, Chapter 10 Benthic Ecology, Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammal Ecology

Consultee	Date /Document	Comment	Response / where addressed in the ES
		protection provided at comment 21 above.	
Natural England	May 2014	Given the potential impacts on marine mammals described, it is clear that mitigation will play a key role in any wind farm developments in the North Sea, in particular in the context of this development, reduce cumulative effects arising from disturbance. It will therefore be beneficial if all developers make a concerted attempt to reduce the acoustic output from pile driving (e.g. sleeving), to investigate alternative installation methods (e.g. suction bucket) and to plan activities within the scope of what is proposed to reduce the potential that they contribute to negative effects on populations.	EATL confirms their ongoing support of strategic initiatives and will continue to work with other developers, Regulators and SNCBs in order to understand and reduce cumulative impacts where possible.
Informal consultation			
Natural England	March 2015	If available the ES should include the Marine Scotland work on EMF effects upon Salmon.	Recent reports from on salmon and eel have been included, see section 9.11.2

9.3 Scope – Underwater Noise

9.3.1 Study Area

6. An area encompassing approximately 180 by 180km around the modelled foundations was adopted for single piling, sufficient to encompass modelled injury and behavioural disturbance distances.

9.3.2 Worst Case

7. The worst case noise source modelled is impact pile driving (Chapter 5 Description of the Development). Hammer strike energies of up to 3,500kJ have been modelled (see *Table 9.2*), with 3,500kJ representing the highest hammer strike energy that is proposed for use at the East Anglia THREE site (representing that required for a monopile up to 12m diameter). The maximum energy required to complete pile installation is however likely to be less than 3,500kJ (see Chapter 5 Description of the Development).

8. Foundation types which rely on impact piling are considered the worst case in terms of the resulting underwater noise, and other foundation types (other than jackets and monopiles) are therefore not considered in this aspect of the assessment. The underwater noise resulting from other foundation types or alternative installation methods would be expected to be lower in level. Of note the worst case in terms of temporal aspects and multiple piles etc. would likely be receptor dependent and is therefore not appropriate to consider in this Chapter, these are assessed in the respective Chapter 10 Benthic Ecology, Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammal Ecology.

Table 9.2. Modelled Scenarios for Underwater Noise

Scenario	Key parameters modelled	Rationale
Modelling of impact piling for 20 foundation locations to establish instantaneous injury and behavioural disturbance ranges for both lowest and highest astronomical tide (LAT and HAT, respectively).	• Range of hammer energies modelled: 1,400kJ; 2,000kJ; 2,300kJ; 3,000kJ; 3,500kJ. • Injury or behavioural disturbance ranges for specified criteria (maximum was taken from LAT and HAT).	20 locations chosen to capture spatial extent of and bathymetry variation within the East Anglia THREE site for wind turbine, offshore platforms, met mast and accommodation platform foundations.
Modelling of 12 locations along the East Anglia THREE boundary to establish the noise footprint to show noise resulting from construction irrespective of the timing, specific piling location, or number of piling vessels operating within the project boundary. This is presented in *Appendix 9.1.*	• Range of hammer energies modelled: 1,400kJ; 2,000kJ; 2,300kJ; 3,000kJ; 3,500kJ. • Injury or behavioural disturbance ranges for specified criteria.	Noise footprint modelling carried out as the exact locations at any given time and timing of the construction activities are unknown.
Illustrative modelling of two concurrent piling vessels operating at two different separation distances. This is presented in *Appendix 9.1.*	• Hammer energy of 3,500kJ. • Vessel separations of ~4km and ~33km.	Two vessel separation distances chosen to demonstrate the effect of using two piling vessels at different ranges.

Scenario	Key parameters modelled	Rationale
Illustrative modelling of Sound Exposure Level (SEL) dose carried out for a single location to show potential for prolonged exposure to result in Permanent Threshold Shift (PTS). This is presented in *Appendix 9.1.*	• Hammer energy ramp up from 1,400kJ to 3,500kJ for a piling duration of 230 minutes. • Location with greater propagation ranges modelled. • 500 m start distance assumed at the onset of piling. • Animal assumed to swim away at onset of piling. • Animal assumed to remain submerged at a water depth where highest levels generally occur for the duration of piling. • No inter-pulse hearing recovery assumed. • No effective quiet hearing recovery assumed.	Exact details of piling sequence unknown. Modelling carried out is illustrative due to lack of data on animal swim profile behaviour during high-intensity noise exposure, and lack of sufficient knowledge of hearing recovery and effects of effective quiet.

9.3.3 Embedded Mitigation

9. Receptor specific mitigation is provided in the fish and marine mammal impact assessments (Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammal Ecology respectively).

9.4 Assessment Methodology – Underwater Noise

9.4.1 Legislation, Policy and Guidance

10. Specific consideration has been given to the relevant National Policy Statement (NPS), the principal decision making documents for Nationally Significant Infrastructure Projects (NSIP). The NPS relevant to the underwater noise assessment for these projects include; Overarching NPS for Energy (EN-1) (National Policy Statement (NPS) EN-1 2011); and NPS for Renewable Energy Infrastructure (EN-3) (NPS EN-3 2011).

11. Guidance is also provided by the Joint Nature Conservation Committee (JNCC) protocol for minimising the risk of injury to marine mammals from piling noise (JNCC 2010).

12. The Marine Strategy Framework Directive (MSFD) 2008/56/EC (European Commission 2008) Descriptor No. 11, Criterion 11.1, Indicator 11.1.1 (Van der Graaf et al. 2012) requires the distribution of loud low and mid frequency impulsive sources, in time and space, to be captured as a measure of Good Environmental Status (GES). The MSFD is further described in Chapter 3 Policy and Legislative

Context. Pile driving using an impact hammer is considered such a source and is therefore likely to be included in a UK register of such sounds.

13. The Good Practice Guide for Underwater Noise Measurement (Robinson et al. 2014), funded by the National Measurement Office, Marine Scotland, and The Crown Estate, describes the metrics which should be used when reporting underwater noise levels. It also provides guidance for the technical requirements for propagation models used for underwater noise. Consistency with these metrics has been maintained throughout this assessment and the guidance relating to the acoustic propagation model has been followed.

9.4.2 Data sources

14. No underwater noise measurement data have been collected for this assessment. Details of the sound propagation modelling and the input data are provided in *Appendix 9.1*. Data sources relating to the fish and marine mammals assessments are reported in Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammal Ecology, respectively.

9.4.3 Impact Assessment Methodology

9.4.3.1 Background

15. By convention, sound levels are expressed in decibels (dB) relative to a reference pressure, which is 1 μPa for underwater sound. Common parameters to describe the received level of a sound pulse are the zero to peak sound pressure level (hereafter referred to as peak pressure level) expressed in dB re 1 μPa, and the sound exposure level (SEL) expressed in dB re 1 $\mu Pa^2 \cdot s$ which is related to the energy contained in the sound pulse.

16. The output amplitude of a sound source is commonly described in terms of a source level, which may be considered to be the sound pressure level that would exist at a range of 1m from the acoustic centre of an equivalent simple ‘point’ source which radiates the same acoustic power into the medium as the source in question in the absence of any boundary reflections. As with received level, the source level can be described in terms of peak pressure source level (in dB re 1 μPa·m, often expressed as dB re 1 μPa at 1m) or as an SEL source level (in dB re 1 $\mu Pa^2 \cdot s \cdot m^2$, often expressed as dB re 1 $\mu Pa^2 \cdot s$ at 1m). It should be noted that for marine piling, the received level measured at 1m would not be equivalent to the source level due to the complex sound field in such close proximity to the pile.

17. The metrics used during this assessment are peak pressure level and SEL which are suitable descriptors for impulsive sounds such as impact pile-driving. The use of

these metrics maintains consistency with the Marine Strategy Framework Directive (MSFD 2008), and is also consistent with the metrics described in the UK, German and Dutch guidance documents (Robinson et al. 2014; Mueller and Zerbs 2011; De Jong et al. 2011).

18. Another important characteristic of sound is its frequency, described as the number of oscillations per second. The unit of frequency is the hertz (Hz). The frequency range of applications in underwater acoustics is very large, with seismic exploration involving frequencies of less than 1Hz, and acoustic current profilers operating at frequencies of millions of hertz. Marine piling tends to generate noise with most of the energy between around 100 and 400Hz, with the noise levels outside of this frequency range significantly reduced. It is common to see the frequency range divided up into one-third octave bands. One-third octave bands are also commonly used in underwater acoustics as a convenient way of expressing the sound level as a function of frequency, where each band is one-third of an octave, an octave representing a doubling of frequency.

9.4.3.2 Modelling of Piling Noise

19. To predict the received level as a function of range from the source requires both the source level and the propagation or transmission loss to be known. If these are known then the received level (RL) is simply calculated by:

$$RL = SL - PL$$

where SL is the source level which describes the sound radiated into the acoustic far-field, and PL is the propagation loss expressed as a positive number in dB (dependent on frequency, sea bed, bathymetry, etc.).

20. The primary model employs an NPL implementation of the energy flux solution by Weston (1976) which is capable of propagation over large distances whilst accounting for range-dependent bathymetry, frequency-dependent absorption (Thorpe 1967), surface scattering (Coates 1988; Medwin and Clay 1998; Ainslie et al. 1994) and sea bed properties (Hamilton 1980; Lurton 2003).

21. The modelling has been completed at 20 single pile locations inside and around the boundary of the East Anglia THREE site to represent the geographical extent of the windfarm and to account for bathymetric features so as to suitably capture the variability in the regional underwater sound propagation. An example noise propagation map is shown in *Diagram 9.1*. The effect of receptor position in the water column has been considered and is illustrated in the depth dependent

modelling outputs shown in *Diagram 9.2* and *Diagram 9.3* for a north and south transect of an example location in the East Anglia THREE site, respectively.

22. Full details of the underwater noise modelling and the results of this are provided in *Appendix 9.1*.

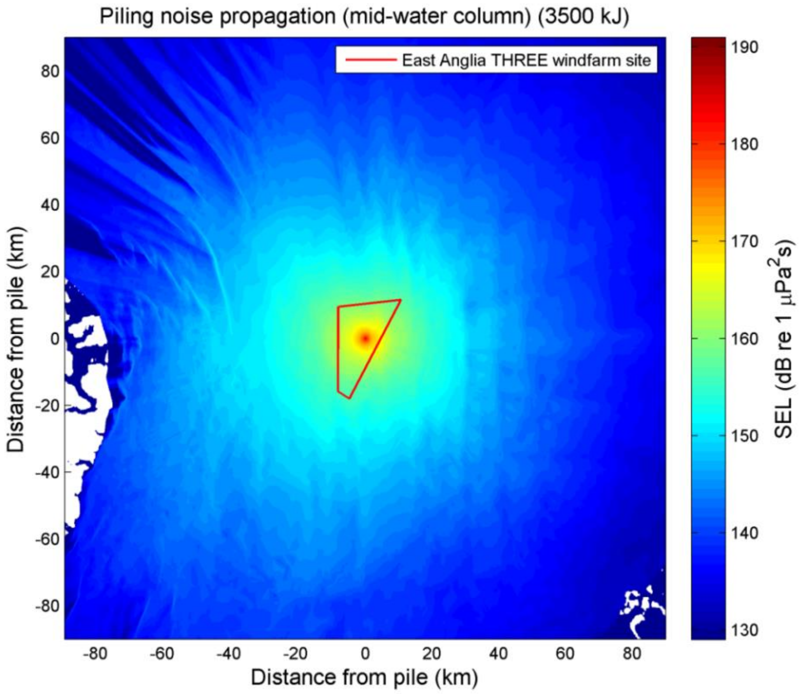

Diagram 9.1. Impact piling noise propagation output for a single pile example location (see *Appendix 9.1* for details on locations modelled) within the East Anglia THREE site for a 3,500kJ hammer blow energy.

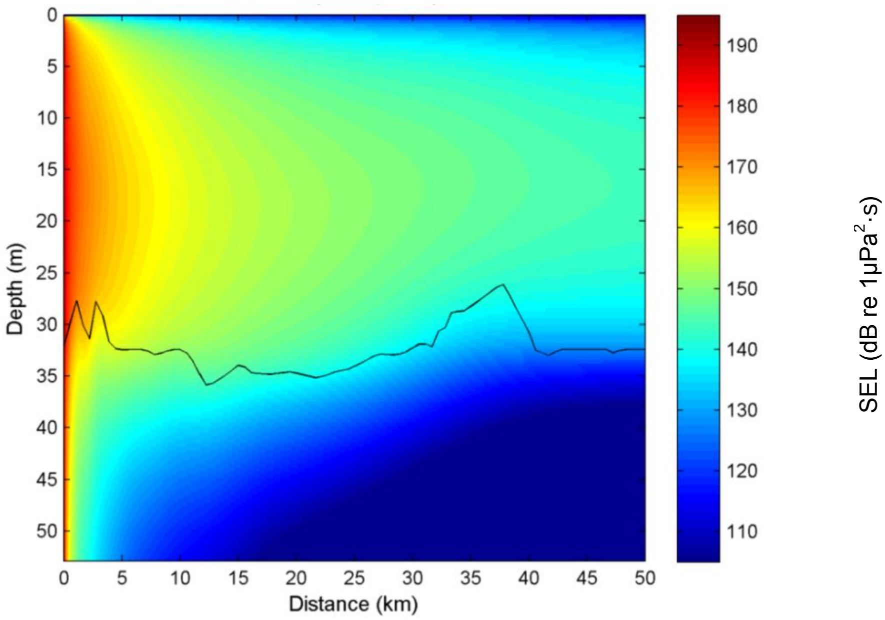

Diagram 9.2. Impact piling noise propagation output, as a function of distance and depth, for a single pile example location along a northerly transect (see Appendix 9.1 for details) within the East Anglia THREE site, for a 3,500kJ hammer blow energy.

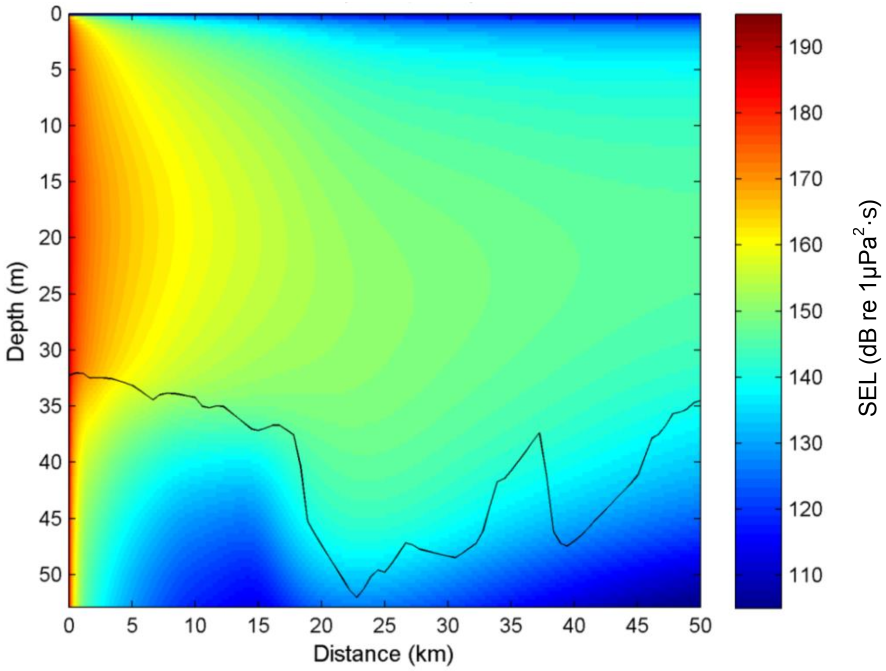

Diagram 9.3. Impact piling noise propagation output, as a function of distance and depth, for a single pile example location along a southerly transect (see *Appendix 9.1* for details) within the East Anglia THREE site, for a 3,500kJ hammer blow energy.

9.4.3.3 Criteria relating to the effect of underwater noise from pile driving

23. For both marine mammals and fish, likely effects are assessed on the basis of risk of injury and behavioural disturbance using the criteria described in Chapter 11 Fish and Shellfish Ecology for fish, and in Chapter 12 Marine Mammal Ecology for marine mammals.

24. The criteria are summarized in *Tables 9.3* and *Table 9.4* for marine mammals, and *Table 9.5* and *Table 9.6* for fish.

Table 9.3. Summary of injury criteria (PTS onset) for marine mammals.

Receptor	Peak Pressure Level (dB re 1 µPa)	SEL (dB re 1 µPa^2·s)
Harbour porpoise *Phocoena phocoena* (High-frequency cetacean)	200	179 (single strike)
Mid and Low- frequency cetacean	230	198 (M_{mf} or M_{lf} weighted)
Pinniped (in water)	218	186 (M_{pw} weighted)

Table 9.4. Summary of behavioural criteria for marine mammals.

Receptor	Peak Pressure Level (dB re 1 µPa)	SEL (dB re 1 $\mu Pa^2 \cdot s$)
Harbour porpoise *Phocoena phocoena* - TTS onset / Fleeing response	194	164
Harbour porpoise *Phocoena phocoena* - Potential avoidance of area	168	145
Mid- & Low- frequency cetacean - TTS onset / Fleeing response	224	183 (M_{mf} or M_{lf} weighted)
Mid- frequency cetacean - Potential avoidance of area	N/A	160 – 170*
Low- frequency cetacean - Potential avoidance of area	N/A	142 – 152*
Pinniped - TTS onset / Fleeing response /Potential avoidance	212	171 (M_{pw} weighted)

*Derived from Southall et al. (2007) severity scaling behavioural response and converted to SEL (of the pulse) from RMS (over the duration of the pulse) by subtracting 10dB for mid-frequency cetaceans and 8dB for low-frequency cetaceans (based on the longer ranges for low-frequency cetaceans).

Table 9.5. Summary of injury criteria for fish.

Receptor	Peak Pressure Level (dB re 1 µPa)
Fish	206

Table 9.6. Summary of behavioural criteria for fish.

Receptor	Peak Pressure Level (dB re 1 µPa)
General behavioural response	168 - 173*
Startle response / C-turn reaction	200*

*These levels have been established from a seismic airgun and should therefore only be applied for impulsive sound source and considered for fish that are sensitive to low-frequency sound (e.g. ~ 500Hz and less).

9.4.3.4 Assessment of other noise sources

25. Other noise sources, including operational wind turbines and surface vessels are considered, in *Appendix 9.1*, using information available in the peer-reviewed

literature to inform the likely noise levels and the potential for impact on marine fauna.

9.5 Existing Environment – Underwater Noise

26. Underwater ambient noise levels are subject to substantial variability depending on a number of natural and anthropogenic factors. Natural factors such as sea-state, rain, surf noise in coastal waters, movement of seabed material and marine animal vocalisations all influence ambient noise levels. These often lead to a diurnal and seasonal variation in the natural ambient noise level in the oceans or regional seas and can cause significant location dependency. The contributions of anthropogenic noise sources to the ambient level are difficult to quantify, although recent studies have indicated that there has been a trend of increasing deep-ocean ambient noise as a result of shipping (McDonald et al. 2008; Andrew et al. 2011). In the North Sea for example, the contribution of shipping noise to ambient levels has been shown to be significant (Ainslie et al. 2009). The ambient noise level is also highly likely to depend on the distance to shipping lanes, fishing areas, dredging areas or other areas where potential noise sources are operating.

27. Previous ambient noise measurements undertaken in UK coastal waters (Nedwell et al. 2007; Theobald et al. 2010; Robinson et al. 2011) indicate the higher-end one-third octave band (TOB) spectral noise levels to be generally between around 95 and 120dB re 1 $\mu Pa^2 Hz^{-1}$ with these peak band levels occurring between frequencies of a few tens of hertz to a few hundred hertz, depending on location and time. Such spectral composition is fairly typical of coastal underwater noise, with higher noise levels at frequencies below a few hundred hertz and falling off at higher frequencies. The ambient noise level over the lower frequency range is largely dominated by shipping noise and may be expected to depend on the distance to ports, shipping lanes and areas of other surface vessel activity.

28. Another type of ambient noise evaluation in the UK entailed assessment of likely ambient noise contributions. This formed a part of the Strategic Environmental Assessment (SEA); however, the assessment was only undertaken for SEA area 6, which includes parts of the western UK coast (Harland et al. 2005).

29. Natural environmental contributors to the ambient noise level in and around the proposed East Anglia THREE project, and the East Anglia Zone in general, will likely be from the wind (sea-state) with contributions from rain noise and biological noise. Noise generated by the interaction of wind with the sea surface is likely to be the dominant natural contributor to ambient noise around the East Anglia Zone, and will range from a few hertz to a few tens of kilohertz. This sea-state related ambient

noise reported by Wenz (1962) is thought to be the result of bubble oscillations and impact from breaking waves at the sea surface (Medwin and Beaky 1989; Medwin and Daniel 1990). Rain can also contribute to ambient noise at several tens of kilohertz in the immediate area through bubble oscillation although this would not be expected to be a dominant component of the overall ambient noise. Biological contribution to ambient noise can be significant depending on the location and time. These sounds can include a variety of marine mammal vocalisations spanning from a few hertz to several tens of kilohertz and include lower frequency sounds made by fish (Richardson et al. 1995; Amorim 2006).

30. The primary anthropogenic contributors to the ambient noise level in the North Sea include shipping (e.g., fishing, cargo, cruise ship, ferries, and aggregate extraction) and oil and gas related activities. Some of the vessels operating in and around the East Anglia THREE site, depending on vessel speed, size, type, age and condition etc., may generate significant noise levels, with the literature indicating maximum TOB source level of over 200dB re 1 µPa·m (Malme et al. 1989) for a large tanker, over 186dB re 1 µPa·m for a cargo vessel (Arveson and Vedittis 2000) and over 170dB re 1 µPa·m for a passenger ferry (Malme et al. 1989) (for the TOB where the source level is maximum). These would generally be expected to result in noise levels above ambient levels out to distances of several km and local ship traffic would influence the ambient noise to an extent. However, these would be localised, short term changes and the more constant contributor to noise within the East Anglia THREE site would be distant shipping.

31. Dredging vessels could also be a source of noise, which may be noisier at higher frequencies than commercial vessels operating in the shipping lanes (Robinson et al. 2011). There are no licensed or active dredging areas within the East Anglia Zone, although a number of Active Dredge Zones, Dredging Application Option and Prospecting Areas (DAOPAs), and Production Agreement Areas exist to the southwest and further to the north and northwest of the East Anglia Zone (The Crown Estate 2014). It could be assumed that, at ranges of several km (>10km), these may be too far away to considerably contribute to an increase in ambient noise, above existing shipping noise, around the East Anglia THREE site.

32. The southern North Sea supports a concentration of oil and mostly gas fields, which are concentrated mostly to the north of the East Anglia Zone (Department of Energy and Climate Change (DECC) 2014), which if operational may radiate low frequency machinery noise and general broadband noise into the water that could potentially influence ambient noise trends in the North Sea and the southern North Sea area. Whilst oil and gas activity in the UK Continental Shelf quadrants immediately

adjacent to the East Anglia THREE site may contribute to ambient noise, the ambient noise around the East Anglia THREE site would likely be dominated by local shipping and sea-state.

33. Non-continuous sound sources, such as seismic surveys and pile-driving, will contribute to the ambient noise and if persistent or present for substantial periods of time will result in an overall increase in the ambient noise level, depending on the averaging time used to calculate the ambient noise.

9.6 Modelled Injury and behavioural Disturbance Distances

34. The underwater noise assessment detailed in *Appendix 9.1* provides an assessment of the likely underwater noise conditions during the different phases of the proposed East Anglia THREE project, including the assessment of the ranges for injury and behavioural disturbance to sensitive marine receptors, criteria described in *Chapter 11 Fish and Shellfish Ecology for fish, and in Chapter 12 Marine Mammal Ecology for marine mammals* and summarised below. The resulting instantaneous injury and behavioural disturbance ranges, for impact piling, are tabulated in Table 9.7 to Table 9.10 for marine mammals and in Table 9.11 to Table 9.12 for fish.

Table 9.7. Summary of harbour porpoise *Phocoena phocoena* (around mid-water column) injury and behavioural disturbance distances estimated for pile driving during construction at the East Anglia THREE site for different hammer strike energies. Possible avoidance of area is stated as the minimum to the 95th percentile impact distance, where the actual 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). Distances are rounded up to the nearest 500m for distances of 3km and less, and rounded up to the nearest 1km for distances greater than 3km.

Impact criterion	1,400kJ hammer energy	2,000kJ hammer energy	2,300kJ hammer energy	3,000kJ hammer energy	3,500kJ hammer energy
Instantaneous injury / PTS (pulse SEL 179dB re 1 μPa^2·s)*	<500m	<500m	<500m	<1km	<1km
Fleeing response (pulse SEL 164dB re 1 μPa^2·s)*	~3.0 to 5km	~4 to 6km	~4 to 6km	~5 to 8km	~5 to 8km
Possible avoidance of area (pulse SEL 145dB re 1 μPa^2·s)*	~24 to 44†km (~55km)	~29 to 51†km (~58km)	~31 to 54†km (~60km)	~34 to 59†km (~66km)	~37 to 62†km (~70km)

**Lucke et al. (2009), †95th percentile impact range.*

Table 9.8. Summary of mid-frequency cetacean functional hearing group (around mid-water column) injury and behavioural disturbance distances estimated for pile driving during construction at the East Anglia THREE site for different hammer strike energies. Possible avoidance of area is stated as the minimum to the 95th percentile impact distance, where the actual 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). Distances are rounded up to the nearest 500m for distances of 3km and less, and rounded up to the nearest 1km for distances greater than 3km.

Impact criterion	1,400kJ hammer energy	2,000kJ hammer energy	2,300kJ hammer energy	3,000kJ hammer energy	3,500kJ hammer energy
Instantaneous injury / PTS (M_{mf} weighted 198dB re 1 µPa^2·s)*	<500m	<500m	<500m	<500m	<500m
Fleeing response (M_{mf} weighted 183dB re 1 µPa^2·s)**	<500m	<500m	<500m	<500m	<500m
Likely avoidance of area (pulse SEL 170dB re 1 µPa^2·s)***	~1.5 to 2.0km	~2.0 to 2.5km	~2.0 to 2.5km	~2.5 to 3.0km	~2.5 to 4km
Possible avoidance of area / Change in swimming behaviour (pulse SEL 160dB re 1 µPa^2·s)***	~5 to 8†km (~8km)	~6 to 9†km (~10km)	~6 to 10†km (~11km)	~7 to 11†km (~12km)	~8 to 12†km (~13km)

Southall et al. (2007) Injury Criteria, **Southall et al. (2007) Single pulse behavioural disturbance.*Southall et al. (2007) Multiple pulses severity scoring behavioural disturbance (RMS SPL converted to pulse SEL by subtraction of 10dB), †95th percentile impact range.*

Table 9.9 Summary of low-frequency cetacean functional hearing group (around mid-water column) injury and behavioural disturbance distances estimated for pile driving during construction at the East Anglia THREE site for different hammer strike energies. Possible avoidance of area is stated as the minimum to the 95th percentile impact distance, where the actual 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). Distances are rounded up to the nearest 500m for distances of 3km and less, and rounded up to the nearest 1km for distances greater than 3km.

Impact criterion	1,400kJ hammer energy	2,000kJ hammer energy	2,300kJ hammer energy	3,000kJ hammer energy	3,500kJ hammer energy
Instantaneous injury / PTS (M_{lf} weighted 198dB re 1 µPa^2·s)*	<500m	<500m	<500m	<500m	<500m
Fleeing response (M_{lf} weighted 183dB re 1 µPa^2·s)**	<500m	<500m	<500m	<500m	<500m

Likely avoidance of area (pulse SEL 152dB re 1 $\mu Pa^2 \cdot s$)***	~12 to 22km	~16 to 26km	~17 to 27km	~19 to 32km	~20 to 35km
Possible avoidance of area / Change in swimming behaviour (pulse SEL 142dB re 1 $\mu Pa^2 \cdot s$)***	~34 to 57†km (~66km)	~39 to 66†km (~74km)	~40 to 69†km (~79km)	~41 to 75†km (~84km)	~42 to 79†km (~93km)

Southall et al. (2007) Injury Criteria, **Southall et al. (2007) Single pulse behavioural disturbance.*Southall et al. (2007) Multiple pulses severity scoring behavioural disturbance (RMS SPL converted to pulse SEL by subtraction of 8dB), †95^{th} percentile impact range.*

Table 9.10. Summary of pinniped functional hearing group (around mid-water column) injury and behavioural disturbance range estimates for pile driving during construction at the East Anglia THREE site for different hammer strike energies. Distances are rounded up to the nearest 500m for distances of 3km and less, and rounded up to the nearest 1km for distances greater than 3km.

Impact criterion	1,400kJ hammer energy	2,000kJ hammer energy	2,300kJ hammer energy	3,000kJ hammer energy	3,500kJ hammer energy
Instantaneous injury / PTS * (M_{pw} weighted 186dB re 1 $\mu Pa^2 \cdot s$)	<500m	<500m	<500m	<500m	<500m
Fleeing response / Likely avoidance (M_{pw} weighted 171dB re 1 $\mu Pa^2 \cdot s$) **	<1.5km	<1.5km	<2.0km	<2.0km	<2.5km

**Southall et al. (2007) Injury Criteria, **Southall et al. (2007) Single pulse behavioural disturbance.*

Table 9.11. Summary of injury and behavioural disturbance distances for fish around mid-water column (e.g. pelagic fish), estimated for pile driving during construction at the East Anglia THREE site for different hammer strike energies. Behavioural disturbance of area is stated as the minimum to the 95th percentile impact distance, where the actual 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). Distances 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.

Impact criterion	1,400kJ hammer energy	2,000kJ hammer energy	2,300kJ hammer energy	3,000kJ hammer energy	3,500kJ hammer energy
Instantaneous injury (peak pressure level 206dB re 1 μPa)	<100m	<150m	<150m	<200m	<250m
Startle response (peak pressure level 200dB re 1 μPa)	<350m	<500m	<500m	<1.0km	<1.0km

Behavioural disturbance (peak pressure level 168 - 173dB re 1 µPa)	~10 to 25†km (~28km)	~12 to 30†km (~35km)	~12 to 32†km (~37km)	~14 to 37†km (~44km)	~16 to 40†km (~48km)

†95th percentile impact range.

Table 9.12. Summary of injury and behavioural disturbance distances for fish near the sea bed (e.g. demersal fish), estimated for pile driving during construction at the East Anglia THREE site for different hammer strike energies. Behavioural disturbance of area is stated as the minimum to the 95th percentile impact distance, where the actual 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). Distances 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.

Impact criterion	1,400kJ hammer energy	2,000kJ hammer energy	2,300kJ hammer energy	3,000kJ hammer energy	3,500kJ hammer energy
Instantaneous injury (peak pressure level 206dB re 1 µPa)	<100m	<150m	<150m	<200m	<250m
Startle response (peak pressure level 200dB re 1 µPa)	<350m	<500m	<500m	<1.0km	<1.0km
Behavioural disturbance (peak pressure level 168 - 173dB re 1 µPa)	~7 to 20†km (~22km)	~9 to 23†km (~26km)	~10 to 24†km (~27km)	~10 to 27†km (~31km)	~11 to 30†km (~34km)

†95th percentile impact range.

35. There is considerable variability in the extent of the level of underwater noise resulting from piling within the East Anglia THREE site due to variable bathymetry, with the greatest ranges observed to the west (south-west to north-west) of the East Anglia THREE site.

36. The noise levels present in the water will also depend on the depth of the receptor and hearing sensitive receptors near the surface will be exposed to lower noise levels with correspondingly smaller impact ranges. For example, a receptor just below the water line would be exposed to substantially reduced pressure levels, and even at one metre below the surface of the water, the receptor would be exposed to much lower levels than those predicted in the propagation modelling.

9.7 Summary – Underwater Noise

37. Pile driving of foundations is expected to be the prevalent source of high amplitude underwater noise during the construction phase of the East Anglia THREE site. Underwater noise modelling has been completed for a number of locations within and around the windfarm boundary and injury and behavioural disturbance ranges have been estimated using the criteria outlined in Chapter 11 Fish and Shellfish Ecology for fish, and Chapter 12 Marine Mammal Ecology for marine mammals. This modelling is presented in detail *Appendix 9.1* and the resulting impacts on fish and marine mammals are presented in Chapter 11 Fish and Shellfish Ecology, and Chapter 12 Marine Mammal Ecology, respectively.

9.8 Scope – EMF

38. This section considers the possible effects of electromagnetic fields on benthic invertebrates and fish during the operation of the proposed East Anglia THREE project. Cumulative impacts are also considered. Chapter 10 Benthic Ecology and Chapter 12 Fish and Shellfish Ecology assess the significance of the impact of EMF upon benthic and fish receptors.

39. A study was commissioned by East Anglia ONE Limited to examine the potential effects of EMF caused by the type of offshore sub-sea cables (AC and DC) that were being considered for that windfarm at the time. The work completed for that study which is presented in *Appendix 9.2* is also relevant to the proposed East Anglia THREE project and used as the basis for assessment.

9.8.1 Study Area

40. The study area comprises the East Anglia THREE site and offshore cable corridor.

9.8.2 Worst Case

41. The worst case is defined by the maximum footprint of potential change, i.e. the maximum extent of cabling for the proposed project, and the maximum potential cable ratings. This is detailed in *Table 9.13*.

Table 9.13. Worst Case Assumptions for EMF

Impact	Key design parameters forming the worst case scenario	Rationale
Operation		
Changes to background EMF	Installation of up to: • 550km AC inter-array cables (75kV) • 240km three core AC Platform link cables (maximum expected voltage 600kV, realistic worst case 400kV) • 380km single core AC Interconnector cables (600kV). • 664km of DC or AC export cables (600kV) Cables buried to a depth of 0.5 – 5 m (realistic worst case 1m)	The maximum length and maximum rating of cables within the East Anglia THREE site and offshore cable corridor.

42. For the proposed East Anglia THREE project, three core AC cables would be used for both the inter-array cables and the majority of the high voltage alternating current (HVAC) platform link cables (see Chapter 5 Project Description section 5.5.13). Array cables are likely to be rated between 33kV and 75kV; platform link cables could be rated up to 600kV under the LFAC solution.

43. Interconnector cables will connect the East Anglia THREE site and the East Anglia ONE windfarm; these would be either HVAC or HVDC cables and would have a maximum rated voltage of 600kV.

44. Export cables would be either cross-linked polyethylene (XLPE) or Mass Impregnated HVDC cables of typically ± 220 to ± 600kV under the HVDC solution or XLPE AC 3-core cables with a voltage range of 110 to 600kV, in the case of the LFAC solution.

9.8.3 Embedded Mitigation Specific to EMF

45. All cables would be sheathed and armoured, which would prevent the propagation of electric (E) fields into the surrounding environment.

46. Inter-array and export cables would be buried where possible to depths between 0.5 to 5m. Cable protection measures would be applied in areas where burial is not possible, for example at cable crossings and in areas of hard ground.

47. Electro Magnetic Fields emitted by HVAC three core offshore subsea cables are minimised due to the method of manufacture, with the three cores laid together in trefoil and as the phase currents are balanced, the magnetic fields of the three cores tend to zero.

9.9 Assessment Methodology – EMF

9.9.1 Legislation, Policy and Guidance

48. The assessment of potential impacts of electromagnetic fields has been made with specific reference to the relevant NPS (EN-1 and EN-3).

49. EN-3 refers to the assessment of EMFs in relation to fish (Paragraph 2.6.75). The document suggests that where mitigation is applied, it is expected that the residual effects of EMF on sensitive species from cable infrastructure during operation are likely to be not significant. The mitigation described (Paragraph 2.6.76) includes the use of armoured cables and cable burial to a sufficient depth, both of which are suggested for the proposed East Anglia THREE project.

9.9.2 Data sources

50. A research and literature review was undertaken by CMACS, see *Appendix 9.2.* In addition to these sources of information, more recent reports have also been consulted for this chapter (MMO 2014, Orpwood et al 2015 and Armstrong et al 2015).

9.9.3 Impact Assessment Methodology

9.9.3.1 Introduction to Electromagnetic Fields

51. Submarine power cables of the types that would be used in the proposed East Anglia THREE project are widely employed for offshore power transmission. The transportation of electricity within cables results in the generation of electric (E) and magnetic (B) fields. The design of the cables, including lead sheathing and armoured cores, prevents the propagation of the E fields beyond the cable. However, these materials are permeable to B fields that therefore emanate into the surrounding environment. The magnitude of the B field produced is directly dependent on the amount of current flow through the cable. The B field attenuates with both horizontal and vertical distance from the cable conductor.

52. Three core AC cables transmit three current flows that fluctuate between positive and negative polarity. Because of the alternating current (AC), the B fields produced are not static but fluctuate in time according to the frequency of the AC. The fluctuating B fields induce another E field, the induced E field (iE), in the surrounding medium. This iE field has been the focus of much industry research, specifically its potential effects on elasmobranchs (CMACS 2003; Gill et al. 2009).

53. In contrast, the B field generated by bipole DC cables is static and thus varying iE fields are not induced in the same way as for AC cables. Review of the literature reveals a large number and wide variety of organisms that are sensitive to EMFs.

The main concerns relating to B field emanation are potential impairment of navigation and physiological effects. The main concerns relating to iE field emanation are potential repulsion, confusion with bioelectric fields and physiological effects.

54. Whilst there is good understanding of the physical processes that result in EMFs, research into electromagnetically sensitive species and their interactions with anthropogenic EMF has been largely inconclusive. The assessment of potential impacts has therefore been carried out using the best information available.

9.9.3.2 Predicted Range of Fields from the Cables

9.9.3.2.1 Alternating Current Cables

55. Data on B and E fields are available for industry standard three core AC cables from 33kV to 132kV and therefore well supported predictions can be made for these ratings. Assumptions have been provided for the higher powered and single core designs.

56. The magnitude of EMFs that might be expected for the different AC cables under consideration for East Anglia THREE, both at the sea bed immediately above the buried cable and at a distance (both horizontal and vertical) from the cable, is described in *Appendix 9.2*. Estimations have been based upon existing information where possible but for designs where no data exist (75kV, 220kV and 275kV) approximations have been suggested.

57. It is recognised that the study presented in *Appendix 9.2* does not make predictions for the higher rated cables (up to 600kV) which are being considered for the proposed East Anglia THREE project and therefore it has been necessary to extrapolate the findings of that study further.

58. Data presented in *Appendix 9.2* show rapid attenuation of both B and iE fields with increasing distance from the cables, such that the strongest fields are limited to an area in close proximity to the seabed above where the cables are buried. The depth to which the cables are buried would affect how strong the fields at the seabed are, with shallower depths resulting in stronger fields.

9.9.3.2.2 Direct Current Cables

59. In contrast to AC cables, the B field generated by bipole direct current (DC) cables is static and thus varying iE fields would not be induced in the same way as for AC cables. However, localised static iE fields may be induced as seawater (tidal flow) or other conductors such as marine organisms pass through the HVDC cable's B field.

60. The magnitude of B and iE fields that might be expected from the HVDC cables under consideration for East Anglia THREE is described in *Appendix 9.2*. Owing to relatively few data being available for similar industry standard cables, informed predictions have been made where possible, with more general assumptions where data are lacking.

61. These data show that both B and iE fields vary with the voltage capacity of the cable, with higher rated cables generating stronger fields. Fields attenuate rapidly with increasing distance from the cables; attenuation occurs at significantly shorter distances around bundled cables compared to those separated by 50m, owing to cancellation effects.

9.10 Existing Environment – EMF

9.10.1 Background Fields

62. The background geomagnetic field off the coast of East Anglia is approximately 48 to 49µT (NOAA 2015).

63. The background electrical field in the area would depend upon the tidal flow moving through the local geomagnetic field. Using a conservative estimate of maximum seabed flows of 1.2m/s, background electric fields could therefore be expected to reach a maximum of approximately 60µV/m.

64. *Appendix 9.2* shows that B fields generated by the AC cable designs proposed are expected to rapidly attenuate to levels below the magnitude of the background geomagnetic field at the seabed (assuming 1m burial). It is EATL's intention to bury all cables to as great a depth as possible, up to a maximum of 5m. This will help protect the cable by reducing the possibility of it becoming exposed due to changes in sea bed morphology. It is recognised however that this may not always be possible and in areas where the cables cannot be buried to a greater depth than 0.5m, cable protection (preferably in the form of mattresses) will be employed. Cable protection will reduce the range at which the effects of EMF can occur. Therefore the 1m burial depth can be considered appropriate as a realistic worst case on which to base the assessment.

65. iE fields associated with 75kV AC are expected to be below background electrical fields. In the case of the higher voltage AC cables, iE fields would be above the background E field induced by tidal flow. However, they would attenuate quickly within 0.5 to 1m for 132kV and 5 to 10m in the case of cables rating at 220kV (*Appendix 9.2*). The higher rated (600kV) AC cables which may be used for East

Anglia THREE interconnector or export cables could therefore be expected to attenuate to background levels within 50-100m of the cable.

66. In the case of DC cables, both B fields and iE fields are predicted to be similar to or below background levels where cables are buried more than 1m from the seabed surface (both depend on the same tidal flow flowing through the B fields).

67. For 320kV cables buried to 0.5m, both fields would be reduced to below background within 0.5m if cables are bundled, and 4.5m if cables are laid separately. For 500kV cables buried to 0.5m, fields would be reduced to background within 2.5m (bundled) and 9.5m (separated) (*Appendix 9.2*). It can therefore be predicted that for the 600kV worst case cable fields would be reduced to background levels within 10s of meters of the cables.

68. How, or whether, the fields generated by the proposed East Anglia THREE project would interact with background fields is not certain. Current understanding is that the B field is more intense and more likely to be detected and is therefore of greater relevance to marine organisms. Once B fields attenuate to below the geomagnetic field, they may be of less relevance to an organism, however owing to differences in fields' geometries and characteristics, the two fields may be decipherable.

69. Similarly, once iE fields generated by AC cables attenuate to below the background (tidally induced) iE field, they may be less relevant to organisms, although the two fields may still be decipherable.

9.10.2 Electromagnetic Field Detection

70. A relatively large number of organisms in the marine environment are either known to be sensitive to electromagnetic fields or have the potential to detect them (Gill and Taylor 2001; Gill et al. 2005).

9.10.2.1 Magnetic Field Detection

71. Magnetically sensitive organisms can be categorised into two groups based on their mode of magnetic field detection: induced electric field detection and direct magnetic field detection.

72. The first group relates to species that are electroreceptive, the majority of which are elasmobranchs (sharks, skates and rays), although it also includes agnathans (i.e. lampreys). These animals detect the presence of a magnetic field indirectly by detection of the electrical field induced by the movement of water through a magnetic field or by their own movement through that field. The magnetic field could be the Earth's own (geomagnetic) field or a magnetic field produced by a power cable.

73. The second group is believed to use magnetic particles (magnetite) within their own tissues in magnetic field detection (Kirshvink 1997), detecting magnetic cues, such as the Earth's geomagnetic field to orientate during migration. In UK waters, such organisms include cetaceans (whales, dolphins and porpoises), chelonians (turtles), teleosts (bony fishes, e.g. salmon and eels), crustaceans (lobsters, crabs, prawns and shrimps) and molluscs (snails, bivalves and cephalopods).

9.10.2.2 Electric Field Detection

74. Elasmobranchs are the major group of organisms known to be electrosensitive. They have specialist electroreceptive organs called Ampullae of Lorenzini (AoL) and are highly sensitive to electric fields, being able to detect very weak voltage gradients, as low as 5 to 20nV/m (Kalmijn 1982; Tricas and New 1998). These species naturally detect bioelectric emissions from prey, conspecifics and potential predators/competitors (Gill et al. 2005).

75. Other species that are electrosensitive (e.g. lampreys) do not possess specialised electroreceptors but are able to detect induced voltage gradients associated with water movement through the geomagnetic field. The actual sensory mechanism is not yet properly understood but it is likely that the E fields that these species respond to are associated with peak tidal movements (Pals et al. 1982).

9.11 Potential Impacts – EMF

76. As research in this area is relatively undeveloped, uncertainty remains as to how or whether potential effects of AC and DC electromagnetic fields upon marine organisms may differ. The effects of these two types of electromagnetic fields may also not be the same owing to the differing geometric characteristics.

77. The potential impacts of the proposed East Anglia THREE project are all associated with the operational phase.

9.11.1 Invertebrates

78. Despite many marine invertebrates being magnetically sensitive, evidence of interactions with anthropogenic sources of magnetic fields is limited and often contradictory. The brown shrimp (*Crangon crangon*) has been recorded as being attracted to AC B fields of the magnitude expected around windfarms (ICES 2003). Shore crabs (*Carcinus maenas*) have been demonstrated to be less aggressive in the presence of an AC B field generated to match the magnitude of windfarm cabling (Everitt 2008). Contrastingly, Bochert & Zettler (2004) found no effects of exposure to static B fields upon the same species, or upon the round crab (*Rhithropanopeus harrisii*), an isopod (*Saduria entomon*) or the mussel (*Mytilus edulis*).

79. The deeper the cables are buried, the weaker the B field encountered by most marine fauna would be (except burrowing species such as polychaetes and bivalve molluscs). However, where cables are covered by cable protection (preferably mattresses), invertebrates are likely to colonise interstitial spaces within and between the mattresses and may therefore come into direct contact with the cables and potentially be exposed to stronger fields.

80. The potential for effects of B fields from the proposed East Anglia THREE project on invertebrate navigation or physiological effects may exist within tens or hundreds of metres of separated HVAC cables and within close proximity of bundled HVDC and three core HVAC cables. However, physiological effects are expected to be largely negated through burial.

81. No marine invertebrates have been definitively demonstrated as being electrically sensitive. The iE fields expected to be induced by the proposed East Anglia THREE project are of relatively minimal strength and therefore no effects are expected upon marine invertebrates.

9.11.2 Fish

82. Available research suggests that magnetic fields from cables have little ecological effect. Bochert & Zettler (2004) found no significant effects of static B fields upon flounder *Platichthys flesus*. Swedpower (2003) found no measurable impact of subjecting salmon and trout to magnetic fields twice the magnitude of the geomagnetic field. In line with this, Atlantic salmon *Salmo salar* migration in and out of the Baltic Sea, over a number of operating sub-sea HVDC cables, seems to continue unaffected (Walker 2001). The MMO (2014) suggest that effects of EMFs upon migratory and diadromous species need to be better understood, however recent laboratory work on salmon (Armstrong et al 2015) conclude that salmon are unlikely to be seriously adversely affected by MF under many circumstances. The European eel *Anguilla anguilla* has been shown to deviate from its migration route in the presence of a 5µT HVDC field, however the effect was short term and over a short distance (Westerberg 2000; Ohman et al. 2007), and such effects are therefore thought unlikely to affect key functions such as breeding or feeding success. Orpwood et al (2015) however, found no evidence of behavioural changes associated with the AC magnetic fields of approximately 9.6 µT.

83. In general, marine teleost fish are not believed to be electrically sensitive. The European eel has been demonstrated as being sensitive to weak electric AC and DC fields (SNH 2010). However, any effects are expected to be minimal and temporary.

84. By far the most likely group to be affected are the elasmobranchs, owing to their sensitivity to even minute electric fields. Both attraction and repulsion reactions in elasmobranch species have been observed associated with E fields. Avoidance behaviour has been documented in lesser spotted dogfish when presented with DC electric fields of 1000µV/m and certain species of shark exposed to both DC and AC fields of 1000µV/m. Other research demonstrated repeated, unequivocal attraction behaviour to DC fields of approximately 60µV/m (Kalmijn 1982; Kimber et al. 2011), and from personal observation (Kimber pers. obs.). Whilst the majority of responses to DC fields of approximately 400 to 600µVm were attraction, some occurrences of avoidance were observed. This suggests that the threshold E field between attraction and avoidance lies somewhere between approximately 400 and 1000µV/m.

85. *Table 9.14* shows that iE fields of more than 400µV/m are not expected for AC cables rated between 33kV and 132kV, with avoidance therefore unlikely at these ratings. Such iE fields are only expected to occur at around 5m or less from the cables laid at the surface of 220kV, 275kV and 500kV AC cables. Burial would reduce this small avoidance zone and it could be eliminated should burial be to a depth of 1m or more (effectively negating avoidance), or reduced to tens of centimetres should burial be to 0.5m depth. Similarly, for HVDC cabling, (*Table 9.15*) iE fields greater than 400µV/m are only expected within a few tens of centimetres (bundled) or one to 2 metres (separated) of 500kV cables. For 600kV cables (the worst case) this would be slightly further potentially up to 3m. Again, burial would reduce these small potential avoidance zones. However, it is worth noting that 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 (MMO 2014).

Table 9.14 Elasmobranch Avoidance Zone Distances Expected for East Anglia THREE AC Cables Assuming Different Cable Burial Depths

Burial Depth (m)	Avoidance Zone Distance from Cable					
	33kV	75kV	132kV	220kV	275kV (trefoil)	500kV
None	0	0	0	<1m	1m	5m
0.5	0	0	0	Tens of cm	Tens of cm	No data available
1	0	0	0	0	0	No data available
For 600kV (separated) cables, distance would be slightly further						

Table 9.15 Elasmobranch Avoidance Zone Distances Expected for East Anglia THREE DC Cables Assuming Different Cable Burial Depths

Burial Depth (m)	Avoidance Zone Distance from Cable			
	320kV		500kV	
	Bundled	Separated	Bundled	Separated
None	Tens of cm	1m	0.5m	1-2m
0.5	0	0.5m	0	0.5-1.5m
1	0	0	0	1m
For 600kV cables, distance would be slightly further				

9.11.3 Marine Mammals

86. It should be noted that impacts of EMF on marine mammals were not scoped into the assessment (EATL 2012) and were not part of the agreed list of impacts agreed with Natural England as part of the Evidence Plan process (see Chapter 12 Marine Mammal Ecology and *Appendix 12.1*). The justification for scoping out these effects is that there is little evidence to suggest that marine mammals would detect EMF at the levels predicted to occur within the proposed East Anglia THREE project.

9.12 Summary - EMF

87. There are a number of cabling designs being considered for the proposed East Anglia THREE project, which include AC and DC cables of different voltage ratings. AC cables are most likely to consist of three-core technology, although there is a small possibility that single-core cables might be used (deployed in trefoil but possibly separately). DC cables would be bipole systems, whereby current is transmitted along two separate cables in opposite directions with bundling of the two cables the most likely deployment method although there is a small possibility that they may be separated.

88. B fields from AC cables likely to be used within the proposed East Anglia THREE project are predicted to rapidly attenuate to a lower intensity than the earth's magnetic field within a few meters of the cables. iE fields associated with the maximum 600kV cables are predicted to be above background fields but are expected to fall to background levels within 50 - 100m of each cable (assuming burial to 1m).

89. For the worst case 600kV DC cables buried to 0.5m, both B and iE fields would fall to below background levels within a distance of a few metres if cables are bundled and tens of meters if cables are laid separately.

90. The ecological significance of the predicted EMFs has been assessed using available literature. No effects are expected on marine mammals and impacts of EMF to marine mammals have not been taken forward to the marine mammal assessment (Chapter 12 Marine Mammal Ecology) (see section 9.2 for an explanation). Marine invertebrates may be affected by B-fields but any effects are expected to be largely negated by burial. Elasmobranchs have been highlighted as potentially vulnerable taxa owing to their acute sensitivity to EMFs. Potential avoidance zones have been calculated and suggest that significant avoidance reactions are unlikely to occur. Industry research into avoidance / repulsion effects has been largely inconclusive, and although a potential impact cannot be ruled out, any effects are expected to be minor and occur within close proximity of the cables. Further information on the significance of these effects and what impact they will have on fish and shellfish species is presented in Chapter 11 Fish and Shellfish Ecology.

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Chapter 9 Ends Here